Management Options for Sorghum Stem Borers for Farmers in the Semi-Arid Tropics

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Abstract

Currently recommended control measures against sorghum stem borers are briefly reviewed Generally, successful methods applied in developed countries have been tested at research stations in developing countries and recommended to farmers in the semi-arid tropics The extent of their use by farmers is assessed and farm-and sector-level constraints to adaptation are evaluated Past research leading to control recommendations did not adequately take local farming practices into account An approach for farmer-oriented research on control methods is suggested

Résumé

Différentes options proposées aux paysans des zones tropicales semi-arides pour la lutte contre les foreurs des tiges du sorgho : *Les techniques de lutte recommandées actuellement pour lutter contre les foreurs des tiges du sorgho sont rappelées En général les méthodes appliquées avec succès dans les pays développes ont été testées dans les stations de recherche des pays en développement et proposées ensuite aux paysans dans les zones tropicales semi-arides Le degré de leur adoption par les paysans est évalué ainsi que les contraintes pour leur usage au niveau des champs paysans Les recherches menées antérieurement en matière de lutte n'ont pas suffisamment pris en compte les pratiques culturales locales Une approche est proposée pour une recherche orientée au milieu paysan sur les techniques de lutte*

Introduction

Literature abounds with information on the control of sorghum pests, and much of it deals with stem borers Recommendations for stem borer management range from the simple cultural practice of sowing date, to chemical and biological control, modern resistant genotypes, and more ambitious integrated pest management However, very few farmers of the semi-arid tropics (SAT) practice these recommendations, which gather dust in libraries

Specific research has not been conducted on the adoption by farmers of stem borer management recommendations Prerequisites to the success of any pest-control technology, and thus the success of any stem borer management research program have been identified by Reichelderfer and Bottrell (1985, p 284) "Basically any pest-control technology must meet four criteria before it can be considered a likely candidate for acceptance and overall effectiveness it must be politically practical, socially acceptable, and economically feasible, as well as technically effective "

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Traditional research concentrates on the technical effectiveness of pest management recommendations, usually neglecting or ignoring other criteria vital for success. This emphasis on technical feasibility often results in pest control recommendations that can, at best, be adopted only by progressive farmers. Progressive researchers should, ideally, take all four criteria into account so that their recommendations can be adopted by traditional farmers in the SAT.

In this paper we explore some implications of adopting a farming systems perspective in stem borer management research in an attempt to increase the utility of the research output for farmers. The essence of this approach is that by spending more effort on anticipating the consequences of management practices that are important for farmers, we reduce the chance of recommending pest management practices that are not adopted by farmers.

Importance of Sorghum and Sorghum Stem Borers

FAO (1986) reports sorghum production from 89 countries, 33 of which are developing countries in the SAT. These countries contribute about 50% of the annual world sorghum grain production of 80 million tonnes, and account for 75% of the 50 million hectare planted with sorghum, worldwide.

In contrast to the sorghum-growing countries in Latin America where sorghum grain is used as animal feed, nearly 90% of sorghum produced in developing countries of the SAT of Asia and Africa is used for food (FAO 1984). Sorghum grain is a staple diet of many subsistence farmers and rural laborers in the SAT, and is an important source of calories and protein. For example, poor rural families in India on average derive 15% of their daily calories and 16% of their daily protein from sorghum (Murty and von Oppen 1985). Detailed surveys in India (Ryan et al. 1984) showed that sorghum contributes about 2/3 of daily protein and calories consumption by rural people in sorghum growing tracts. Sorghum grain is also widely used in the production of indigenous beer in Africa (Haggblade 1987). The uses of sorghum are not confined to grain. Sorghum stalks, for example, became increasingly valuable in parts of India in periods of drought from 1980 to 1986. During that time the price of sorghum fodder rose by about 270%. Fodder's share in the value of sorghum production has increased in the same period from below 50% to more than 70% (Walker 1987). Sorghum stalks are also used for fencing, and provide bedding for livestock.

The severity of damage to sorghum by stem borers varies considerably across regions of the SAT. Harris (1985) estimated overall losses to be on the order of 5-10% in many sorghum-growing areas of West Africa, especially where early attack causes loss of stand. Avoidable grain losses on the hybrid sorghum CSH 1 and the variety Swarna were estimated to be about 55-83% in India (Jotwani et al. 1971, Jotwani 1972). In a survey of cereal losses in Kenya and Tanzania, Walker (1967) reported losses in yield of sorghum due to stem borer damage ranging from 18-27%. A recent survey of farmers' perception of losses due to stem borer in western Kenya reported a range of 15-40% (Seshu Reddy In press). Most losses in yield are attributed to early attack on the growing plant. Correlations of counts of stem damage with yield at or before harvest, have often failed to demonstrate any reduction in grain yield (Harris 1962, ICRISAT 1987).

Review of Recommendations for Stem Borer Management

Pest management strategies that have been suggested for sorghum stem borers in the SAT (cultural, chemical, and biological control, host-plant resistance, and integrated pest management) are briefly reviewed in this section. The more exotic control methods such as the use of pheromones, juvenile hormones, and chemosterilants are excluded.

Cropping Practices

Cropping practices can be conceived as having evolved over long periods of time and being well-adapted to local environments. Changes in cropping practices can have important impacts on stem borer ecology that may be exploited in pest management. Such changes may, however, have intricate agronomic and economic side effects that are difficult to anticipate and that diminish the acceptance of recommended cropping practices by farmers.

Rotations

Rotations can check stem borer population build-up by removing primary hosts of the pest for extended periods Rotations including fallow, however, have vanished in parts of the SAT with explosive population growth, increasing land pressure, and declining land productivity (Matlon and Spencer 1984) Furthermore, the arrival or absence of rains, sudden changes in price ratios, and other variables outside the control of farmers often impede the planned succession of crops For example, analysis of the crop choices of a small sample of farmers in India showed that about half of all attempted rotations are interrupted (ICRISAT 1987)

Intercropping

Most farmers in the SAT grow sorghum in crop mixtures, usually with legumes and sometimes with other cereals In general, crop mixtures reduce pest incidence when the choice of the crops in the mixture is properly done However, the individual compo- crops may not equally benefit For example, in 'a, Ogwaro (1983) found increased borer levels in maize when intercropped with sorghum, while borer levels remained the same in sorghum Amoako-Atta and Omalo (1983) found that a sorghum/maize intercrop was more favorable to *C partellus* attack than an intercrop of sorghum and cowpea Similar studies by Mahadevan and Chelliah (1986) in India showed a much higher incidence of borer attack and lower yield in monocrop sorghum compared to sorghum intercropped with lablab (*Lablab purpureus* (L) Sweet) Although there is scientific evidence of an effect of the composition of sorghum intercrops on stem borer ecology, there are no studies showing that farmers grow specific sorghum intercrops to exploit this effect

Sowing Date

he sorghum tracts of the SAT, sowing of ium is determined by rainfall Planting after the rains is the first step the farmer takes to ensure a good crop This practice has considerable relevance to stem borers since the early sown crop usually suffers less borer attack than a crop sown later (Harris 1962, Nwanze 1981) Deviations from this rule are usually founded on other constraints that farmers have to consider, such as soil type and topography of plots (Matlon 1980), labor bottlenecks, or risk of crop damage from other insects Given the many constraints affecting farmers' choice of sowing dates, it is unlikely that a change in sowing dates alone will result in higher sustainable sorghum yields

Farm Sanitation

Several stem borer species will carryover in sorghum stems (*C partellus, B fusca, A ignefusalis*) or survive the dry season on alternate wild grass hosts (*Sesamia* spp) Collecting and burning stubble and stalks, or plowing and destroying crop residue are recommended practices (Bowden 1956, Nye 1960, and Harris 1962) Adesiyun and Ajayi (1980) found in northern Nigeria that partial burning of stalks killed 95% of diapausing *B fusca* larvae, and cured the stalks, improving their quality for housing and fencing material Species that survive on dry season wild graminaceous hosts are effectively controlled by crop removal In the densely populated SAT areas of India, field sanitation can hardly be improved Here all plant residue is either grazed or collected by the abundant farm labor In Africa, where farm labor is scarce and draft animals are not typically used, postharvest plowing is very costly Sorghum stalks used as fencing material may have no cheap substitutes in remote rural areas or may be too valuable as fodder to be burned

Manuring

Farm manure provides nutrients, improves soil structure, and increases soil water-holding capacity, which in turn improves plant vigor and growth Vigorously growing sorghum suffers less borer damage and escapes deadheart formation Although livestock numbers are increasing at a slow pace in the SAT of India, the ratio of livestock per cropped area is stagnating, limiting the scope for increasing application of manure Furthermore, where firewood is scarce, dung is also used for fuel Farming households in India burn about 1 t of dried dung per year (ICRISAT 1986) These factors cause farmers to apply manure less frequently and in lesser quantities than they would if more manure was available

Local sorghum cultivars in India rarely receive manure Walker and Rao (1982) found that only 1 4% of the plots planted with postrainy season local sorghum in two villages of Maharashtra, India, received manure In contrast, 60% of the high-yielding varieties (HYV) sorghum plots in another village of the same state received inorganic fertilizer Farmers believe that sorghum is more responsive to inorganic fertilizer than to manure and reserve the available manure for cash crops Evidence from 56 villages in 10 countries in sub-Saharan Africa indicates that manuring fields is a practice that evolves with increasing farming intensity from fallow to annual cropping systems (Binswanger and Pingali 1984)

Chemical Control

Several insecticides have been tested for the control of stem borers Their efficacy depends crucially on the timing of application In Africa, chemical control by carbofuran, carbaryl, and endosulfan were found effective against *B fusca* and *Sesamia* spp (Taneja and Leuschner 1985, Seshu Reddy and Omolo 1985) Sharma (1985) listed nine insecticides that are effective against *C partellus* in India Granular formulations of carbofuran applied directly into the whorl gave reasonable control against *C partellus* although the procedure is labor-intensive and was recommended only as a last resort (Teetes et al 1983) High labor intensity would probably not prevent farmers in India to do this if stem borer were a severe yield reducer These insecticides are, however, often unavailable in rural areas or too expensive for subsistence farmers The assessment of chemical control of sorghum in the SAT by Davies (1982 p 220) is as valid today as it was 6 years ago "In general there is little convincing evidence of the economic soundness of some of the recommendations made for insecticide use on sorghum, in developing countries, except in special high input, or at least high fertility situations"

Chemical insect pest control on local cultivars of sorghum is conspicuously absent in India Evidence from three study villages in different agroclimatic zones in SAT India (Binswanger and Ryan 1980) shows that only hybrid sorghum is sometimes treated with insecticides in the event of shootfly or midge attack We have no reports from our village investigators that farmers actually apply insecticides directly into the whorl

Biological Control

A number of natural enemies have been reported (Pradhan et al 1971, FAO 1980, Seshu Reddy and Davies 1979, and Sharma 1985) In general, the efficiency of natural enemies in particular farming environments is not known The scope for successfully controlling sorghum stem borers with natural enemies is limited by the short cropping period and the lack of continuous habitats for the natural enemies The introduction and establishment of *Trichogramma exiguem*, a parasitoid on *C partellus* eggs, represents a notable success in India (Jotwani 1982) In Africa, the overall rate of parasitism is low and only increases when borer damage is well advanced (Harris 1962, Nwanze 1985)

Host-plant Resistance

At ICRISAT Center, more than 70 germplasm sources and breeding lines have been identified as resistant to stem borer *C partellus* These materials are currently being used in ICRISAT's breeding programs Sharma (1985) also listed 34 entries of which 25 were highly promising, having stable resistance and good agronomic characteristics Several local cultivars and landraces exhibit a high tillering ability and tillering, as an aspect of varietal tolera low borer infestations, may result in an overall increase in head production (Harris 1962) Mechanisms of resistance and further studies on oviposition behavior and crop physiology will provide an adequate foundation for the development of integrated pest management programs At this time, however, stem borer resistant cultivars have yet to be released in the SAT Furthermore, germplasm has not been screened for multiple resistance We cannot, therefore, deny the possibility that cultivars developed from stem borer resistant germplasm might break down when exposed to multiple pest and disease pressure in farmers' fields

Integrated Pest Management (IPM)

The individual control methods discussed above have their limitations and none is sufficient to adequately control stem borer outbreaks When no single control option is sufficient, one may try exploit the interactions of different control strategies integrated in a pest management system IPM takes into account the interactions between biotic, abiotic, and economic factors of crop production, and pest management itself becomes part of managing or producing a crop The limitations of individual control methods indicate that host-plant resistance and cultural practices should be major components in the integrated management of sorghum stem borers

Where integrated pest management has seriously been tried, its transfer to farmers often met with constraints that were not anticipated by entomologists or social scientists The main deficiency of many IPM recommendations is that they are too complicated to be explained by extension workers and to be adopted by farmers Adoption of thresholds a cornerstone of IPM is an example Carlson and Mueller (1987) found that adoption of thresh olds by pigeonpea growers in SAT India was much slower than adoption of ultra-low volume sprayers and that farmers with little or no formal education are very unlikely to be among the early adopters of thresholds Drawing on her experiences of IPM field work in the developing countries Goodell (1984 p 18) characterized IPM as follows

'Of the various components of modern agriculture IPM presents by far the most difficult challenge to traditional small-scale farmers in the Third World as they make the transition to scientific farming

Assessment of the Recommendations

Recommendations for stem borer management al though appearing promising have not carried far beyond the research stations and libraries Farm sanitation can either not be improved or only be improved at high cost Sowing dates are confined by several constraints and are likely to be well-timed in traditional farming systems that have evolved over long periods Rotations are often obstructed by the vagaries of the weather in the SAT Manuring local cultivars of sorghum is unattractive to farmers Sorghum cultivars that are acceptable to farmers and resistant or tolerant to stem borer and other yield reducers are yet to be released There is no consistency in stem borer control through intercropping and biological control is inefficient Integrated stem borer management finally is likely to everely constrained by the limited management ibility of farmers What has prevented stem borer research from contributing more to sorghum improvement? It was certainly not a lack of com mitment on the part of researchers nor were they lacking in competence or devoid of a sense of urgency to solve the stem borer problem More likely it was the contrary highly motivated compe tent researchers attempted to achieve transferable results quickly, often with frugal financial support by applying research approaches from mentor institutions in developed countries to the SAT

Applying methods and principles of entomology in subject matter research on stem borers in the SAT is necessary Transferring approaches to problem solving stem borer research from developed to developing countries is perilous it encourages cursory problem identification and acceptance of recommendations without critical appraisal

Problem-solving stem borer research has to consider that practical problems are location-specific As mentioned earlier estimates of yield losses from stem borer attack vary considerably across regions and range from 5 83% Second yield losses from stem-borer as perceived by scientists may be imperfect indicators of farmers perceptions of the importance of stem-borer management Third solutions of practical problems have to take into account the preferences skills resources and constraints of the people whose problems are to be solved We do not have to elaborate again here the contrast between farmers and their environments in the SAT and in the developed countries from where research approaches have been borrowed These differences often prevent solutions from being successfully transferred from developed to developing countries In short stem borer research has not been conducted with a farming systems perspective This defect most likely contributed to the dearth of stem borer man agement recommendations that can be adopted by farmers

Stem Borer Management: A Farming Systems Perspective

Elements of Research Conducted

Over the last decade literature on farming systems research has burgeoned and the farming systems approach has been recommended for research on pest management technologies for small-scale farmers (Altieri 1984) The essentials of farming systems research are that it is conducted with a farming systems perspective that research begins and ends with the farmer (Plucknett et al 1987) Several of the objectives and methods employed in farming sys tems research should be considered for introducing a farming systems perspective into applied stem borer research

The main objectives of research with a farming systems perspective that are relevant for stem borer management research are

to understand the physical social economic, and human environment of agricultural production

- to understand farmers' skills, constraints, preferences, and aspirations,
- to comprehend farming systems,
- to identify possibilities for improving existing farming systems,
- to evaluate new or improved practices for possible testing on farms, and
- to test practices under normal farm conditions

Research with a farming systems perspective pursues these objectives mainly with three methods (a) Base-data analysis for describing the farming environment in a region, (b) research station studies for the development of new components or the assembly of new farming systems, and (c) on-farm studies which involve on-farm experimentation studies of existing farming systems and studies of adoption and farm-household impacts of a new technology

Objectives and Methods Applied to Stem Borer Research

In Table 1 we have correlated objectives and methods for stem borer management research conducted with a farming systems perspective In this section the elements of Table 1 are discussed

Production Environment In the past, stem borer research has given adequate attention to the physical environment of sorghum production We expect researchers will also quickly absorb more detailed information on the climatic and edaphic conditions in the SAT as it becomes available through research reports

But the economic and political environment of sorghum production in the SAT also requires continuous monitoring by researchers This is particularly true in Africa, where some governments have not yet attained levels of stability found in many Asian countries, and where agricultural research and extension systems often are less developed We do not suggest that entomologists engage in detailed surveys of the economic, political, and infrastructural environment of agricultural production, because much of the necessary information is provided by social scientists and by the local press We do recommend, however, that sorghum entomologists consult social scientists and watch key price ratios that indicate changes in the economic environment Some of the key indicators are the price ratios between the farm-gate sorghum price and rural labor wage rates, or the prices for other food staples, or the prices for insecticides

Table 1 Objectives and methods of stem borer management research conducted with a farming systems perspective

	Methods			
		Experiments		
Objectives	Surveys	On-farm	On-station	Modeling
Environment	**			
Farming System	**	**		
Farmer	**	**		
Improve technology		**	**	
Evaluate new technology			**	**
Test new technology	**	**		

Farming System. An understanding of the farming system, not just the cropping system, is particularly important for stem borer researchers in the SAT There are many intricate linkages between the various production and consumption activities of small subsistence or semi-subsistence farmers, and farmers may attribute little importance to stem borers as yield reducers If stem borer management options are to be adopted by farmers they must fit into existing farming systems Rarely are stem borer losses sufficiently high that farmers are likely to change their farming system only to accommodate a stem borer management recommendations

Farmers At the outset of any applied, problem-solving stem borer management research, entomologists should provide evidence on whether the insect is merely a pest or a pest problem for farmers This distinction between pests and pest problem[illegible] important Stem borers are regarded as pests be[illegible] they cause economic damage to sorghum This is necessary but not a sufficient condition for stem borers to become a pest problem for farmers Several other conditions must also hold before stem borers can be regarded as a pest problem

First of all, farmers must be able to associate the pest with economic damage This ability is likely to be conditioned by farmers' knowledge and skills, the degree of their exposure to farm management information from extension services and other farmers and the attention they give to sorghum

Second, farmers may not regard stem borers as a problem pest when the perceived losses are small in relation to the perceived losses caused by other biotic and abiotic yield reducers of sorghum, or where sorghum contributes little to the subsistence of the farm families Under such conditions stem borers are unlikely to attract the scarce management attention of farmers

Third, stem borers are not a pest problem unless farmers have at their disposal means for reducing economic losses Without a feasible pest management option, farmers may regard stem borers as a pest but not as a pest problem

Establishing that stem borers are a pest problem for farmers requires that surveys of stem borer damage in farmers' fields are complemented by surveys of farmers' perceptions of stem borers as a pest Such surveys do not have to be large exercises involving entomologists agronomists and social scientists equipped with a detailed questionnaire Often an ɔratory survey using rapid rural appraisal tech-ɛs may be sufficient to pesuade the researchers that stem borers are not a burning problem for farmers in whose fields entomologists have detected deadhearts and stem tunneling Where more substantial evidence is required a formal questionnaire survey may be needed Guidelines for formal perception surveys can be obtained from a pest perception network operating from the Open University UK (Tait 1981) Whether a recommendation is a solution for a farmer's stem-borer problem depends on the skills of the farmer and the farm's labor force on the costs of implementing the recommendation and on the expected returns from stem-borer management The adequacy of farmers' and laborers' skills for implementing a recommended control practice can be assessed from experiences with similar practices but can be determined only in on-farm trials Assessment of the costs of a stem-borer management option has to be based on the farm-gate prices of purchased inputs, and the value of the farm-owned ıurces in their best alternative use at the time n they are needed for stem-borer control The value to farmers of their owned resources may deviate considerably from average market prices are usually location-specific and may fluctuate considerably during the cropping season

Assessment of the expected returns has to be based on farmgate prices for sorghum at the time it is sold This assessment must take into account that sorghum stems are a valuable commodity, and should consider the effect of stem-borer management on the farmers' production and marketing risks Methods for assessing the costs and returns of pest management options are well established and an excellent exposition was provided by Reichelderfer et al (1984) In many instances the required methods do not require an economist

Improve Technology. Sometimes there may be an opportunity for improving farmers' pest management practices with adaptive on-farm research Several researchers have invested much hope in this approach (Matteson et al 1984) From our experience in India we are skeptical about this approach because we have so far been unable to identify traditional methods used by farmers to manage sorghum insect pests that have a potential for improvement through research (Rao and Mueller 1986)

Evaluate New Technology. Evaluating new technologies in on-station experiments is the mainstay of traditional pest management research Adoption of a farming systems perspective would not require substantial changes in the experimental methods It would however require a broader set of criteria for evaluating the results from experiments and appropriate selection of controls Conventional research uses classical statistical hypothesis testing to decide whether a new management technique performs in some variable(s) better than a control technique with some arbitrary level of significance Such research may be irrelevant from a farming systems perspective Classical statistical techniques are designed to rule out Type I errors, the error of rejecting the null hypothesis when it is true or the error of recommending a technology that is not superior to the control The conventionally chosen probability of committing this error bears no relation to the economic consequences of this error The farming systems perspective could be introduced into the analysis of experiments with neo-classical statistical methods that take the costs of selecting a nonsuperior technology into account (Manderscheid 1965 Dillon and Officer 1971)

Technology evaluation, the evaluation of new cultivars in particular, is often conducted according to rigid rules defined by a large government research administration These rules are designed to select the best technologies for a country, or for large agroclimatic zones, but may be too rigid for location-specific technologies that perform very well in some locations, but poorly in the larger environments covered by these evaluation rules

With the rapidly falling costs of computer time, modeling is becoming an increasingly attractive opportunity for introducing a farming systems perspective into the evaluation of new technologies before they are actually tested on farms However computer models usually have high set-up costs and their use can be recommended only when the prospective technology will have many important and complex repercussions in the existing farming systems

Testing New Technology. Once a promising new stem borer management option has been identified in on-station experiments it should be tested on a small number of representative farms before it is recommended to a large number of farmers These tests should be designed to evaluate the feasibility and the performance of the new option compared with farmers' conventional techniques These tests also help to identify weaknesses or defects of the technique that may have gone unnoticed in on-station experiments They provide feedback from farmers that is essential for fine-tuning the recommendation

The most crucial test of any new technology is its adoption by farmers The recommendation of a new pest management technology should be followed by adoption studies that include adopters as well as nonadopters Such studies rely on surveys They allow researchers to document the success of their research they provide information on the characteristics of researchers' clients and their assessment of the new methods This information helps researchers to design the next generation of technology and to obtain funds for its development

Summary and Conclusions

In this paper we have briefly reviewed the practicality and adoption of stem-borer management recommendations that have been reported in the literature This review indicated that most recommendations are impractical and have not been adopted by farmers in the SAT The introduction of a farming systems perspective to applied stem-borer management research was suggested and some appropriate objectives and research methods were discussed Our expressed concern was for applied stem-borer research to take into account farmers' perception of the stem-borer pest problem and farmers capacity to implement recommended stem borer management practices so that applied research results in recommendations of practical use to SAT farmers This notion has been aptly summarized by Reichelderfer and Bottrell (1985 p 286) "Identification of the basic needs and objectives of a technology recipient group is obviously an important step but one that is not always performed Bypassing this step will probably lead to poorly designed pest-management programmes "

References

Adesiyun, A A, and **Ajayi, O** 1980 Control of the sorghum stem borer *Busseola fusca* by partial burning of the stalks Tropical Pest Management 26 113 117

Altieri, M A 1984 Pest-management technologies for peasants a farming systems approach Crop Protection 3(1) 87 94

Amoako-Atta, B, and **Omolo, E O**, 1983 Yield losses caused by the stem pod-borer complex within maize cowpea sorghum intercropping systems in Kenya Insect Science and its Application 4(1 2) 39 46

Binswanger, H P, and **Ryan, J G** 1980 Village-level studies as a locus for research and technology adaptation Pages 121 129 *in* Proceedings of the International Symposium on Development and Transfer of Technology for Rainfed Agriculture and the SAT Farmer 28 Aug 1 Sep 1979 ICRISAT Center India Patancheru A P 502 324 India International Crops Research Institute for the Semi Arid Tropics

Binswanger, H P, and **Pingali, P I** 1984 The evolution of farming systems and agricultural technology in sub-Saharan Africa Agriculture and Rural Development Department Report no ARU 23 Washington D C USA World Bank

Bowden, J 1956 New species of African stem boring Agrotidae (Lepidoptera) Bulletin of Entomological Research 47 415-428

Carlson, G A, and **Mueller, R A E** 1987 Farmers perceptions education and adoption of pest management strategies by small farmers Presented at the 11th International Congress of Plant Protection 5 9 Oct 1987 Manila Philippines Patancheru A P 502 324 India International Crops Research Institute for the Semi-Arid Tr (Limited distribution)

Davies, J C 1982 Pest losses and control of damage on sorghum in developing countries the realities and the myths Pages 215 223 *in* Sorghum in the eighties proceedings of the International Symposium on Sorghum 2 7 Nov 1981 ICRISAT Center India Vol 1 Patancheru A P 502 324 India International Crops Research Institute for the Semi-Arid Tropics

Dillon, J L, and **Officer, R R** 1971 Economic v statistical significance in agricultural research and extension a pro-Bayesian view Farm Economist 12(1) 1 15

FAO 1980 Elements of integrated control of sorghum pests FAO Plant Production and Protection Paper no 19 Rome, Italy FAO 159 pp

FAO 1984 Food balance sheets 1979-1981 Rome, Italy FAO

FAO 1986 1985 FAO Production year book vol 39 Rome, Italy FAO

Goodell, G. 1984 Challenges to international pest management research and extension in the Third World do we really want IPM to work? Bulletin of the Entomological Society of America 30(3) 18 27

Haggblade, S. 1987 Vertical considerations in choice-of-technique studies evidence from Africa's indigenous beer industry Economic Development and Cultural Change 35(4) 723-742

Harris, K.M. 1962 Lepidopterous stem borers of cereals in Nigeria Bulletin of Entomological Research 53 139 171

Harris, K.M. 1985 Lepidopterous stem borers of sorghum 161 167 *in* Proceedings of the International um Entomology Workshop, 15 21 Jul 1984, College Station Texas, USA Patancheru, A P 502 324, India International Crops Research Institute for the Semi-Arid Tropics

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1986 Annual report 1985 Patancheru A P 502 324, India ICRISAT

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1987 Annual report 1986 Patancheru, A P 502 324, India ICRISAT

Jotwani, M.G., Chandra, D., Young, W.R., Sukhani, T.R., and **Saxena, P.N.** 1971 Estimation of avoidable losses caused by insect complex on sorghum hybrid CSH-1 and percentage increase in yield over treated control Indian Journal of Entomology 33 375 383

Jotwani, M.G. 1972 Insect pests major limitation in producing higher yields of sorghum Entomologists Newsletter 2 75

Jotwani, M.G. 1982 Factors reducing sorghum yields ect pests Pages 251 255 *in* Sorghum in the eighties eedings of the International Symposium on Sorghum, 7 Nov 1981 ICRISAT Center, India Vol 1 Patancheru P 502 324, India International Crops Research Institute for the Semi-Arid Tropics

Mahadevan, N.R., and **Chelliah, S.** 1986 Influence of intercropping legumes with sorghum on the infestation of the stem borer, *Chilo partellus* (Swinhoe) in Tamil Nadu, India Tropical Pest Management 32 162 163

Manderscheid, L.V. 1965 Significance levels-0 05, 0 01, or? American Journal of Agricultural Economics 47(5) 1381-1385

Matlon, P.J. 1980 Local varieties, planting strategies, and early season farming activities in two villages of central Upper Volta West African Economics Program Progress Report no 2 Ouagadougou, Upper Volta International Crops Research Institute for the Semi-Arid Tropics (Limited distribution)

Matlon, P.J., and **Spencer, D.S.** 1984 Increasing food production in sub-Saharan Africa environmental problems and inadequate technological solutions American Journal of Agricultural Economics 66(5) 671-676

Matteson, P.C., Altieri, M.A., and **Gagne, W.C.** 1984 Modification of small farmer practices for better pest management Annual Review of Entomology 29 383-402

Murty, K.N., and **von Oppen, M.** 1985 Nutrients distribution and consumer preferences in India some policy implications Pages 179 200 *in* Agricultural markets in the semi-arid tropics proceedings of the International Workshop 24 28 Oct 1983, ICRISAT Center, India Patancheru, A P 502 324, India International Crops Research Institute for the Semi-Arid Tropics

Nwanze, K.F. 1981 Les borers des tiges des cereales en Afrique de l'Quest Sahelienne distribution, importance relative et contuale (In Fr) Pages 109 145 *in* Proceedings, Lutte Biologique Contre les Ravageus et ses Possibilities en Afrique de l'Quest, 9 13 Feb 1981, Dakar, Senegal Washington, D C , U S A United States Agency for International Development

Nwanze, K F. 1985 Sorghum insect pests in West Africa Pages 37 43 *in* Proceedings of the International Sorghum Entomology Workshop, 15 21 Jul 1984, College Station, Texas, USA Patancheru, A P 502 324, India International Crops Research Institute for the Semi-Arid Tropics

Nye, I W.B. 1960 The insect pests of graminaceous crops in East Africa Colonial Research Study no 31 London, UK Her Majesty's Stationery Office 48 pp

Ogwaro, K. 1983 Intensity levels of stem borers in maize and sorghum and the effect on yield under different intercropping patterns Insect Science and its Application 4(1 2) 33 37

Plucknett, D.L., Dillon, J.L., and **Vallaeys, G.J.** 1987 Review of concepts in farming systems research the what, why, and how Pages 2 9 *in* Proceedings of the Workshop on Farming Systems Research, 17-21 Feb 1986, ICRISAT, Center, India Patancheru, A P 502 324, India International Crops Research Institute for the Semi-Arid Tropics

Pradhan, S. ed. 1971 Investigations on insect pests of sorghum and millets final technical report 1965 70 New Delhi, India Indian Agricultural Research Institute 157 pp

Rao, V.B, and **Mueller, R A E.** 1986 Some traditional pest control practices of SAT farmers Research Management Program Economics Group VLS Miscellaneous Series Patancheru A P 502 324 India International Crops Research Institute for the Semi-Arid Tropics (Limited distribution)

Reichelderfer, K H, **Carlson, G A**, and **Norton, G A** 1984 Economic guidelines for crop pest control FAO Plant Production and Protection Paper no 58 Rome Italy FAO

Reichelderfer, K H, and **Bottrell, D G** 1985 Evaluating the economic and social implications of agricultural pests and their control Crop Protection 4(3) 281 297

Ryan, J G, **Bidinger, P D**, **Rao, N P**, and **Pushpamma, P** 1984 The determinants of individual diets and nutritional status in six villages of southern India Research Bulletin no 7 Patancheru A P 502 324 India International Crops Research Institute for the Semi Arid Tropics

Seshu Reddy K V and **Davies J C** 1979 Pests of sorghum and pearl millet and their parasites and predators recorded at ICRISAT Center India up to August 1979 Cereal Entomology Progress Report no 2 Patancheru A P 502 324 India International Crops Research Institute for the Semi Arid Tropics 23 pp (Limited distribution)

Seshu Reddy, K V and **Omolo, F O** 1985 Sorghum insect pest situation in eastern Africa Pages 31 36 *in* Proceedings of the International Sorghum Entomology Workshop 15 21 Jul 1984 College Station Texas USA Patancheru A P 502 324 India International Crops Research Institute for the Semi Arid Tropics

Seshu Reddy K V (**In press**) Assessment of on farm yield losses in sorghum due to insect pests *In* Proceedings of the Regional Study Workshop on On Farm and Post Harvest Losses of Cereal Crops in Africa Due to Pests and Diseases 11 15 Oct 1987 Mbita Point Kenya Nairobi Kenya International Centre for Insect Physiology and Ecology

Sharma H C 1985 Strategies for pest control in sorghum in India Tropical Pest Management 31 167 185

Tait E J (**ed**) 1981 Guidelines for research Perception and management of pests and pesticides network Milton Keynes Buckinghamshire UK Open University Technology Faculty Systems Group

Taneja S L, and **Leuschner, K** 1985 Methods of rearing infestation and evaluation for *Chilo partellus* resistance in sorghum Pages 175 188 *in* Proceedings of the International Sorghum Entomology Workshop 15 21 Jul 1984 College Station Texas USA Patancheru A P 502 324 India International Crops Research Institute for the Semi Arid Tropics

Teetes, G L, **Seshu Reddy, K V**, **Leuschner, K**, **House, L R** 1983 Sorghum insect identification handbook Information Bulletin no 12 Patancheru A P 502 324 India International Crops Research Institute for the Semi-Arid Tropics 124pp

Walker, P T 1967 Survey of losses of cereals to pests in Kenya and Tanzania FAO Symposium on Crop Losses Rome 2 79 88

Walker, T S 1987 Economic prospects for agroforestry interventions in India s SAT implications for research resource allocation at ICRISAT Resource Management Program Economics Group Progress Report no 79 Patancheru A P 502 324 India International Crops Research Institute for the Semi Arid Tropics (Limited distribution)

Walker, T S, and **Rao, K V S** 1982 Yield and net return distributions in common village cropping systems in the semi arid tropics of India Economics Program Progress Report no 41 Patancheru A P 502 324 India International Crops Research Institute for the Semi-Arid Tropics (Limited distribution)

Discussion

Reyes Since older plants (six weeks old) are preferred for oviposition is this related to the nutritional status of the plant on which the larvae will feed?

Harris Possibly but I do not have relevant information Borers on crop hosts seem to have developed the strategy of going for the youngest tissues Evidence of recent work on *Chilo* in Africa suggests that leaf whorl tissue is more nutritious

Nwanze You spoke on the co-evolution of cereals and their stem borers We know that sorghum and pearl millet originated in Africa and that the important stem borers are indigenous to Africa One would have expected that the natural enemies of stem borers would have also evolved in parallel with their hosts but this is not the case Could you please elucidate?

Harris This is a relevant question and it is a huge to[illegible] It is a matter of balance part of the answer is th[illegible] the natural enemies are not operating the strategy that you would like them to operate Furthermore the strategy of natural enemies is not aimed at eliminating their hosts Many are general parasitoids or predators developing on a wide range of hosts What we have are specialist stem borers that we would like best controlled by highly specialized parasitoids Not that many exist

Vidyabhushnam It was suggested that chemical control measures should be adopted whenever necessary How do you ascertain which situation warrants the use of chemical control? Furthermore would it be valid in the case of peduncle infestation?

Prem Kishore The reference to chemical control was in the context of determining economic thresholds Studies on insecticide application to protect against peduncle infestation are still lacking This needs to be investigated

Sharma If I have understood correctly you have mentioned that carbofuran provides borer control f[illegible] up to 45 days In that case would you recommend any insecticide control since at that stage the crop will be in the boot leaf stage?

Prem Kishore Data from trials conducted on seed treatment soil furrow application or side-dressing at 15 days after germinaton indicate that under moderate levels of resistance there is no need for another application of carbofuran

Suryanarayana Murthy What are the effects of insecticides used in borer control on the natural enemy complex? What are the dangers of borer resistance to insecticides as we now have in *Heliothis*?

Prem Kishore The effect of different insecticides used in sorghum stem borer control on natural enemies has not been studied in detail However data generated on the effect of endosulfan 4% granules or dust show that its application does not affect natural enemies *C partellus* has not developed resistance to insecticides

Vidyabhushnam Delayed planting has been suggested in cultural control of stem borers But this practice would be disastrous in the Indian context where shoot fly infestation would surely wipe out a late crop Moreover a fortnight s delay in planting will seriously affect the crop expression Is this recommendation therefore of any practical value?

Varma The suggestion in question is not a generalization for saving the crop against stem borer It is pertinent however in regions where shoot fly is not a problem For example in northern India where sorghum is grown for fodder we sow in July

Lukefahr Do you know of an example where the combined action of the native parasites actually suppressed borer population below the economic threshold level?

Betbeder Matibet A good example is in West Africa with the sugarcane stem borer *Eldana saccharina* The natural enemy complex of ants parasites and predators have kept borer damage to less than 5% We have monitored this borer for more than 10 years in several sugarcane farms and have found this level maintained When this balance is upset for example through the use of insecticides borer damage on stems increases to between 15 and 20%

Seshu Reddy In assessing yield loss using various larval densities at various growth stages what precautions did you take to eliminate natural infestation?

Taneja In trials conducted at ICRISAT Center crops were planted in mid June when natural infestation is negligible Any natural infestation is taken into consideration by comparison with the control (zero infestation) Usually this is less than 1% infestation

Seshu Reddy In your studies on avoidable losses you certainly encountered other sorghum pests such as midge and headbugs What steps did you take to protect your crop against these insects so as to have accurate data on losses due to stem borer?

Taneja We spray to protect the crop from possible panicle feeding pests as and when required Similarly we use bird scarers against birds

Chundurwar You have presented the results of your studies with particular hybrids such as CSH 1 but we need to have results on the released hybrids in India especially CSH 5 and CSH 9 for comparison

Taneja We do not have such results and similar trials with CSH 5 and CSH 9 need to be conducted

Nwanze Dr Leuschner has pointed out that the effect of stem tunneling on grain yield depends on crop age at infestation and point of borer entry and attack However there are no data to show this I believe that with the stem cage technique we should conclusively show that this is the case Experiments should be designed in this regard

Wiseman This should be a major point for discussion by Dr Verma's group

Lukefahr Based on data provided by Dr Taneja one needs to have infestation early in the season with a level of infestation that greatly exceeds what one normally expects in the first or second generation I am wondering if there really is a problem in farmers fields

Mueller There may be a problem in farmers fields but from our observations farmers are not particularly concerned with stem borers Farmers may have 5 10% losses due to borers but they may have bigger problems such as drought and *Striga* that dwarf losses due to borers

Nwanze There are practically no data available from farmers fields on actual losses due to borers There are however reports on pest incidence Our definition of a pest is often based on research station findings We need data that show its magnitude on farmers fields We also need to take farmers perception of the problem into consideration

Lukefahr We should be careful because otherwise you set up a research program to see if a problem exists rather than to solve a problem

Nwanze But that is where the problem lies It is wrong to set up a research program based on information generated solely from a research station We must accumulate base line information on the extent of damage on farmers fields

Leuschner How would your decision in terms of research priorities on stem borer control be affected in a situation where farmers perceive 15% damage by stem borer as unimportant?

Mueller What is important is farmers perception of stem borer damage relative to losses from other yield reducers For example if the same farmers perceive losses from other yield reducers such as *Striga* to be much higher than 15% and if this perception is supported by yield loss surveys stem borers would not be listed as top priority for applied problem-solving research

Seshu Reddy We cannot solve all the problems in one day There are several constraints besides insect pests which the farmers must deal with We need to support our on-station research with what is really happening on the farmers' field

Harris There are all sorts of technicalities and technical aspects to the issue of whether stem borers are a problem or not We as entomologists may see this as a problem but I think in many cases farmers do not There must be situations when they do and those are the situations that have to be defined so that something practical can be done in providing solutions These are some of the key issues being considered in this workshop If there are problems where are they and what do they amount to? The first thing to do is to try and assess the losses if they occur It is not easy but it is the first step in setting up proper research programs which are intended to provide applied solutions