CEREAL ENTOMOLOGY:
ACHIEVEMENTS AND PROJECTIONS FOR THE FUTURE

REPORT OF
PRINCIPAL CEREAL ENTOMOLOGIST

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INTRODUCTION

Research in Cereal Entomology was initiated at ICRISAT in 1973 under the leadership of Dr. J.C. Davies. In 1973, Dr.K.V. Seshu Reddy joined as Research Associate and he left the sub-program in 1980. In 1979, Dr. H.C. Sharma was employed followed by Dr. S.L. Taneja in 1981. After Dr. Davies became Director of Cooperative Programs, Dr. Klaus Leuschner was appointed Principal Entomologist in 1981.

The Cereal Entomology sub-program is part of an integrated research effort to improve sorghum and pearl millet production in the SAT. The primary objective of the ICRISAT Sorghum and Pearl Millet programs is to produce high yielding genotypes with stability of yield and acceptable nutritional quality.

Insect pests are major constrains in achieving this objective in sorghum but they are a lesser problem in pearl millet in India. Since both crops have a low cash value and are grown by resource-poor farmers of small holdings which belong mostly to the lower income group of people in the SAT plant protection methods have to be selected carefully according to their economical value. Under these circumstances insecticides are mostly out of question while host plant resistance and cultural methods may be more appropriate.

One of the major thrusts of ICRISAT Sorghum and Millet Improvement Programs is the development of pest and disease resistant varieties.

The objectives of the cereal entomology sub-program were to:

1. identify the major insect pests of sorghum and pearl millet
2. understand their population dynamics and biology
3. identify reliable methods of control, such as host plant resistance and cultural control practices
4. training of scientists and coworkers in entomological techniques etc.

REVIEW OF PAST WORK DONE AT ICRISAT

Identification of major pests on sorghum and pearl millet

Based on surveys and the experience of various researches in the SAT region of the world a list of the most important pests has been accumilated and listed down according to their importance in the various regions (House, 1978).

Based on this investigation the major insect pests of sorghum and pearl millet in India are

Sorghum	Pearl Millet
1. Stemborer (*Chilo*)	Various potential pests identified
2. Midge (*Contarinia*)	like Armyworm (*Mythimna*), Shootfly
3. Headbugs (*Calocoris*)	(*A. approximata*), White grubs
4. Shootfly (*Atherigona*)	(*Holotrichia*)

In Africa they are

Sorghum

1. Stemborer (*Busseola*, *Sesamia*, *Eldana*, *Chilo*)
2. Shootfly (*Atherigona*)
3. Midge (*Contarinia*)
4. Headbugs (several species)

Pearl Millet

1. Head caterpillar (*Raghuva*)
2. Stemborer (*Busseola*, *Sesamia* *Acigona*)
3. Headbugs, Blister beetle (several species)

With changing agricultural practices and introduction of new high yielding varieties the spectrum may change and the list has to be updated from time to time by reviewing the literature and conducting surveys.

Research areas covered from 1973-1981 on target pests

Once the key insect pests had been identified 3 projects on shootfly stemborer and midge were established. Headbugs and oriental armyworm were included in separate projects only in 1981.

Research was carried out on the following topics

1. Identification of species, their host ranges and natural enemies.
2. Studies on population dynamics and biology
3. Development of resistant screening techniques and identification of resistance
4. Identification of resistance mechanisms.

SHOOTFLY (*Atherigona* spp.)

The shootfly attacks sorghum in the seedling stage and the larvae cause deadhearts which results in stand loss. The seedling susceptibility period ranges from 6-20 days depending on the cultivar. Tiller production after attack is common in certain lines which provides a recovery mechanism. The shootfly population monitored by fishmeal traps developed at ICRISAT, is low in March to June, peaks in July-August, is lower in September-October and increases again in November-February. This knowledge enabled the identification of the best screening time: Kharif: July-August: Rabi: January-February. With the help of the fishmeal trap and by collecting shootfly-infested sorghum, millet and wild grass species, thirteen shootfly species were found attacking sorghum and sixteen other Gramineae. 95% of the shootflies reared from sorghum were *A. soccata* while in pearl millet *A. approximata* was the dominant species. It was also established that irrigated fodder sorghum is especially liable to carry-over shootfly in the dry season.

In collaboration with the Max Planck Institute, West Germany, studies are under way to isolate the active shootfly attractant component of fishmeal.

To develop a reliable field screening method the effect of soil and plant density has been studied in detail. It was found that soil type did not affect oviposition but variation of plant density resulted in significant differences in numbers of eggs laid. High plant densities within the row favoured egg laying, but 10-15 cm spacing between plants was optimal for screening.

Based on this information, the Starks (1970) interlard/fishmeal screening technique, which increases shootfly pressure, was used and modified. Interlards were sown 20 days before the test material with high density and fishmeal applied to ensure high shootfly build up. Test materials were sown at the optimal spacing. Screening is done twice a year at the optimal time indicated above.

Work on resistance to shootfly was first carried out by Ponnaiya (1951) and continued by Rao and Rao (1956). No attempts were made initially to incorporate the resistance into cultivars with acceptible agronomic background. Similar work has been started by Blum (1965, 1967, 1968 and 1969) in Israel, Starks et al (1970) in East Africa, Harwood et al (1972) in Thailand, Rao et al (1974), Bala Kotaiah et al (1975) and Rana et al (1975) in India. Significant contributions in breeding for shootfly resistance have been made.

When screening for shootfly resistance started at ICRISAT efforts were made to obtain any sorghum line mentioned in the literature to be shootfly resistant. From these materials, and other germplasm collected, several entries have shown consistantly lower levels of attack.

The resistance observed in sorghum is probably of three types: non preference, antibiosis and recovery. It has been observed also that glossiness and trichomes are factors associated with resistance (Maiti and Bidinger, 1980) but their role is not fully understood. Besides using resistance as a mean of control, early sowing of the crop which often enables the crop to escape attack is recommended and is well known to the farmer.

STEMBORER (*Chilo partellus*)

The spotted, or lowland, stemborer is an important pest of sorghum in India and in the lowland areas of East Africa. The world distribution and biology of the species has been well worked out in the laboratory. However, information on seasonal carryover, oviposition by the moth, larval movement, and parasite range was incomplete.

Studies undertaken on population dynamics at ICRISAT with light and pheromone traps indicate that there are three major peaks of activity, the most important one in the March-April period which coincides with the harvesting of the post-monsoon sorghum crop and two smaller peaks in September-October and late November-December. Pheromone studies were carried out in collaboration with TPI (Tropical Products Institute, London).

Carryover studies done in 1978-79 on CSH-1, Swarna and local cultivars showed that diapausing larvae were recovered from CSH-1 and Swarna stalks longer than from local cultivars. Several species of natural enemies of *Chilo* were identified during this process.

Chilo was recovered from finger millet, italian millet, maize and several wild grass species.

Screening for resistance against *Chilo* was difficult at ICRISAT because of relatively low populations. Recently an off-site location at Hissar was identified with reliable and sufficient borer pressure. In order to be able to utilise ICRISAT Center for screening and ensure a uniform infestation an artificial diet for *Chilo* rearing has been developed. Resulting first-stage instar larvae were released for field tests using the CIMMYT Bazooka method. Several hectares can be infested in both seasons. Twenty-day-old seedlings are preferred for infestation. It was found that screening in post-rainy season was more effective than in the rainy season. Notes are taken on leaf feeding, deadheart formation, stem tunnelling and peduncle breakage. Resistance screening work had already been carried out before ICRISAT came into existence. Work done in India and East Africa indicated several highly promising resistant lines (Pant *et al*. 1961; Swarup and Changale, 1962; Singh *et al* 1968; Starks and Doggett, 1970). Pradhan (1971)noted a significant advance when two resistant cultivars (M35-1 and BP53) were crossed with dwarf agronomically elite lines. Hotwani *et al* (1974) bred two cultivars, E302 and E303, by successfully incorporating the resistance from BP53 into two agronomically desirable high yielding lines.

As in the case of shootfly, resistant lines have been obtained and screened together with available germplasm under artificial infestation at ICRISAT and under natural infestation at Hissar.

Several lines have been identified with a high level of deadheart symptom resistance.

In cooperation with COPR, London, a detailed study on moth oviposition, larval migration, and possible chemical resistance factors has been carried out. There were marked differences in the number of eggs laid on test lines, and mortality was highest among first instar larvae due to plant surface structures and chemical resistance factors in the young leaves.

MIDGE (*Contarinia sorghicola*)

Sorghum midge is present in all sorghum growing areas of the world except South East Asia. The adult midge female lives for less than 24 hours and lays eggs into the florets during anthesis. The young larvae feed on the developing ovaries preventing grain formation. Most of the biology of the pest has already been worked out in USA, Australia, South and West Africa, where the midge is important. The midge problem is greatly increased where cultivars with differing maturity are grown, allowing the build up of several midge generations. In India the importance of the problem varies from location to location. Dharwar and Bhavanisagar are locations with higher midge populations. At ICRISAT Center lower levels of this pest occur.

A scan of the literature (Wireman *et al*. 1968; Johnson *et al* 1973) was made to locate lines which were claimed to be resistant. S-Girl-MR1 has been one of the best sources. This material together with existing germplasm has been screened at Dharwar and Bhavanisagar. In the meantime attempts have also been made to develop screening methodology at ICRISAT Center. It was found that by using mixed maturity spreader rows sown 20 days before the test material, and spreading midge infested heads populations were increased satisfactory. For more detailed tests a headcage method has been developed which allows "no choice" screening.

These tests are usually carried out in September-October at ICRISAT and Dharwar when the midge population is high. The midge activity in the field is influenced by temperature and humidity. Cloudy weather deters midge activity. Maximum midge activity occurs between 9-11 am. It was found that parasites regulate midge populations in nature and that Tetrastichus is the most important parasite.

Hemiptera-Calocoris, Campyloma and Oxycaronus are important midge predators and make screening for midge in certain years difficult.

HEADBUG (Calocoris Angustatus)

This insect is locally extremely severe in some seasons. The damage is often mistaken for that caused by midge, but is infact quite distinct. Headbugs attack sorghum immediately after head appearance to dough stage. The earlier the attack takes place the less grain develops. Later attacked grain shows distinct dark brown spots. Headbug population peaks are usually observed late in the rainy season. The female lays eggs into the glumes. Humidity higher than 60% is necessary for population build up. Midge and headbugs compete against each other to an extent because Calocoris predate on midge larvae and pupae.

Screening for resistance under natural conditions is often difficult because of unreliability of population build up. At ICRISAT Center attempts have been made to improve the situation by planting mixed maturity infestor rows for headbug build-up before test material is sown. Also the head cages used for midge screening are used for headbugs.

By utilizing these methods and natural populations at Dharwar and ICRISAT a several lines have been isolated with significantly lower levels of attack. Some brown seeded and loose head cultivars seem to be less susceptible. Both in midge and headbug screening escapes are frequent because of the maturity range of test cultivars and the depondance of both pest on the early development of grains.

ORIENTAL ARMYWORM (Mythimna separata)

Mythimna is regarded as a pest in India, South East Asia, China, Australia and one which will increase in importance with the introduction of improved varieties or hybrids. In order to have a better understanding of this pest, data have been collected on the population fluctuation, on parasites and predators and on its biology. The peak populations are observed during August and September. Plant density, presence or absence of weeds and the nature of the canopy determine the extent of damage by *Mythimna* larvae. Preliminary studies on screening millet material against *Mythimna* under glasshouse conditions proved to have potential. Significant differences in feeding were observed. It was also observed that parasite levels are lower in millet compared to sorghum and sex ratio was in favour of females which results in more damage usually observed in this crop.

PEARL MILLET ENTOMOLOGY

Pest incidence and relative importance of millet pests have been studied in 4 cultivars over several years. *Mythimna*, wireworms, thrips, *Heliothis* and other head worms are the important pests at ICRISAT Center. Late sown crops in kharif suffer moderate levels of shootfly damage. None of these pests are of significance currently.

FUTURE AREAS OF RESEARCH BASED ON PREVIOUS WORK DONE

SHOOTFLY (*Atherigona soccata*)

By going through the work done on shootfly it is apparent to me that the species complex, hostplants and natural enemies have been fairly well covered. We are now able to distinguish species and we know how to monitor the population. In the area of hostplant resistance the field screening methodology has been developed and nearly all germplasm has been screened. Resistant sources exist and have been partly used by the breeders. Resistance is heritable and has been incorporated in good agronomic types (Agrawal 1981). Resistance levels have reached upto 40% of the susceptible check which is usually above 90%. Having reached this level of resistance after so many years of research two main questions arise.

1. is the level of resistance we have achieved sufficiently high enough to protect the crop adequately against shootfly; and if not

2. how can we improve the level of resistance further?

Shootfly on world wide bases is not the major pest problem in sorghum. It can be easily avoided by planting early at the beginning of the rain. Resistance is only required when planting is delayed or when drought or other factors delay seedling development and during the rabi season when shootfly levels are moderate. For a lower shootfly population like in the rabi season the level of resistance may be adequate. For high levels like we are facing in July it may not be adequate although we don't know how a resistant variety performs under no choice conditions in farmers fields. If the resistance will hold and there is strong evidence that it will (discussed later) a 60% population reduction factor has probably a cumulative effect on the population depression over several years provided a larger area is planted with the same variety. Normally natural mortality factors like natural enemies, and environmental stresses suppress an insect population upto 90%. 10% or even less are able to establish a new cycle during the next growing season. If in this system which I only roughly described an additional mortality factor like resistance is introduced insect populations should be reduced significantly over number of years (Kripling 1979). Therefore I speculate that the present level of resistance to shootfly combined with the ability to tiller (recovery mechanism) may be sufficient to control shootfly in farmers fields during kharif season.

Up till now no concrete information on this aspect is available. Therefore I recommend that sorghum and cropping entomologist with the help of economists should join together and conduct test trails under farmers conditions. Further I like to see cropping entomology to take a more active part in testing the impact of resistant crop varieties under various cropping patterns and combinations on the pest-hostplant-natural enemy system.

In order to make further progress in increasing the level of resistance to shootfly in case the level is not satisfactory for the kharif or Rabi season, we need to improve our techniques to identify more diverse sources for our breeding program. This should be conducted on identified resistant sources to group them according to the resistance mechanism involved. At present we have only four parameters to identify resistant sources in the field. These are deadhearts, number of eggs layed, glossyness and trichomes. Deadhearts can clearly be identified. Egg counting is too labour intensive, and in the case of glossiness and trichomes we don't know what role they play. Therefore we have to have a better understanding of the roles of the individual parameter. And finally we have to test all identified less susceptible sources under no choice conditions because this will be the real situation in farmers fields. For all these reasons the future shootfly program will mainly concentrate on two aspects.

1. Identification of levels of resistance required under farmers conditions

2. Improvement of methodology to identify resistance mechanism and to group them for the resistance breeding program.

STEMBORER (*Chilo partellus*)

Again with stemborer we have accumulated adequate knowledge on the population built up over seasons, we have some overview about the natural enemy complex and the carry over mechanism. For our main project, development of resistant varieties, we still have to improve the situation. We have identified a good screening location in Hissar where the stemborer population has been high for the last 3 years. This enables us to screen large amounts of germplasm and breeding material in one season per year. In order to speed-up the screening and breeding process and to increase the accuracy of screening results it is necessary to screen also at ICRISAT Center. For this purpose an artificial rearing unit for stemborer was initiated. It worked for 2 years but the culture broke down in 1981 for unknown reasons. This has been brought back into production. The parameters for evaluation have been established. These are leaf feeding, deadheart formation, stem tunneling and peduncle breakage. Leaf feeding and deadheart formation are caused during the vegetative growth of the plant while the two other parameters are expressed during generative growth. The time gap in which both groups of symptoms occur indicate that we are dealing with at least two separate stemborer generations which are exposed to two entirely different physiological stages of the plant, the vegetative and generative once. As in the case of the European cornborer different mechanisms of resistance may operate during these two periods. Therefore they have to be separated in the screening procedure. In addition shootfly damage interferes with screening during September which would be the ideal time according to our population studies. Taking all these points into consideration the stemborer program will concentrate on the following areas of research.

1. Improvement of artificial rearing unit and infestation technique
2. Separation of vegetative and generative growth stages for screening of resistance
3. Control of shootfly for non-interference with stemborer screening
4. Identification of resistance mechanisms to identify diverse source and grouping them for utilisation in resistance breeding program.
5. Study of inheritance of resistance

MIDGE (Contarinia sorghicola)

Midge is one of the most difficult insects to work with on sorghum. Screening procedures have improved considerably over the last years. We know to some extent what factors contribute to population build-up and are able to utilize these findings, like increasing the humidity through irrigation and inoculation of trials with infested sorghum heads carrying diapausing larvae. The no-choice screening technique under head cage has improved the accuracy of screening results considerably.

But still we are not able to manage the population to the extent desired for the following reasons.

1. Early flowering material is liable to escape because midge population build-up may not be in time.
2. Headbugs serving as predators on midge larvae interfere with the expression of symptoms and population built up.
3. Parasites may, in certain years, interfere with the build up of the midge population especially at the population peak.
4. The midge fly is extremely sensitive to environmental changes, especially humidity.
5. Short life of female flies requires continuous hatching of fresh flies from infested heads which is influenced by weather factors.

The problem was partly solved by using Dharwad and Bhavanisagar as places for screening. Bhavanisagar has been dropped because of headbug interference. But we still need a place in the north where midge is high and headbugs don't interfere.

With all these difficulties several lines have been identified showing moderate to high levels of resistance. Therefore, increased effort should go now in the identification of resistance mechanisms apart from the routine germplasm screening. Especially promising are detailed studies on the morphology of the floret, growth of the ovary and biochemical factors like tannins. Therefore the following areas of research will be carried out.

1. Improvement of field screening technique by reducing headbug and parasite interference by chemical means
2. Improvement of cage technique by semi mechanising collection of midge flies
3. Identification of mechanisms of resistance by studying morphological characteristics of the floret, the increase of the ovary and identifying the role of tannins.
4. Study of inheritance of resistance.

HEADBUGS (Calocoris angustatus)

Headbugs have only recently come into the picture for reasons not fully understood. Since headbugs thrive best under humid conditions early maturing sorghum is more liable for attack. Screening methods have been established and there are no problems at ICRISAT to maintain a high population. In fact it is too high. Up till now no relaible sources for resistance have been found although they were mentioned. From my experiences with pod bugs on cowpeas I predict that it will be pretty difficult to find resistance. Nevertheless in order to find resistance sources we have to be able to manage the bug population in a way which ensures low uniform pressure at preanthesis stage. Only under this situation we will pick up some differences. In addition the biology and the population build up on individual lines have to be observed because slight changes in nutritional quality of the food may lead to reduction of the population. Morphological characters of floret and sorghum head have to be studied together with biochemical factors like tannins. Since headbugs cause such a problem at ICRISAT and finding of resistance is questionable an alternative control programs with insecticides should be carried out in order to protect breeding material and give recommendations to the farmer. Late flowering material should be developed for areas where headbugs are a problem.

The following areas of research will be carried out

1. Development of a screening technique which allows graded and uniform pressure

2. Studies on biology to find any weak link in the development of the insect.
3. Study of the morphological and biochemical characters found in sorghum florets as soon as differences in susceptibility are established.
4. Development of an insecticide control program to ensure safe and efficient control.

MILLET ENTOMOLOGY

In general the objectives in millet entomology will be largely observational and assistance will be given in cases of outbreaks of certain pests. Mythimna remains the only exception since screening for resistance under greenhouse conditions against Mythimna has proved to be effective. This work will continue. We will concentrate on A and B lines and advanced breeding material.

The collaborative work with the Regional Research Laboratories on Neem extracts has proven to be very effective. Extracts and an assistant are provided from RRL. The main thrust will be on finding an effective formulation based on easy obtainable neem extracts.

General Remark

In summary the main change which has been made in the objectives of Cereal Entomology is to devote at least 80% of our time to host plant resistance because I feel that only in this area we can make our main contribution to the overall objectives of ICRISAT.

INTERNATIONAL COLLABORATION

The collaboration with COPR has been very fruitful. A lot of basic information on stemborer larval behaviour and surface structure in relation to resistance has been accumulated. The most important aspect which came out so far is that mechanism of resistance operate already before the larvae enters the whorl. Since the bozooka method of larval distribution doesn't allow this aspect to be observed egg infestation in advanced material will be taken into consideration. Shootfly attractants produced by seedling may be another area COPR could work on.

The collaboration with TPI on Chilo pheromones for monitoring purposes will also continue. The present pheromone samples tested are still less effective than virgin females.

The program with the Max Planck Institute on identification of the active fishmeal component has made no progress and it will be decided in near future whether we will continue it. The program is also of less significance to our projects.

INTERACTION WITH ICRISAT COOPERATIVE PROGRAMS

The interaction with our cooperative programs in Africa and elsewhere will be done in two ways.

1. By exchange of screening material (International Nurseries) especially shootfly, stemborer, midge and headbug nurseries.
2. By frequent exchange of ideas through visits and at ICRISAT when staff visits here. I like to recommend that a scientist working on a specific problem which is also a problem in the country where our programs are should be able to spend some time there.

In this way a better understanding on pests of world wide importance can be developed by this scientist. In addition work approaches can be modified in a way that they are more widely applicable.

BRIEF REVIEW OF WORK DONE IN 1982

Based on the main areas of work mentioned in the chapter, future programs, first experimental findings and techniques can be presented. For the purpose of discussion and to indicate how our approach will be incomplete experiments have also been included. Furthermore some of the changes made and techniques developed are implemented to increase the efficiency of assistants and laborers. This I like to say is necessary to cope with the shortfall of money which I foresee in future.

SHOOTFLY (*Atherigona soccata*)

The first item which was designed after my arrival was a new shootfly trap. The old water trap was labour intensive and not easily useable under outside conditions because it uses water. The new trap is made out of plastic containers available in India, contains fishmeal as attractant and a volatile insecticide as killing agence. A collection bottle attached to the funnel makes collection easy. The trap can be used for live trapping also. The trap is selective for flies less than 3 mm in width. The size of entry holes restricts larger flies. The fishmeal remains active for 7 days compared with 3 days in the water trap. Trap catch results are equal or even higher than in the water trap. Traps have been distributed all over India to interested researchers and to ICRISAT program in Africa.

To improve the shootfly screening method the cage screening technique developed by Dr. Soto has been modified. Seedlings are sown with in the field and caged after 10 days. 50 pairs of shootflies are released and allowed to lay eggs for three days. After this the cage is removed and deadhearts are counted. Shootfly adults for infestation are collected from deadhearts and live traps. The advantage of this system is that shootfly pressure can be varied and a no choice situation can be simulated. The system is ment for advanced material and detailed testing for mechanisms of resistance only.

During the process of establishing this method it was found that ovary development in shootfly females is influenced by the presence of the hostplant. In the absence of sorghum the preoviposition time was prolonged by 5 days. This may be a contributing factor for the survival during the dry season.

It is common knowledge that shootfly attack can only take place during a certain period of the seedling stage (6-25 days). It was then speculated that the susceptibility time for various cultivars may be different. An experiment was carried out with IS 2146 (resistant) and CSH-1 (susceptible) under no choice conditions. They were infested with shootflies every 2 days from the 6th to 16th days. The results showed clearly that the susceptibility period in IS 2146 was significantly shorter than that of CSH-1. In addition, larvae successfully entered the whorl but fed above the growing point.

[illegible] newly formed leaves show distinct feeding symptoms. The larvae doesn't survive as far as we know. This finding is very significant and may be used for selection. It may indicate an antibiotic mechanism. There is also an indication that the length of the susceptibility period is influences by seedling growth. Therefore plant vigour should be an other parameter of selection. The whole experiment also demonstrated that the observed shootfly resistance in IS 2146 holds under no-choice screening conditions. This experiment will be continued once a month to see whether environmental changes will influence the results.

The role of trichomes is not fully understood. Experiments carried out in early morning hours when larvae hatch from the eggs gave inconclusive results. It was found that below 80% rel. humidity the larvae had great difficulties to hatch and to reach the whorl in trichomed and nontrichomed lines. Above 80% rel. humidity the larvae had no difficulties to move and to establish. This finding is in line with Dr. Agarwal's analysis which showed that trichomes alone contribute only marginally to resistance. This experiments may lead to a better understanding why shootfly populations are high during July and August but remain lower after the rainy season. More information is necessary.

By making cross sections through the seedling stem it was found that trichomes form a sort of physical barrier between the roled leaf layers. It may be that here the real role of the trichomes can be found. This may also be the reasons why larvae feed above the growing point because they can't proceed through the trichomes.

To screen the trichomes more efficiently two methods have been developed. Using the mechanism of a modified stethoscope the roughness of the leaf surface can be scanned. (V.Madhusudhan Rao and S.K.V.K. Chari contributed to this method significantly). A microphone mounted behind the membrane and an amplifier transmits the sound through earphones. This method allows with an experienced person quick identification of low, medium and high trichome density lines. The accuracy is on the low side 100% and on the medium and high one 90%. No glandular trichomes can be detected in this way. The microscopic method consists of a microscope with overhead screen for easier reading. The samples are cleared in acetic acid+ alcohol within 2 hours without boiling. Two people can read 20 samples in 15 minutes. There is also evidence that shootflies are attracted to their hosts by chemical attraction and that this odor is only released at a certain period during seedling growth. Parahydro-benzaldehyde was found in surface waxes of sorghum by COPR. Benzaldehyde was used as an attractant to catch shootflies successfully. During the cage experiment with IS 2146 and CSH-1 egg laying decreased after 12 days on IS 2146 without obvious reasons which indicates less attractiveness.

Beside these activities shootfly screening of germplasm and advanced material continued. We have now several less susceptible lines to work with.

STEMBORER (*Chilo partellus*)

Stemborer is an area which will take most attention over the next few years. Since the stemborer population broke down in the rearing unit efforts have been made to bring it back into production. To achieve this several new diets have been tested but the one developed by Reddy remains the best. The larva rearing room was separated from the kitchen and a temperature control system installed. Hygenic conditions have been improved and the borer population thrives well. New egg-laying cages have been designed in which egg laying takes place in rows to allow easy cutting of the paper. The bazooka for larvae distribution has been modified for more uniform release and a new carrier "Gus Gus" has been found. Pearl Millet seeds were to heavy and caused high mortality. The distribution pattern per 100 strokes is also more uniform with "Gus Gus". We are prepared now for two hectares artificial infestation during Rabi season, if no disease interferes.

Bi-weekly plantings from June onwards have been carried out to establish the best screening time for borers. One part of the planting was naturally and one artificially infested. The results show that deadheart formation, probably due to the environment and subsequent fast growth of the plant, as the main damage criteria is not expressed sufficiently during early Kharif but September may be the best month for expression. The natural *Chilo* population is also high during this month.

To utilize this month for screening we have to plant in August when shootfly population is too high. Therefore an insecticide trial with Furadan has been carried out to investigate the effect of Furadan on stemborer. It was found that during Kharif it has no effect on stemborer 25-30 days after seedling emergence. This gives us hope that we may be able to screen twice a year during late Kharif and Rabi season.

Test catches carried out with TPI *Chilo* pheromone versus virgin female showed no advantage of the pheromone. There is some evidence that the trap design has to be improved.

Hissar screening on germplasm and advanced lines was successful in the sence that a number of deadheart resistant lines could be identified. Unfortunately the phenotypic expression of these lines are very similar which raises questions about the real genetic diversity we have. Also in the breeding lines of Dr. Agarwal good resistance could be observed.

MIDGE (*Contarinia sorghicola*)

In case of midge a lot of more detailed information has to be produced and a reliable screening method developed. Monitoring of the midge has been done up till now by counting midge flies on 100 heads during morning hours daily. This is time-consuming. Sticky color traps have been tested for their effectiveness in catching midge. Yellow has been the color attracting most midge flies and it remains to be seen whether catches with traps are corresponding with actual counts. The next step was to increase the midge population in the field for screening purpose by using mixed maturity infestor rows and midge damaged heads with diapausing larva. The result shows that mixed maturity infester rows plus infested heads sown and spread in the field 20 days before sowing of test material gave the highest midge infestation in the test material.

Since it was known that midge fly needs high humidity a trial was layed out to test sprinkler and no sprinkler irrigation effect on the build up of the population during rabi season. Sprinkler irrigation increased the population significantly on less susceptible and susceptible material.

The next step was then to separate midge from headbug predation. A series of insecticides have been tested and it was found that most insecticides tested didn't affect the midge larvae hidden in the floret. Sevin and malathion were most effective against headbugs. This gives us hope that we can fix the midge damage as soon as infestation has taken place.

For headcage inoculation it was essential to find out at what time in the morning midge flies are most active and can be collected. For ICRISAT and Dharwad it was found that from 8.30 to 11 a.m. collection can take place.

Midge flies start laying eggs very soon after mating. The ability of the female to lay eggs decreases during the morning. This effects the effectiveness of the head-cage method because late caught flies lay fewer eggs. In a test in which flies collected at various times during morning hours, it was found that fly females caught between 8.30 and 11.00 o'clock still laid still sufficient eggs to create the desired damage. To compensate for this fact mentioned above and to be able to inoculate enough head-cages it was decided to use 40 flies/day and cage.

The head cages are covered with muslin cloth. The cloth and the head color are two color attractions a fly can react on. It was therefore speculated that in order to confine the midge to the head the cloth color should be less attractive. The color test which was conducted indicates that darker colors like blue and black are less attractive, yellow again shows higher attraction which is indicated in less egg laying activity. Midge egg laying activity is associated with the opening of the glumes during antheses. Therefore a test in which flies were released a various antheses stages was carried out. The result shows that the top anthesis stage seems to be the stage where infestation should take place. (Top anthesis stage: First flowering at the head tip).

With this knowledge now available on field and head cage screening techniques the precision of the results has increased.

Eggs are layed mostly during antheses. The larvae hatches after 2-3 days. Then the hatching larvae have to crawl down to the base of the ovary where they resume feeding. The space between glumes and

and ovary is small in many lines. Glumes are tightly [illegible] to the developing grain and very [illegible]. Therefore, the hypothesis was that fast growing ovaries may fill the space between ovary and glume very quickly not allowing the larvae to reach the base of the ovary. To measure the rate of development of the ovary the thickness of the floret was measured. For the measurement a special instrument was designed, which allows to measure always under equal [illegible] pressure. Measurements taken up with this instrument at every second day after anthesis indicate that there are differences in increase which may be associated with resistance.

A question of great importance in the case of midge is whether there are differences in the genotype in maintaining a carry-over population. A test carriedout on various cultivars indicate that large difference exist in different genotypes. This aspect of indirect resistance should also be taken in consideration.

HEADBUGS (Calocoris angustatus)

The biology and population dynamics of Calocoris have been worked out. The head cage screening technique used for midge can also be used for headbugs. In the case of Calocoris 15 females released into the cage give a score of 5 in CSH-1. Several hundred germplasm and breeding lines were screened. No strong sources could be identified.

Late maturing material usually escapes damage. The headbug population peaks are during September and February. For regions in India where headbugs are a potential problem late maturing varieties have definitely a role to play.

Experiments on chemical co...rol o. headbugs . wed that carbaryl and malathion are ve: effective and that po. anthesis is the optimum stage to start spraying at 10 day intervals. Because of the special situation created in an experiment station insecticides have definitely a role to play in protection of test material and for separation of insect pests for experimental purpose.

ORIENTAL ARMYWORM (Mythimna separata)

Biology and population dynamics have been worked out. Lower parasitism on larvae on pearl millet seems to be one of the major causes for extensive defoliation. Screening for resistance continued under greenhouse conditions. In collaboration with R.R.Labs active antifeedant and antimolting components in Neem Kernals have been identified which seem to have the potential of being used for pest control.

COOPERAT..ON BETWEEN DISCIPLINES

[illegible] integrated progr... like the Sorghum Improvement Program is essential to achieve the objectives. In the case of entomology the most vital cooperator is the breeder. Without a close cooperation of these two disciplines a resistance program is bound to fail.

I feel that cooperation has and continues to improve. Some of the recent improvements in the identification of resistance mechanisms

... effectively screen for sources of resistance and breeding stock. As these capabilities improve the base is strengthened for interdisciplinary cooperation.

Final Remarks

At the end I like to mention that Dr. Sharma was largely responsible for the midge and headbug projects and Dr. Taneja for the shootfly and stemborer projects. Apart from my overall responsibility for the program I have chosen the project on mechanism of resistance in shootfly. I would also like to acknowledge the interaction with Dr.B.L.Agarwal as he has also contributed to our progress.

Finally I like to thank all staff of Cereal Entomology for their dedicated effort to make the progress possible which we have made. I like also to put a work of thanks to the support units like PPS, information services and purchase to make the changes and support required for the program possible.

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