A REVIEW OF LABORATORY AND FIELD SCREENING PROCEDURES FOR *CHILO PARTELLUS*

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Abstract—Laboratory and field methodologies for screening for resistance against *Chilo partellus* on sorghum and maize are reviewed in relation to the insect biology, plant phenology and insect-plant interaction. The value of field and laboratory techniques in achieving the goal to produce resistance varieties and hybrids is discussed. Recommendations for future work are made.

Key Words: Chilo partellus, Busseola fusca, sorghum, maize resistance, screening methods, resistance mechanisms

Résumé—Les méthodes en pratique de détermination en laboratoire et sur terrain de la résistance du sorgho et du maïs contre le *Chilo partellus* sont actuellement en cours de révision en tenant compte de la consitution biologique de l'insecte, de son apparition suivant les saisons climatiques, et de l'interaction entre l'insecte et la plante. L'efficacité des techniques utilisées en laboratoire et sur terrain pour une mise au point des variétés de plante et hybrides résistant au *Chilo partellus* est à présente très discutée. Aussi des recommendations (ou propositions) ne cessent de nous parvenir concernant les travaux futurs.

Mots Cléfs: Chilo partellus, Busseola fusca, résistance du maïs, résistance du sorgho, méchanismes de résistance

INTRODUCTION

For any host plant resistance programme it is essential to develop a screening procedure based on the interaction between the host and insect.

In the case of *Chilo partellus* such screening methodologies have been developed by various research institutions like ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), ICIPE (International Centre of Insect Physiology and Ecology), and various other institutions in India. In the following paper an attempt will be made to review these resistance screening methodologies developed for sorghum and to a lesser extent for maize for their value in screening and breeding for resistance against *C. partellus*.

CHILO PARTELLUS BIOLOGY AND INSECT HOST-INTERACTION IN RELATION TO HOST COLONIZATION AND HOST PLANT DAMAGE

Chilo partellus survives the dry season in larval diapause. The survival of diapausing larvae has never been used as a resistance criteria, but the physiological aspects of aestivation diapause of *C. partellus* larvae have been extensively studied by Scheltes (1978). As soon as sufficient moisture is available at the beginning of the rainy season, the diapause is broken and the first generation of adults appears.

After mating, host finding and oviposition are the first two activities, especially the female moth performs. No references could be found for

host finding from a distance but, probably olfactory and visual senses attract the insect to the crop. After being near or inside a sorghum or maize field, females start searching for oviposition sites.

Various plant characters like volatiles, colour, water vapour may be responsible as short distance perceivable characters. Evidence that these characters are involved in selection of sorghum plants have been given by Saxena (1984, 1985). After contact with the plant, surface waxes (chemicals) and the physical structure of the leaf surface become the next selection criteria. There is evidence from work done by Saxena (1985) that contact perceivable characters also play a role in selection of a plant for oviposition. Trichomes and waxes (glossiness) on the lower surface of sorghum leaves where eggs are laid have been considered at ICRISAT as possibly being responsible for lower oviposition.

Once females have made their choice for oviposition, they lay their egg masses near the base of the lower leaves of sorghum seedlings from about 10–15 days after seedling emergence (DAE) onwards. Incubation time for eggs lasts about 5–7 days. The first instar larvae climb from the oviposition site to the plant whorl, which they enter. The number of larvae successfully reaching the whorl again depends to a large extent on physical and chemical characteristics of the leaf and stem surfaces. Bernays et al. (1983,1985), studied the climbing behaviour of the first instar larvae on sorghum in detail. They found that strong positive phototaxis is of primary importance for the larvae to reach the whorl. Larvae hatch during the early morning and they respond to the light sky. The rate of climb is influenced by the cultivar and plant age. In seedlings, the chemical nature and physical structure of surface waxes, orientation of edge spines and the anatomical complexity of the leaf base and sheath are factors for orientation and disorientation of larvae on their way to the whorl. Generally, climbing is faster on seedlings than on older plants probably due to surface wax bloom on older plant stems. Larvae which do not reach the whorl may disperse on silken threads produced by the larvae and infest neighbouring plants in the same row and across the row (Chapman et al., 1983). After the larvae have reached the tip of the outer whorl leaf, downwards movements are initiated when the larvae perceives the dark area of the funnel contrasting with the light sky above (Bernays et al., 1983).

As soon as the larvae enter the maize or sorghum whorl they feed on the young tender leaves near the base of the whorl. This feeding activity is later visible as elongated scars on the expanded leaves. This symptom is the first indication for a farmer or researcher of the presence of *Chilo* larvae. Feeding activity continues in the whorl until the larvae reach the second or third instar (Van Hamburg, 1980). The intensity of feeding depends on the number of larvae reaching the whorl and the suitability of the genotype as a food source. After having reached the second or third instar, larvae leave the whorl for unknown reasons and migrate to the base of the seedling where they bore into the seedling base at soil level or a few centimeters above (Fig. 1a). Migration of larvae to the seedling base takes place about 8–10 days after hatching, depending on temperature. The length of time larvae feed in the whorl depends most probably on the genotype. It has been observed at ICRISAT that in certain genotypes (IS 1099, IS 2123, IS 5585 and IS 13100) only 10% of the larvae were observed at the seedling base 10 days after infestation compared with 21% in IS 18333 and 35% in IS 2309 which was probably due to a delay in larvae development in the whorl (Taneja and Woodhead, 1987). Prolongation of whorl feeding by larvae was also reported by Jotwani et al. (1978). Feeding inside the seedling base causes two symptoms, depending on the position of the growing point (Taneja and Woodhead, 1987). If floral initiation has taken place and the apical meristem has moved upwards, larvae may feed only on the initial stem resulting in stem tunnelling. If the apical meristem is still present at the point of larval entry, it will be destroyed, causing dead heart (Fig. 1a). This usually happens 25–35 days after germination and depends on the time of larval infestation. Very little is also known as to why larvae sometimes enter at the stem base and sometimes a few centimeters above (Fig. 1b). The loose or tight attachment of the lowest leaf sheath seems to be responsible. Genotypes with tight leaf sheaths tend to have more basal entry holes. In genotypes with loose leaf sheaths, larvae tend to enter behind the leaf sheaths and bore into the stem a few centimeters above the base, which has implications in terms of dead heart formation.

During migration from the whorl to the stem, larvae mortality is high (exposure of larvae to natural enemies) and migration also takes place to neighbouring plants. One can only speculate that surface structures like wax, stem hardness and surface chemicals may contribute to disorientation and subsequent dispersal. With the death of the main stem, apical dominance has been removed and a

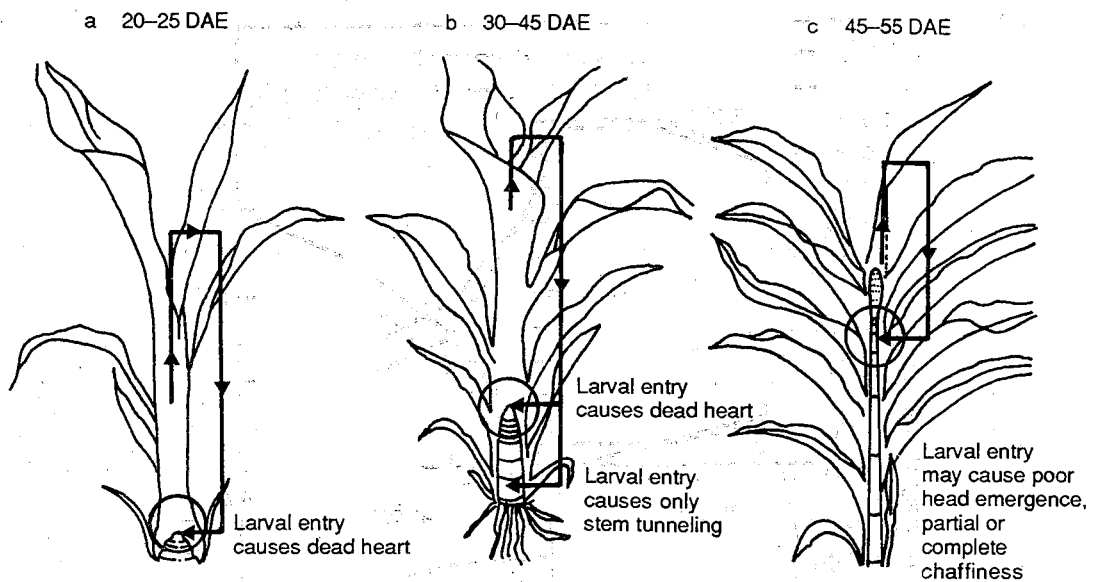a   20–25 DAE   b   30–45 DAE   c   45–55 DAE

Fig. 1. Larval movement and entry points in relation to plant growth stages: (a) before panicle initiation, (b) after panicle initiation, and (c) flag leaf stage.

number of tillers are formed (usually two). The earlier these tillers are formed the greater the chance that they will synchronize with the main head development. This mechanism serves as a recovery mechanism according to Starks and Doggett (1970). If no dead heart is formed the larvae continues to tunnel below the growing point until pupation. If dead hearts are formed there may not be enough feeding space left and larvae may migrate to tillers or neighbouring plants. Stem tunnelling in the stem base weakens the plant, making it susceptible to wind breakage. After about 30–40 days the first generation stem borer life cycle is completed with the emergence of a new generation of moths. The second generation of moths (if there are discreat generations, usually there are overlapping generations) will infest the plant again between 45 DAE to the flagleaf stage. Egg masses are preferably laid on the lower leaves of the plant as shown by Dabrowski and Kidiavai (1983). According to Van Hamburg (1980), survival of larvae is lower on late infested plants. Whether this is associated with the absence of a whorl for feeding of the first instar larvae after the flagleaf stage or not, is not clear. For sorghum if we assume flowering takes place 60–65 DAE the last egg masses from which larvae can complete their development in the whorl have to be oviposited 45–50 DAE. Again first instar larvae climb from the egg-laying side to the whorl. At this plant growth stage larvae climb may be hindered by surface wax bloom pockets, caused by upwardly curled leaf bases and hairs in the leaf axil in which larvae can get trapped (Bernays et al., 1983). Such obstacles become especially important in older plants where the distance for the larvae to travel is greater and more obstacles are encountered.

Compared to the early generation infestation, very little information is available on the behaviour of the second generation larvae attacking the plant before the flag leaf stage or later. Feeding symptoms in the whorl are the same as with early infestation. The second or third instar larvae again leave the whorl and will move up to three internodes below the whorl (not to the plant base) and enter the stem usually behind a leaf sheath close to the node. Larvae will tunnel on the closely packed internodes, and premature peduncle below the nearly or fully formed head if the head is still in the whorl (Fig. 1c). If the peduncle is out of the whorl, feeding will not interfere with peduncle elongation. If the peduncle is not elongated, larvae tunnelling may interfere with peduncle elongation and the head may become lodged in the whorl (Leuschner, 1987). If vascular tissue is extensively destroyed, incomplete grainfill and partial or complete chaffiness of the head may be observed. As long as feeding is restricted to the pith grainfill will be normal or only slightly reduced. Weakened by tunnelling,
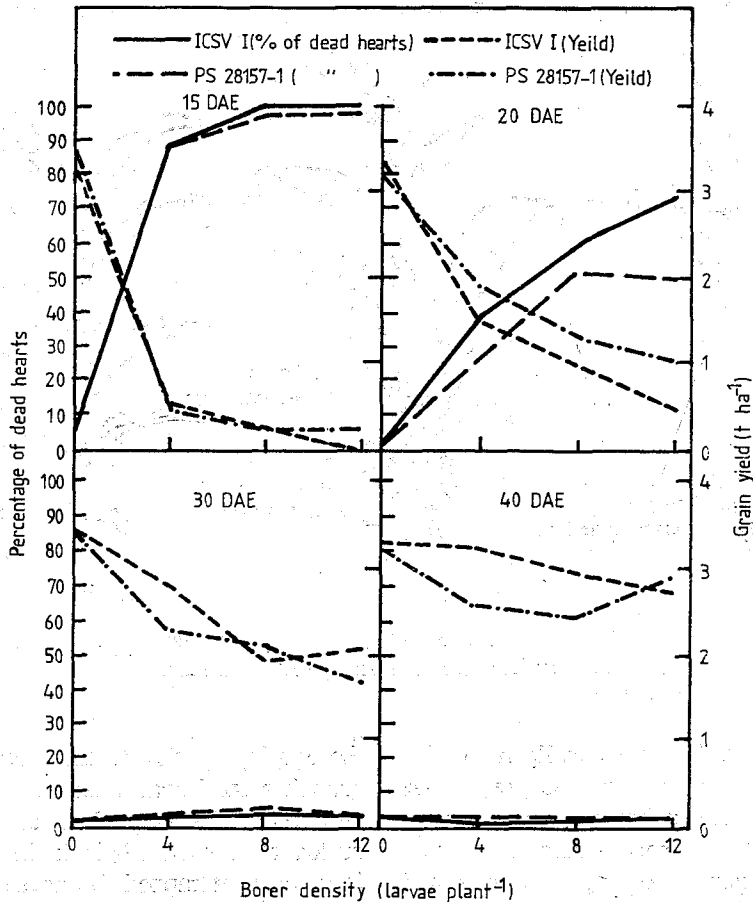
Fig. 2. Relationship between stem borer density, infestation and yield under artificial infestation, ICRISAT Center, rainy season 1985 (from Taneja and Nwanze, 1987).

however, the peduncle may not be able to support the weight of the head and becomes especially susceptible to wind damage. Peduncle breakage after physiological maturity will not reduce yield provided the peduncle remains affixed to the stem.

YIELD LOSS CAUSED BY *C. PARTELLUS* IN RELATION TO PLANT PHENOLOGY

After having discussed the host finding, host colonization, insect biology and damage symptoms of *C. partellus*, it is equally important also to know the crop growth stage and insect density at which the insect causes maximum damage (yield loss) to the crop. This has implication for the time of infestation in the case of natural and artificial infestation. Important work in this area of research has been done by Seshu Reddy (1985) in Kenya, Taneja and Leuschner (1984); Taneja and Nwanze (1987) at ICRISAT, India. Time of infestation studies have been carried out with the help of sequential

planting trials, selective plant protection trials and sequential artificial infestation trials. In all cases similar results could be obtained. Highest yield loss was always caused by *Chilo* on sorghum when the crop was infested between 10 and 25 DAE. Yield loss of up to 87.8% was observed when plants were infested with 10 first instar larvae at 10 DAE, while only 13% occurred at 60 DAE infestation (Seshu Reddy, 1985). At 15 DAE infestation, yield loss on sorghum at ICRISAT (Taneja and Nwanze, 1987) was about 88% compared to about 20% at 40 DAE (Fig. 2). Results are variety-dependent. Similar results could be obtained for maize. Infestation with larvae 21 DAE reduced yield by one fifth to one fourth on the uninfested control, compared to much less at 56 DAE (Botchey, 1985). When different larval densities were used, maximum yield reduction was caused by four to five larvae at 15–20 DAE (Taneja and Nwanze, 1987). Higher numbers, above five cause additional reduction, but of lower magnitude
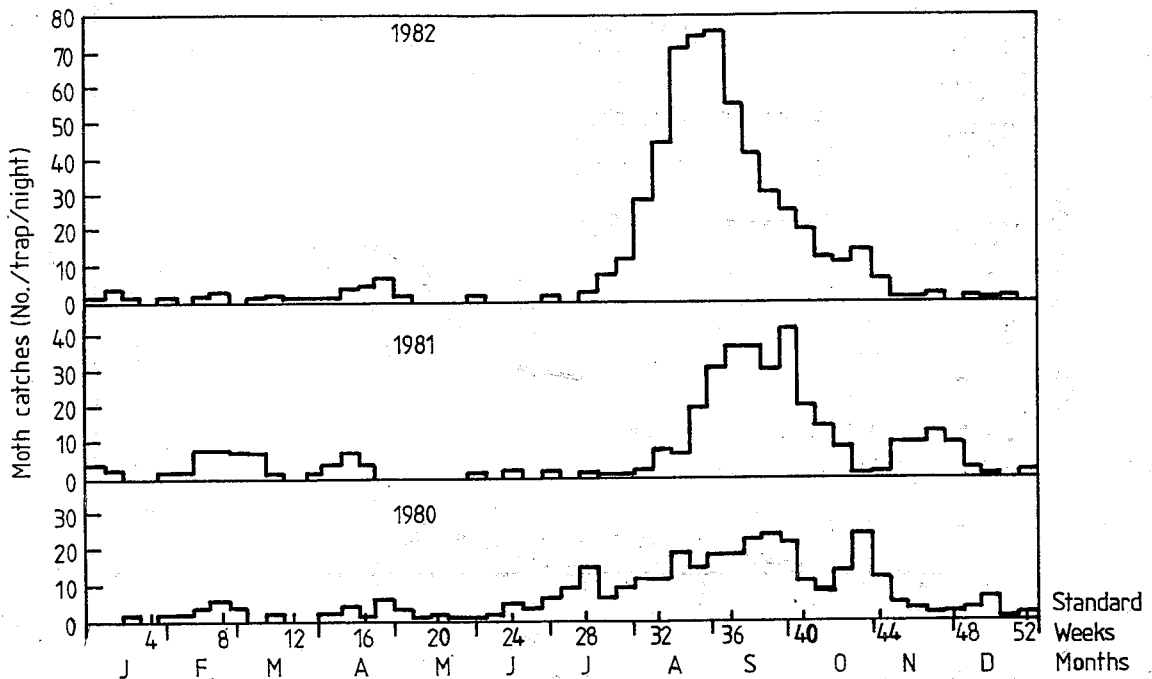
Fig. 3. Seasonal activity of *Chilo partellus* based on light trap catches of moths at Hisar (1980–1982) (from Taneja and Nwanze, 1987).

(Fig. 2). At late infestations, 40 DAE, larvae densities between four and 12 larvae per sorghum plant, did not show significant yield reduction differences. For *Busseola fusca* on maize, Van Rensburg et al. (1988) showed that there was significant difference in ear mass between 0 and 1 to 3 larvae per plant, but the decrease was gradual and more related to an increase in the number of damaged zones per plant.

All these experimental results indicate the importance of infestation time and insect population pressure for the design of a screening methodology and interpretation of results.

SCREENING METHODOLOGIES

Screening under natural infestation

For a good host plant resistance programme it is essential to develop an efficient and reliable screening technique that ensures a uniform level of insect pressure, at the most susceptible stage of the crop. These requirements can be met to a certain extent by selecting a location where the insect occurs regularly (hot spot). Once such a location has been identified it is important to know the population dynamics over time in order to match the most susceptible crop stage with the population peak of *C. partellus*. To find this out three principle possibilities are available:

Adult trapping, fortnightly planting trials and sequential destructive sampling of larvae and pupae in a field. Trapping of *Chilo* adults alone can be done with light traps or pheromone traps (for females only). For example at Hisar in India the seasonal activity of *Chilo* population started in July and peaked in August–September (Fig. 3). Consequently, screening trials were sown at the beginning to the middle of July. Seshu Reddy (1983) followed the population development at Mbita Point Field Station (MPFS) (ICIPE) by weekly destructive sampling of plants from the beginning to the end of the cropping season. These plants were examined for a number of larvae, pupae and pupal cases of each stem borer species. The results are given as an example of a different method for studying stem borer population dynamics (Fig. 4). In this case a delay in planting for about 4 weeks will probably match the susceptible crop stage with high *Chilo* population pressure. Delay of planting has to be carefully monitored for two reasons:

(1) not to overwhelm the crop with stem borer, and

(2) not to alter crop growth by too late planting.

From all experiences available, only degrees of resistance can be found, which means that under too high pressure no resistance may be found. In addition, if sorghum or maize is planted
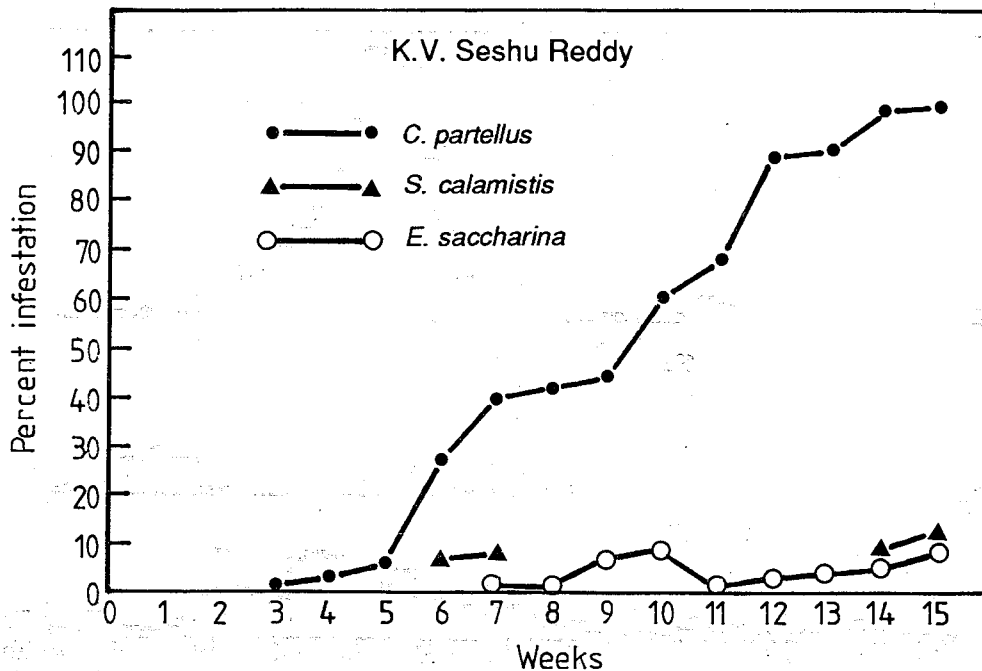
Fig. 4. Incidence of stem borer on sorghum (Serena) at MPFS — long rainy season 1981 (from Seshu Reddy, 1983).

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From all experiences available, only degrees of resistance can be found, which means that under too high pressure no resistance may be found. In addition, if sorghum or maize is planted too late, crop growth may be abnormally slow and resistance or susceptibility found under these conditions may not be expressed at normal planting time. This was clearly indicated in trials conducted by Sithole (1986), where stem borer damage was grossly overestimated in a very late planted crop. The yield loss expressed was due to later planting, but not due to stem borer damage. Once the right planting time has been established, materials to be screened should be interplanted at regular intervals (10) with a susceptible and resistant cultivar. This will allow for later estimation of uniformity of the stem borer infestation and plant growth, and by using these cultivars as checks, a nearest neighbour analysis can be made.

Screening under artificial infestation

The major bottleneck in screening for resistance under natural infestation is that *Chilo* population may fluctuate over years leading to low and different levels of infestations in certain cropping seasons. In addition, breeders require uniform infestation to be able to select in segregating generations. Only artificial infestation can meet this requirement.

Screening under artificial infestation involves rearing of *C. partellus* on natural or artificial diets. On a small scale a number of entomologists (pers. commun.) have tried with various success to rear *C. partellus* on sorghum leaves and stalks. This method is labour intensive and not recommendable for large scale rearing. It may have some place in some detailed studies for the identification of mechanisms of resistance which will be discussed later.

Rearing of stem borer on artificial diet is successfully done by ICIPE (Kenya), ICRISAT and Indian Agricultural Research Institute (IARI) and SADCC/ICRISAT in Zimbabwe. Basically, wheat germ or sorghum leaf powder - legume diets, or pure legume diets are used (Sharma and Sarup, 1978; Seshu Reddy and Davies, 1979; Taneja and Leuschner, 1984; Ochieng, 1985). On all these diets, scientists are able to rear *Chilo* for a few generations before they rejuvenate the culture by introducing a new wild population. No long-term rearing experiences over more than 10 generations have been published. Since no major diseases have been

encountered by these various institutions, long term rearing of one population may not be necessary and rejuvenation can take place whenever desired.

Rejuvenation of the population may have the desirable effect to avoid inbreeding and the production of less competitive strains. This is in fact a major requirement for resistant screening. An artificially introduced population has to be genetically and behaviourally the same as the wild population. Artificial infestation is done either by pinning egg masses on the sorghum or maize leaves in the field or by distributing first instar larvae with the help of the "bazooka" in the plant whorl (Mihm, 1982). The use of egg masses has the disadvantage that for large scale screening the rearing population has to be large and the method is labour intensive. The advantage is that resistance plant characteristics like plant surface chemicals and anatomical obstructions of a genotype come into operation, while larvae are climbing to the whorl. Oviposition non-preference as experienced with natural egg laying females cannot be experienced. In contrast, larvae infestation is the most economical and fastest way of infestation, but it does not allow for screening for oviposition preference and climbing success of the larvae. In general egg infestation is therefore used for more advanced screening of already selected genotypes, while larval distribution is used more in large scale screening to reduce the number of plant genotypes to a manageable level. It is realized that in this way a number of genotypes with resistance mechanisms expressed before whorl infestation are lost. The field lay out for screening under artificial infestation is the same as in the case of screening under natural infestation. The main advantage of screening under artificial infestation is that the time of infestation is known, each plant is infested with a more or less uniform number of larvae (5–8) and early and late generation infestation can be simulated separately or together. It may be possible that early and late generation resistance to *Chilo* is governed by different resistance mechanisms like in the case of the European corn-borer (Guthrie et al., 1971) and this advantage is important.

Criteria commonly used in evaluating Chilo *resistance to sorghum, and the components they help identify*

According to Ortega et al. (1980) "the reactions of plants exposed to insect attack must be measured at the proper stage of growth. This can be done by visual observations or by actual measurements of the effects of insects on plants or the effects of plants on insects. It is also important to recognize the extent to which environmental factors influence the expression of resistance."

The commonly used evaluation criteria for *C. partellus*, the plant growth stages at which they should be evaluated and the resistance components they identify are listed in Table 1.

The resistance components are important for the type of resistance sought. If basically antibiosis and nonpreference are sought, criteria like egg laying, larvae counts, leaf feeding, dead hearts and stem tunnelling can be taken into consideration. Each criteria depends on the insect-host inter-relationship and they are inter-dependent. High numbers of eggs would result in high leaf feeding, dead hearts and stem tunnelling in a susceptible cultivar.

A reduction in oviposition would indicate oviposition nonpreference. High oviposition and subsequent lower leaf feeding, dead hearts and stem tunnelling would point in the direction of antibiosis, provided the environment is not adverse to insect and plant development.

Since stem borer resistance is a polygenetic trait (Rana and Murty, 1971), it is difficult to use it in a breeding programme. In this case it would be useful to search for tolerance. There are indications from personal experience that tolerance can be found in hybrids and varieties with good agronomic characteristics and growth vigour.

The search for tolerance requires knowledge of the different damage symptoms in their impact on yield loss. From my experiences I would like to propose the following research approach. This can be best achieved by developing a resistance index to which each symptom has a weighted impact.

An attempt to develop a resistance index has been made by Seshu Reddy and Saxena (1988). In this case equal weightage has been given for each

Table 1. Criteria commonly used in evaluating resistance to *C. partellus* in sorghum and the components they help identify (after Ortega et al., 1980)

Criteria	Plant development stages at which to evaluate*			Components		
	I	II	III	Antibiosis	Tolerance	Non preference
Direct methods of evaluation on insects						
(1) Number of egg batches laid per plant genotype	X	X				X
(2) Surviving insect population (larvae, pupae)		X	X	X		X
Visual estimates of insect damage on plants						
(1) Leaf feeding score (1–9)	X	X		X		X
(2) Dead heart %		X		X	X	X
(3) Stem tunnelling %		X	X	X		X
(4) Estimates of standability, stunting, peduncle breakage and chaffy heads			X		X	
Direct methods of evaluation on plants						
(1) Number of plant infested (with leaf feeding symptoms)	X	X	X			X
(2) Number of surviving plants at various growth stages	X	X		X	X	X
(3) Yield loss between infested and protected plants			X		X	

*Growth stage I : up to 25 DAE.
Growth stage II : 25 DAE to flag leaf.
Growth stage III : flag leaf to grain maturity.

evaluation parameter based on a study by Saxena (unpublished) that each parameter (larvae/plant, % dead hearts, foliar lesions, % stem tunnelling), causes yield loss in sorghum. Since equal weightage is given to each parameter one has to assume that equal yield loss is caused by each parameter. Based on Fig. 2 results and studies conducted by Sithole (unpublished) this is not the case. In Fig. 2 the main symptom contributing to yield loss in 15 and 20 DAE infestations is the dead heart. In 30 DAE infestation, dead hearts are negligible but still about 40% yield loss occurs. This has to be attributed to leaf feeding and stem tunnelling. In the 40 DAE infestation, only marginal yield loss occurs due to leaf feeding and stem tunelling. This indicates that once the plant is fully grown stem borer has less impact in terms of yield loss. From this study one can conclude that each evaluation

Table 2. Proposed damage symptom weightage system

Yield components	Leaf feeding	Dead hearts	Stem-tunnelling	Chaffed heads	Stem breakage	Peduncle breakage	Total
No. of heads	–	+++	+	–	–	–	
No. of kernels	+	+++	+	++	–	–	
Grain weight	++	+++	+,	++	++	+	
1000 kernel weight	++	+++	+	++	–	+	
Weightage no.	5	12	4	6	2	2	31
% of total	16.1	38.7	12.9	19.4	6.5	6.5	100%
Index no.	1.6	3.9	1.3	1.9	0.7	0.7	10

criteria has to be given a different weightage. Depending on the time of infestation each weightage may contribute more or less to the index.

If tolerance is sought, yield is the primary factor against which the impact of all stem borer damage symptoms have to be judged. Each symptom has to be weighed by multiple regression and correlation for its impact on yield reduction. Based on the relative importance of each symptom on yield reduction each one has to be given a weightage which altogether should represent 100% yield loss. An attempt has been made in Table 2 to demonstrate such a theoretical weightage system which could lead to the development of a resistance index. This preliminary system is not based on actual data and needs to be verified. It also does not include tiller and time of infestation which in any future studies have to be taken into consideration.

The index can also be used if all the three components, non-preference, antibiosis and tolerance are searched for, because each resistance component would contribute by giving a higher or lower value and finally a higher or lower index.

Resistant mechanisms and methods for identification

According to Painter (1951) resistance can be classified as nonpreference, antibiosis and tolerance. For practical resistance breeding it is always desirable to know which resistance mechanisms are present in a particular genotype.

By using plant genotypes with different mechanism it may be possible to combine them in a final variety or hybrid with increased overall level and stability of resistance. The field screening methodology allows only to a certain extent the identification of resistance mechanisms. For any further studies on additional mechanisms like distance perceiving leads for adults to identify the crop and subsequent oviposition sites, climbing success of larvae related to surface chemicals, larvae mortality and adult reproductivity need specific detailed tests under field or controlled greenhouse and laboratory conditions. Such tests have been developed and carried out by ICIPE and Center of Overseas Pest Research (COPR). Intensive work has been done by Chapman et al. (1983) on survival and dispersal of young larvae, by Bernays et al. (1983, 1985) on the behaviour of newly hatched larvae of *C. partellus* in relation to its establishment on the host plant and by Woodhead (1986) on surface chemicals of sorghum on the behaviour of *Chilo* larvae. All tests were carried out on IS 1151 (susceptible) and IS 2205 (resistant) under field and laboratory conditions by observing larval behaviour on the plant, or in the laboratory on dummy leaves and specifically coated surfaces. Chemicals in surface waxes and anatomical features of the plant accounted for the lesser establishment success of larvae in the IS 2205 whorl.

At ICIPE (Ampofo and Saxena, 1984), a method for oviposition preference on maize has been developed by planting maize genotypes in

radial rows, 2 m long each, along the circumference of a circle of 2 m dia under cage conditions. Females were released at the centre and could select plants with equal chances for egg laying. Distance perceivable characters for oviposition were identified at ICIPE by Saxena (1985) by placing a wire net barrier between the female moths and the sorghum plants outside. Oviposition response was greater on paper attached to the wire opposite IS 18363 and IS 2146 than opposite the reference IS 18520. In addition, larval feeding was monitored on whorl leaves at ICIPE (Alghali et al., 1984). The area of leaves consumed in 48 hr was higher on IS 18363 (susceptible) than IS 2146 (resistant). Similar feeding tests have been carried out by Jotwani et al. (1978) by feeding larvae on leaves and stems. Mortality in the early larval stages was found to be significantly higher in resistant cultivars like IS 5629. In bioassay tests done at ICIPE where fresh leaves or stems were incorporated into artificial diet, it could be demonstrated that leaf and stem tissue of resistant cultivars reduced larval development and pupation. The factors responsible for resistance were less present in dried tissue than fresh one (Saxena, 1986).

All these detailed tests are very useful in identifying different mechanisms of resistance in different genotypes. They are especially useful in classifying selected resistant cultivars according to mechanisms of resistance. Their only disadvantage is that such tests can mostly only be carried out on a small number of genotypes and they cannot be used in breeding for resistance programme, where large numbers of crosses have to be evaluated.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

Good progress has been made in developing and refining the various methodologies for screening for resistance in sorghum and maize. About 70 sorghum cultivars have been identified at ICRISAT and other institutes with different levels of resistance to C. partellus. Screening and breeding for resistance in sorghum is going on over at least the last 20 years. Up until now no variety or hybrid with appreciable levels of resistance has been released. Why? There are several major reasons:

(1) Resistance to C. partellus is polygenic and quantitatively inherited, very difficult to be handled in a breeding programme.

(2) Most identified resistant sources have poor agronomic characterisitics and because of this, breeders are reluctant to use them. Breeders are still yield-orientated and want quick progress, which is not possible with the resistant sources available.

(3) In spite of the progress made in refining field screening methodologies, they are still too crude to identify small differences under field conditions.

My feeling is that entomologists and breeders have too heavily relied on leaf feeding and dead heart/formation as the main criteria for selection. For example, in the SADCC countries under farmers' field conditions, very early attack by Chilo is rare. Mostly, later infestations are experienced. In addition it is common experience that in a well-managed crop where crop growth is good seldom Chilo attack is devastating. Yields are high in spite of stem borer damage. I therefore recommend that we have a fresh look at tolerance combined with good management practices which may solve the problem of C. partellus for the time being, until better resistant varieties or hybrids can be bred. To get a better understanding of tolerance, a resistance index should be developed based on weighted damage symptoms.

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