CHAPTER 25

Contribution of ICRISAT to Studies on Plant Resistance to Insect Attack

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25.1 INTRODUCTION

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has a mandate to serve, in particular, the small farmers of the semi-arid tropics. The target crops are: sorghum *(Sorghum bicoior* (L.) Moench), pearl millet *(Pennisetum americanum* (L.) Leeke), pigeonpea *(Cajanus cajan* (L.) Millsp.), chickpea *(Cicer arietinum* L.) and groundnuts *(Arachis hypogaea* L.). All these crops suffer major losses caused by insect pests, yet all, except groundnuts, are generally grown without pesticide protection in the target farmers' fields. One of the most attractive options for pest management in such circumstances is the provision of cultivars that are more resistant to insect pests and that yield more in the low input systems than the currently available materials. A brief summary of our progress in this area to date is presented for each of the target crops.

25.2 SORGHUM

At the ICRISAT Centre, three sorghum pests of major international importance arc found in our fields and so have been selected for study. These arc the shootfly *(Atherigona soccata* Rond.), a stem borer *(Chilopartellus* Swin.), and the midge (*Contarinia sorghicola* Coq.). A fourth pest, the earhead bug (*Calocoris angustatus* Leth.), is important in certain parts of India, and related species may have damaging effects in certain situations in Africa, so we have added it to our management studies.

The major objectives of our programme include the development of screening techniques for the major pests of sorghum, identification of lines from the available germplasm having resistance characteristics, and assisting breeders with screening of materials emanating from their programmes.

25.2.1 Shootfly

Sorghum shootfly, *Atherigona soccata* Rond., occurs over much of Africa and Asia, attacking seedlings and young plants. It is responsible for severe crop losses, especially in late-sown sorghum and in areas where the dry season is not prolonged (Doggett, 1972; Rao, Rana & Jotwani, 1978; Seshu Reddy & Davies, 1978). The use of resistant varieties of sorghum is likely to be the most useful method of minimizing damage by this pest since it is recognized that varieties of sorghum differ in the extent of damage by shootfly (Ponnaiya, 1951; Pradhan, 1971; Soto 1974; Jotwani, 1978).

A large-scale screening operation was started in the rainy season, 1974, on a newly opened block of pesticide-free land at the ICRISAT. To ensure that high, repeatable, and uniform levels of shootfly are available at the susceptible stages of sorghum growth, a fish meal-spreading technique (Starks, 1970) has been modified and adopted. Spreader rows of a known susceptible sorghum hybrid (CSH-1) are sown about 3 weeks after the break of rains and shootflies are attracted by using fish meal. The test material is sown 3 weeks later and flies emerging from the spreader rows are attracted to the rows of test seedlings, again using fish meal. Oviposition is observed on 80-100% of the plants under test. Known susceptible checks are included as controls.

A large number of lines that had been screened for resistance to shootfly earlier in India and elsewhere, and some untested ones, have been exposed to heavy shootfly attack over several seasons. Resistance is assessed by counts of eggs and of "dead hearts" produced on the material under test. At harvest, a count of the number of harvestable heads is taken.

More than 300 lines have been identified as having significant levels of resistance/tolerance to shootfly. This resistance has been found to be mainly due to non-preference for egg laying and secondary or recovery resistance. There appears to be a definite link between non-preference for oviposition and the presence of trichomes (minute hairs) on the under-surface of leaves (Maiti, Bidinger, Seshu Reddy & Davies, 1980). In many lines, the presence of trichomes appears to be associated with a glossy leaf surface.

It is now possible to obtain differential levels of shootfly attack by utilizing a combination of sowing dates, spreader rows and fish meal on the breeders' material (Seshu Reddy & Davies, 1978).

25.2.2 Stem borers

The stem borer, *Chilo partellus* Swinhoe, is one of the more serious pests of sorghum in India (Jotwani & Young, 1972) and in the lowland areas of East Africa (Ingram, 1978). It is also present and is potentially important in other areas of the semi-arid tropics.

At the ICRISAT, initial attempts to screen the germplasm were in fields in which stalks from the previous crop had been allowed to stand between seasons and subsequently irrigated, to encourage the pupation of resting larvae. This resulted in some infestation on the test material but it was not great enough for screening and selection.

Consequently, it was decided that we would have to produce large numbers of larvae in our laboratories for introduction into the field plots in order to produce infestations that would allow intensive and repeatable screenings. A suitable diet and a technique that allowed us to produce very large numbers of these larvae were developed (Seshu Reddy & Davies, 1978a) and we can now infest large areas of sorghum. The newly hatched larvae are mixed with finger millet seed and introduced to the whorls of 25-to 28-day-old sorghum plants with the aid of a dispenser that is a modification of the one developed at CIMMYT. Each plant receives two applications, with about six larvae per plant in each. The subsequent leaf damage and "dead heart" incidence is recorded. This method has been found to give a rapid and accurate screening and is enabling us to identify tolerant lines from among our large World collection of sorghum germplasm.

Little information is availabale on the mechanism of resistance to this pest. It appears that non-preference for egg laying is not a factor (Roome, unpublished). The importance of leaf texture cannot, however, be ruled out and it has been suggested that thin stems are not favoured. A preliminary study by scientists of the Centre for Overseas Pest Research, London, of the HGN and phenolic acid levels in sorghum cultivars at the ICRISAT Centre (Woodhead *et al.*, unpublished) has indicated that there are no distinct or repeatable differences in the levels of these chemicals between the resistant and susceptible cultivars. It was also recorded that the phenolic acid levels varied over time and with different agronomic situations. Further studies arc planned on these chemicals.

25.2.3 Midge

Sorghum midge, *Contarinia sorghicola* Coq., is an extremely important pest and a potential source of crop loss in almost all areas where sorghum is grown. The populations of this pest can be greatly increased by poor agronomic practices, and the pest appears to be on the increase particularly in areas where early-maturing and improved cultivars are grown in the same areas as later-maturing local cultivars.

Observations over 6 years have shown that the levels of this pest on the ICRISAT Centre are low. Efforts were made to develop methods of ensuring high midge challenge at another location, using spreader rows of mixed-age cultivars, but were not effective.

In co-operation with the Maharashtra Department of Agriculture, an attempt was made to screen materials that had already been identified in other programmes as midge resistant, in an area where midge was known to be endemic and serious. However, these trials were only partially successful. We are now in the initial stages of developing a technique that, we hope, will allow us to usefully screen for resistance to this pest at Dharwar, in Karnataka State.

Work elsewhere has shown that non-preference is involved in the resistance so far discovered and tolerance does not appear to be important (Teetes, Wuenache & Johnson, 1979).

25.2.4 Earhead bug

The head bug, *Calocoris angustatus* Leth., is very damaging in parts of India, seasonally. Little is known of the biology, carryover or even loss levels caused by this insect, or by head bugs in general. The number of Heteroptera in sorghum heads are often very high, but their significance in economic terms is unknown. The quality of grain can be severely affected.

Screening techniques are still being worked out, but the results to date show that this work will be extremely complex and difficult. Sowing cultivars of mixed maturities immediately after the break of monsoons as spreader rows and sowing the test material protected against shootfly 3 weeks later has shown promise, but further observations are necessary. In general, the compact-head types have been found to be more susceptible than the open-headed types. The detection of resistance is made difficult by the fact that test cultivars mature at different dates which can result in a line appearing to be resistant when it is merely an "escape" since the peak attack by *C. angustatus* is avoided. Attempts are being made to sow trials within which all cultivars have a similar maturity. Careful observations on bug numbers and flowering dates are a necessary prerequisite for satisfactory identification of resistance.

25.3 INTERNATIONAL SORGHUM PEST RESISTANCE TESTING PROGRAMME (ISPRTP)

The prime objective of our sorghum programme is to increase the production of sorghum in the SAT. To achieve this, it will be necessary to provide national programmes with genotypes having not only higher yield potential, but also greater yield stability than those currently grown by the farmers. In order to succeed in those objectives, it is important that the sorghum germplasm be screened across a range of environments and pest situations, to ensure that broad-based resistance to pests are located.

Since 1976 we have been sending pest-resistance nurseries to several countries to evaluate resistance in different environments. The nurseries include lines that have been found to be resistant at the ICRISAT and those identified by our colleagues in the All-India Programme, with whom we enjoy close cooperation. The number of such nurseries that have been despatched are presented in Table 25.1.

TABLE 25.1. ICRISAT PEST-RESISTANCE NURSERIES SENT FOR MULTILOCATIONAL TESTING

	Combined			Shootfly			Stem borer			Midge		
Year	E	C	L	E	C	L	E	C	L	E	C	L
1976	24	9	11	—	—	—	—	—	—	—	—	—
1977	22	3	3	22	5	7	22	6	7	16	3	3
1978	—	—	—	20	8	13	20	7	12	15	6	8
1979	—	—	—	20	8	18	20	9	14	15	10	15

E, entries; C, countries; and L, locations.

The number of successful returns has been disappointing but, at locations where proper observations had been taken, it was clear that the entries selected by our programme showed higher degrees of resistance than local check entries. Some of the shootfly and midge-resistant lines were promising in Kenya, Mali and Upper Volta. There is an increasing demand for identified resistant lines from within India. Currently, several of the identified lines are also being used by our ICRISAT breeders for crossing to agronomically superior material.

25.4 PEARL MILLET

It is generally believed that insect pests do not pose any serious threat in the cultivation of pearl millet. However, this belief is partially contradicted by the long list of more than seventy insect pest species recorded on this crop at ICRISAT (Seshu Reddy & Davies, 1979). The truth is that the actual economic importance of these pests has not been fully worked out, owing to their periodic and sporadic occurrence in farmers' fields. In recent years there appears to have been a considerable change in the status of some of the minor and sporadic pests, which have now assumed the status of serious pests in some of the rnillet-growing areas in India.

At the ICRISAT Centre, observations to date on pearl millet cultivars showed that the pest incidence was generally low with the exception of sporadic attacks by *Mythimna separata* Walk and *Heliothis armigera* Hub. However, observations on millet pests will be continued. Most of our entomological work on pearl millet will have to be done in West Africa where pests appear to cause substantial losses to this crop.

25.5 PIGEONPEA

There arc several insect species which can reduce the yields of pigeonpea, with variation in the composition of the pest complex between and within countries and from year to year. In India, where over 90% of the world's recorded production of this crop is grown, and in several other countries, the major loss is caused by lepidopteran borers that attack the flowers and pods. This complex is usually dominated by *Heliothis virescens* (F.) and *H. zea* Boddie causing major losses in the Americas. In addition the podfly, *Melanagromyza obtusa* Mall. causes considerable losses in most Asian countries, but particularly in the important production areas of northern and central India.

, Work on the screening of the available germplasm and other materials for reduced susceptibility to the pod borers and podfly was initiated at the ICRISAT in 1975 (Lateef, 1977; Davies & Lateef, 1978). A methodology for open-field screening, with augmentation of the natural pest attacks where needed, was developed. To date, nearly 10,000 lines have been screened. Initial evaluation is of small unreplicated plots of the test materials which are compared with check cultivars of comparable maturities in pesticide-free conditions. Ail those entries that yield less and also suffer greater pest damage than the checks are rejected at this stage. Any lines of interest arc tested in trials of a narrow maturity range with increasing replication in each year, each trial containing relevant check cultivars and lines that arc of known high susceptibility. Advanced-stage testing is in balanced lattice square design trials with sixteen or nine entries in each. This design has been found to give useful increases in efficiency which is very welcome in this work where spatial and temporal variations in pest attack result in a high coefficient of variation.

From the beginning it was appreciated that the search for reduced susceptibility to the pests, particularly to *H. armigera,* would be difficult and our experience has confirmed this view. The large plant size, lengthy growing season, compensatory habit, and high incidence of outcrossing have all posed problems and slowed our progress. Nevertheless, we now have several lines that differ markedly in their susceptibility to both *H. armigera* and podfly. We have been looking for and have found, lines that differ not only in their susceptibility to attack by pests, but also those that tolerate attacks and yield a reasonable crop under heavy pest threats in the unsprayed situation. Of particular importance is the ability to compensate for early losses and there appear to be considerable differences among pigeonpea cultivars in this important character.

We found that some *Atylosia spp.,* which are close relatives of pigeonpea, have considerable resistance to both pod borers and podfly. We have found a pod wall barrier and antibiosis. In cooperation with our breeders we have been screening derivatives of the intergeneric crosses between *Atylosia* spp. and pigeonpea in an attempt to transfer the resistance. To date, this approach does not appear to have been as productive as our germplasm screening but the cost of this work is low and it is probably worth persisting with for at least two more seasons.

We are continuing our open-field screening work with individual plant and population selection. Laboratory feeding tests and other experiments are under way in an attempt to distinguish the mechanism of the differences between more and less susceptible cultivars. We already have some useful leads on the possible causes of susceptibility differences to podfly oviposition. Seeds of our selections have been given to our ICRISAT breeders for crossing and to entomologists in India for testing in other environments.

25.6 CHICKPEA

Chickpea is the major pulse crop of India and is of considerable importance in several other countries, particularly those in the Mediterranean region. It has a very restricted range of pests but *Heliothis* spp. attack this crop from the seedling to the maturity stage and can be locally devastating. At present our plant-resistance studies on this crop at ICRISAT are confined to *Heliothis armigera* but we are also helping with work at ICARDA in Syria where the leaf miner, *Liriomyza cicerina* (Rondani), can be very damaging.

Chickpea is much easier to handle than pigeonpea, with a relatively short season, small plants, and little or no outcrossing. Here, however, the small plant size does give us the problem of individual plant escape, so individual plant selection in open-field screening has not been very productive so far.

As with pigeonpea, we have found considerable and consistent differences in the susceptibility of different lines to *H. armigera* attack in the 12,000 germplasm accessions and breeders' materials that we have so far screened. Here again we rejected many lines on the basis of results from unreplicated smalt-plot screening, then embarked on trials of narrow maturity ranges with increasing replication of the more promising lines. In this crop again, the ability to compensate for early losses is very marked and we are selecting not only for resistance *per se* but also for tolerance and compensation which are expressed in the yields under our pesticide-free conditions.

All the green parts of chickpea have a dense cover of glandular hairs which exude a very acidic liquid. This exudate, with a pH of approximately 1.3 and a high content of malic acid, is thought to be a factor in limiting the range of pests that attack this crop. There appear to be differences between cultivars in the amount and concentration of the exudate and this may be associated with differences in observed susceptibility. We hope to develop further co-operation with the Max Planck Institute for Biochemistry at Munich in the chemical studies of this exudate and of other aspects of susceptibility differences among the pulses.

Our breeders have made crosses of the more and less susceptible cultivars that we have identified and we arc now screening the F_2 populations of these. We have begun multilocation testing of the selections and will supply seed, where available, to any interested workers. Further details of our screening, and other entomological studies, on both chickpea and pigeonpea, are recorded in our Pulse Entomology Departmental Progress Reports which are available on request.

25.7 GROUNDNUT

Insect pests have probably been generally underestimated as yield-reducing factors in groundnuts. On this crop, insects are of particular importance as vectors of viral and other diseases, with *Aphis craccivora* Koch spreading rosette disease in Africa and peanut mottle in several countries. Jassids spread phyllody or witches' broom, and desap the foliage by feeding, thus causing poor pod filling. Thrips can also cause severe damage to plants by feeding as well as by acting as vectors of bud necrosis, a disease now known to be caused by the tomato spotted wilt virus. Other insects including wireworms, termites, and earwigs are of particular importance, for they act as agents in allowing entry of the mycotoxin-producing fungi into the pods which they have bored or scarified, while damage from pests such as the seed beetle *(Caryedon serratus* Ol.) can start before harvest and continue in the store.

Of all the ICRISAT crops, groundnut has probably the greatest potential for the economic use of pesticides, but our groundnut entomology programme is utilizing/employing much of its resources to the search for resistance to insect pests. At this stage the screening work is restricted to the four major pests that arc common in the groundnut fields at ICRISAT. Center, these being, *Frankliniella schultzei* (Trybom.) EM the major vector of bud necrosis disease, *Empoasca kerri* Pruthi, *A. craccivora,* and different termite species. Although this programme is relatively young, we have already identified lines that show promise for resistance to pests.

Over 1500 groundnut lines have so far been screened in our fields for thrips damage and we have recorded obvious differences in susceptibility. Five lines have been found to have high levels of resistance as confirmed by feeding tests in the laboratory; on these lines the fecundity of the thrips was substantially reduced. In addition, wild species relatives of the groundnut have been field-and laboratory-screened; *Arachis chacoense* Krap. et Greg was found to be highly resistant while other species showed a range of resistance to thrips.

A jassid, *E. kerri,* is particularly abundant from late August to early September at the ICRISAT. The attacked plants show typical tip-yellowing and in the laboratory, one insect per plant can cause wilting in young seedlings. In our field tests we have so far screened 250 lines by counting the nymphs on the three youngest leaves on each of the ten plants, 60 to 80 days after sowing, and comparing these counts with those from adjacent plots of standard cultivars. We have already recorded high resistance in two lines. Caged seedlings of one of these lines were able to withstand very large populations of jassids without wilting, while plants of a standard cultivar (M-13) wilted and died when similarly exposed. The resistant cultivars were found to have thick cuticles and high tannin deposits. In addition one line had pubescent leaves, with tannin-filled hairs.

Over 1000 lines were screened for resistance to aphids in the seedlings stage in screen houses but no noticeable level of resistance was observed. In a modified screening procedure, month-old plants of 200 lines were screened but again with little or no success. Of the several wild species tested, however, *Arachis villosa* Benth. and *A. chacoense* were immune, while other wild species showed a high to moderate degree of resistance. Additionally, some interspecific hybrids were found to be relatively resistant, so future work will be concentrated upon these.

Termites are known to be serious pests of groundnuts in Africa and India; Johnson (1978) estimated up to 10% losses to these pests in northern Nigeria. Pods left in the ground after maturity suffer scarification and we have used this factor in our preliminary screening efforts. We leave pods of many cultivars in the ground well after maturity in plots that are known to be infested with termites, then score the late harvested pods for scarification. Here again we have found consistent differences in susceptibility over 2 years of testing, with two lines being particularly promising. Groundnut lines that have been found resistant to the various pests are already being supplied to national programmes. Our thrips-resistant lines have been sent to Brazil where *Enneothrips flavens* Moulten is particularly damaging. Promising lines are also being supplied to a programme in the USA where resistance to both jassids and thrips is required. We expect to supply the lines showing reduced termite susceptibility to co-operators in Africa and other areas of India.

25.8 SUMMARY

This paper presents a summary of the progress of ICRISAT's studies on plant resistance to insect attack on its target crops. On *Sorghum bicolor,* progress in screening for resistance to shootfly (*Atherigona soccata),* a stem borer *(Chilo partellus),* midge *(Contarinia sorghicola),* and a head-bug *(Calocoris angustalus)* is described. Pearl millet *(Pennisetum americanum)* suffers relatively little damage by insect pests at the ICRISAT Centre, so a screening programme has not been developed but it is probable that work will be concentrated in our co-operative programme in Africa, where insect pests appear to be of greater importance to this crop. On pigeonpea *(Cajanus cajan),* progress is reported on the search for reduced susceptibility of *Heliothis armigera,* and to podfly *(Melanagromyza obtusa)* on the former crop. On groundnut *(Arachis hypogaea),* progress in screening for resistance to *Frankliniella schultzei, Empoasca kerri, Aphis craccivora* and termites is presented.

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