Pests of African sorghum

R7572 (ZA0377)

Final Technical Report

31 March 2000 - 31 May 2003

Compiled by

Alistair J. Sutherland

Natural Resources Institute

in collaboration with

CPP CROP PROTECTION PROGRAMME

DFID Department for International Development

ICRISAT BETTER AGRICULTURE FOR THE DRY TROPICS

KARI

" This publication is an output from a research project funded by the United Kingdom Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID." [(R7572) Crop Protection Programme]

CONTENTS

EXECUTIVE SUMMARY

1. Sorghum is an important traditional food security crop, and insect pests are one of the main constraints to small-holder sorghum production in Africa. The assumption underlying the commissioning of this project was that pest management technologies exist for the main insect pests of sorghum, but these need to be validated under a range of agro-ecological conditions before being promoted in Africa.

2. Over three years, the project worked in two distinct sorghum production systems in Western Kenya (WK) and Eastern Kenya (EK). Following the selection of representative sites, the project documented farmer pest knowledge and management practices, monitored the key pests of sorghum, identified and validated promising pest management strategies. Uptake pathways for these technologies were explored with stakeholders in dissemination workshops and through a study of livelihoods context for crop protection in semi-arid Eastern Kenya.

3. A wide range of conventional and participatory research methods and tools were used concurrently. On-farm and on-station research trials were done in parallel, alongside focused PRAs, formal surveys and on-farm monitoring . This enabled read across of results so that clear conclusions could be reached within a relatively short time span.

4. In both EK and WK farmer knowledge of the key pests was found to be partial, and to vary in relation to the size of the pest and its economic importance. Farmers are very aware of damage caused by stem borer, the largest of the pests, although they underestimate its economic importance. Farmers have less awareness of shoot fly, particularly in EK where its symptoms are confused with stem-borer. Sorghum midge is known by farmers (but much less by extension staff) to cause widespread damage in WK, but is not known as a pest in EK. Farmers sorghum pest management strategies are preventative rather than reactive. Some farmers are aware of cultural practices which help to avoid damage from these pests, including planting date, intercropping, stover management and extensification. They do not use chemicals to control pests because sorghum is not seen as a lucrative cash crop.

5. The main insect pests identified through monitoring in WK were, in order of economic importance; midge, shoot fly, stem borers, and *Helicoverpa* spp. In EK the order was stem borer, followed by shoot fly, chafer grub, aphids, head bugs, helicoverpa spp and army worm.

6. Two main pest management strategies, varietal resistance and low cost cultural practices, were identified during project formulation and inception meetings and then explored through field trials.

7. In EK, a number of the introduced varieties tested showed reasonable tolerance to stem borer and also acceptability by farmers; KSV12, Gadam el Hamam, KARI Mtama 1, ZSV3, Sudan 142, IESV 920098, IS 23509 and Macia. Two of these also showed shoot fly tolerance (IESV 920098 and IS 23509). In WK Wagita was ranked best for resistance to midge attack followed by IS 8884, AF 28 and IS 3461. Overall, farmers preferred Wagita, IS 8193, Seredo, Gopari and IS 8884, mainly emphasising early maturity and post-harvest qualities.

8. In EK trial results show that both during the long dry season (August to October) and the shorter dry season (February and March) cutting sorghum stover

immediately and spreading or placing in trash lines, for periods of as little as 16 days reduces live borer numbers. The investment of time in slashing down plants at harvest is likely to reduce the carry-over of stem borers by up to 90%. In WK results suggest that cutting and laying stems for six weeks soon after harvest is the best treatment for reducing stem borer carry-over.

9. Survey results suggest that midge damage and carry over in WK is accentuated by poor panicle management practices, related to lack of awareness among farmers and extension agents. There are opportunities to improve panicle management practices through well targeted extension programmes.

10. In EK trials provided evidence that mixed row intercropping with millet can reduce stem borer larval numbers in sorghum in the long (April) rains, which is the season when then stem borer challenge is most severe. Sorghum will compete for early moisture, but stem borers are reduced, with a benefit both in terms of sorghum yield and a lower borer carry over population.

11. In WK results from planting date trials clearly showed that pest damage can be significantly reduced by planting early maturing varieties up to four weeks after the onset of rains, instead of using the longer duration ones. Short maturing sorghum varieties have a valuable role for improved food security in WK.

12. The project built national capacity at various levels. This included field pest assessment, workshop preparation and presentation skills, focused PRA methods, formal survey methods, on-farm and on-station design & layout, participatory evaluation methods, statistical analysis and report writing skills for national research and extension staff. Higher degrees (one Ph D and on M Sc by research) were obtained by two national research staff. 7 farmer panels were trained in trial layout, pest identification and participatory research methods.

13. The review found that Semi-Arid EK (SAEK) has more than 3 million inhabitants who depend largely on agriculture to meet their basic needs. Both field and horticultural crops are important for cash income, particularly grain legumes, fruits and vegetables. For these crops, insect pests and diseases are a major and an increasing constraint. Relevant crop protection research has been undertaken, and some key messages are available, but little has been done to promote results from publicly funded research beyond the immediate area where the research has been conducted.

14. The interest of farmers and development agencies in crop protection is largely related to the extent to which improvements in crop protection translate into visible improvements in income and food security. There are good opportunities for linking promotional activities to other development initiatives in marketing, relief provision and knowledge transfer (e.g. farmer field schools).

15. Future research (including crop protection research) must be informed by an understanding what drives decision making in crop production for the majority of poor households in SAEK. Food security is a key driver, and varieties of the main food crops need to be screened for tolerance to the main environmental challenges (weeds, insect pests, low soil fertility, diseases). For food crops, research should focus on low input pest management practices such as seed management, appropriate forms of inter-cropping, field sanitation, crop rotation and use of locally available botanicals. For higher value crops IPM including more effective use of chemicals and local botanicals is a research area to be developed in partnership with agencies supporting marketing activities.

Plates of Project Activities

SETTING THE CONTEXT

Plate 1: Seed relief programs are an important potential uptake pathway for new crop varieties in semi-arid areas of Eastern Kenya - this picture shows local officials distributing cow pea seed in Mbeere District, as part of a government seed relief programme.

Plate 2: A stand of sorghum grown from seed purchased at a local market showing the range of plant heights in the local land races - Mbeere District, E. Kenya.

Plate 3: New sorghum varieties spread through local markets and also through food relief. Local extension worker Laban Rindile examines this new variety which is believed to originate from Western Kenya and to have come with sorghum food relief. While farmers in Eastern Kenya tend to prefer white seeded sorghum, this red seeded variety has been widely adopted because of its *uji* making qualities.

Plate 4: The local check in a baby variety trial. Using seed bought from the local market it is clear that mixtures of populations with a range of plant heights and head types are common in Kiomo location where sorghum is a minor crop relative to maize for most farmers, but one that is on the increase due to increasing unreliability of the rainfall. Mwingi District, E. Kenya.

Plate 5: Livestock and crops are important sources of cash for households in semi-arid Eastern Kenya. For women poultry and green grams are particularly important cash sources - this picture shows traders waiting to load their sacks of green grams and their trussed chickens purchased in the local weekly market onto a bus bound for Nairobi. Kyuso Market, Mwingi District.

Plate 6: Weekly local markets are important meeting points for farmers and also one of the main sources of seed for planting. Women often bring small amounts of grain for sale in their colourful traditional bags (kiondos) and use the money raised to buy small household necessities such as salt, soap and sugar.

Plate 7: Crop pests, particularly weeds, soil born pests and also stem borers, are less troublesome on newly cleared land in which the branches from felled trees are burned and the tree trunks used for soil conservation. However, new land for clearing is getting scarcer each year, and pest pressure in semi-arid Eastern Kenya is increasing due to semi-permanent cultivation replacing shifting cultivation

Plate 8: Weeds are a key pest to sorghum in semi-arid Eastern Kenya, but one that most farmers feel they can manage. Weeding with an ox plough is a labour saving option being done here in a late planted sorghum crop grown in pure

Plate 9: Maize-sorghum intercropping in alternate rows (or in the same row) is quite common in parts of semi-Arid Eastern Kenya as a risk spreading strategy - the maize matures more quickly than the sorghum, but at a greater risk of crop failure - the sorghum (the shorter plant) is able to withstand long dry spells and capture benefits from late rainfall - the effect on stem-borer carry over is not known.

MANAGING CROP STOVER

Plate 10: Sorghum stover left standing in the field during the dry season is a significant source of stem borer carry over. The sorghum in this picture is mainly the two season variety grown by some farmers in eastern Kenya, particularly on the upper side of soil conservation terraces

Plate 11: This shows two options for managing stover; a) laid in a line by a row of pigeon peas which are used for soil conservation, or b) laid along the upper side of a soil conservation terrace.

Plate 12: Where there are no soil conservation structures, stover is used instead. The picture shows cut crop stover laid out in box shapes on a ridge which has been cleared of trees and cultivated. Trials suggest this method of stover management is effective in controlling stem borer carry over.

Plate 13:Where livestock feed is short during the long dry season, crop stover is often cut and stored in trees, out of reach of livestock. This is a likely major source of stem borer carry over.

GETTING STARTED

Plate 14: Scene from Day 2 of the Stake-holder planning workshop held in Mwingi District, February 2001. After visiting the mother variety observation plot the workshop moved into the shade in the adjacent dry river bed to prioritise the pest problems of sorghum and discuss, farmer strategies for pest management and researchable options.

Plate 15: Getting the local leadership involved in on-farm trials. Assistant chief helps with planting the baby trials during the first season, November 2000, of Kamuwongo Location, Mwingi District, E. Kenya.

Plate 16: In Western Kenya the research team started with focused PRAs in March 2000. Interviewing a female farmer in Ndhiwa location, Homa Bay District in her sorghum planting from the short (September) rains. The effect of striga and midge blasted panicles are apparent.

ON-FARM VARIETY MONITORING

Plate 17: Sorghum variety baby trial farmer, recording book in hand, being visited by project researcher just before harvest Munoni Division, Mwingi District

Plate 18: Baby variety trial farmer and community seed bulker with the location extension officer and divisional extension co-ordinator visiting an observation baby trial planted in November 2000 which yielded very well under good soil and water conservation conditions- Kiomo Location Central Division, Mwingi District.

Plate 19: Sorghum-pearl millet intercropping in the same row is common in much of semi-arid E. Kenya. Trial farmer stands in her observation plot where the effects of this practice on stem borer is damage was assessed - Central Division, Mwingi District, E. Kenya.

EVALUATION WITH EXPERT FARMER PANELS

Plate 20: Farmer panel ranking the criteria used for evaluating sorghum varieties. Criteria from farmers were written on cards in the local language and farmers then arranged the cards in order of importance. This information was used in selection of criteria used when comparing the scores across variety evaluations by six farmer panels in Mwingi District.

Plate 21: Farmer expert panel undertaking an end of season evaluation of the mother trial (17 varieties) at the farm of Beatrice Muthami, Kathiane Location, Mumoni Division, Mwingi District. The good and bad points of each variety are discussed before the panel splits to do a more detailed evaluation of each of 3 sets of baby trials (6-7 varieties per baby trial).

Plate 22: Baby trial farmers expert panel in Twymiwa sub-location (Ferdinand Mutinda's farm), evaluating 7 varieties using stones as counters. The local extension worker (seated bottom right) looks on and takes a record leaving the farmers to get on with the scoring. Twymiwa Location , Kynso Division Mwingi District, E. Kenya.

Plate 23: Baby trial farmers compare results using a matrix scoring framework. Each of the 6-7 varieties is given a score against important criteria, including pest resistance. The criteria are listed in the local language on cards along the left-hand side of the matrix and the varieties are arranged along the top for easy identification. In the background another panel of baby trial farmers can be seen evaluating a different set of varieties. Kathiani, Mumoni Division, Mwingi District, E. Kenya

Plate 24: In some areas existing farmer groups agreed to manage the trials, such as Kathiane Farmer Field School (FFS), Mumoni Division, Mwingi District. Warming up with a song before starting the class which in this case involved evaluation of the mother variety trial followed by a discussion on stover management as part of stem borer control.

Plate 25: Farmers evaluating a mother trial planted at Homa Bay Farmer Training Centre, Western Kenya.

Plate 26: Farmers evaluating the palatability of new sorghum varieties at a utilisation workshop hosted by a trial farmer in Homa Bay District, Western Kenya.

Plate 27: Grain samples of new sorghum varieties on display for evaluation at a utilisation workshop hosted by a trial farmer in Homa Bay District, Western Kenya.

Plate 28: Ugali samples made from new sorghum varieties for palatability evaluation at a utilisation workshop hosted by a trial farmer in Homa Bay District, Western Kenya.

MONITORING PEST PROBLEMS

Plate 29: On-farm observation trial on the effects of stem borer on plant yield. The tall and healthy looking crop on the left has been treated with two applications of buldock while the shorter, less developed and more patchy crop on the right was untreated - farm of location extension officer, Laban Rindile, Kiomo, Central Division, Mwingi District

Plate 30: Signs of stem borer infestation; dis-colouration on the stem of the sorghum plant, the borers crumbs trapped in the leaf-stem intersection and masses of cream coloured borer eggs on the leaf being held - Mwingi District, E. Kenya.

Plate 31: Stem borer damage leading to "chaff head" resulting in zero yield of plant in an on-farm variety trial - Mumoni Division, Mwingi District


32a


32b


32c


32d

32a – Deadheart - symptom of late shootfly and/or early stem borer damage
32b - Stem borer damage by stem tunnelling
32c - Stem borer leaf damage
32d - Stem borer damage causing stem breakage

Plate 33: A midge blasted panicle – there was a sever midge attack in the main season of 2001, causing almost total crop loss for all late planted sorghum in Homa Bay District.

Plate 34: Caterpillars (Helocoverpa spp) cause visible damage when there is an outbreak. As was the case in the October 2001 growing season when the rainfall was good in Kyuso Division of Mwingi District

Plate 35: Farmers' sorghum crop with cover kernal smut: stem being held showing severe effects next to badly affected developed panicle. This, a significant but manageable pest problem in semi-arid Eastern Kenya (Addressed by CCP project R7518)

MID-TERM REVIEW OF PROGRESS

Plate 36: Mid Project Evaluation Meeting. Dr Josephine Songa KARI Entomologist presenting the results from the first season trial on Stover management at Katumani National Dryland Research Centre.

Plate 37: Professor B Obilana, ICRISAT Sorghum Breeder presenting the results of a group discussion on variety evaluation and plans for the coming season at the mid project review meeting, February 2002.

1.0 BACKGROUND

1.1 Project rationale, duration and implementation

Sorghum originated in Africa and is an important food grain in the semi-arid tropics, particularly for poorer farmers. It has been neglected relative to other cereals such as rice, maize and wheat in terms of research and development activities. Insect pests are one of the main constraints to small-holder sorghum production, particularly when the crop is grown under relatively low external input conditions. This project was commissioned in 2000 by DFID's Crop Protection Programme (CPP) of research. The underlying assumption was that technologies exist for the management of the main insect pests of sorghum, but these need to be screened for their suitability for poor smallholders and validated under a range of agro-ecological conditions before being disseminated.

Sorghum is key to sustainable food production in areas of erratic and/or low rainfall in Sub-Saharan Africa and India. 12.5% of the world's acreage is located in East Africa. In Kenya, where this research was conducted, the majority of sorghum is grown by smallholder farmers, particularly by female farmers who value sorghum as a food security crop and also one that can generate rural incomes through brewing and sale in local markets. Kenya was selected as the research site begin one of the DFID nominated countries for the RNRRS programme; having adequate research infra-structure, a range of agro-ecologies where sorghum is grown, a critical mass of research capability (both in ICRISAT and KARI) and providing opportunities for dovetailing with the sorghum pathology project (R 7518).

The project had 3 years in which to select local research sites, identify the key pests, document farmer management practices, monitor pest levels, identify and validate suitable pest management strategies for the two farming systems and identify uptake pathways for each (see activity calendars in section 3). The Western Kenya component was initiated in March 2000 through start up funding for exploratory PRA activities in two communities. Activities in the west were implemented by KARI- Kisii Regional Research Centre with support from NRI, ICRISAT and extension staff in Homa Bay and Busia Districts. The Eastern Kenya component was initiated in October 2000, following issuing of a project contract. Activities in the east were implemented by KARI-Katumani Research Centre with support from NRI, ICRISAT, and Extension staff in Mwingi District.

1.2 Two main production systems

The two main sorghum production systems in Kenya were selected for this research on the basis of agro-ecologies and cropping systems. In western Kenya, the main sorghum producing area of Kenya where sorghum is the traditional food staple, there is one long growing season (March-August). Most farmers grow longer duration single season varieties and prefer sorghum as their staple food. Sorghum also has ritual and medicinal value. Because rainfall and soil conditions are relatively good, insect pests are **the major** limiting biophysical factor to increasing production in the west.

In eastern Kenya there are two growing seasons for sorghum. Both seasons are short and one is also very unreliable. Short duration single season varieties have largely displaced the traditional two season (ratoonable) varieties, due to climate change, changing labour availability, food relief and stem-borer increase, although there is some resurgence of the two season varieties as a result of soil and water conservation improvements. Sorghum is not the preferred staple for most farmers in Eastern Kenya, has a low market price, and is seen largely as an “opportunist” crop (capturing surplus rainfall and using up spare land). Sorghum is valued as a food security crop by farmers. Drought and insect pest constraints are inter-related; some pests are associated with good rainfall, while others with dry spells and drier than average seasons. Insects (mainly stem borer) are a bigger constraint than farmers realise, particularly in drier/average seasons.

Because of these important differences, separate research programmes for Western and Eastern Kenya were designed.

1.3 Identification of demand

Crop protection factors are important in limiting sorghum productivity. Before this project, CPP had already commissioned research into two important pests of sorghum, namely Striga (R7564) and cover kernal smut (R7518). Insect pests comprise a third major category of pest constraint to sorghum production (Young and Teetes, 1977; Seshu Reddy and Davis, 1979; FAO, 1980). While there are a wide range of insect pests affecting sorghum, the most wide-spread and devastating in the semi-arid tropics are shoot fly, sorghum midge and various species of stem borer.

Sorghum grain yield is very low in east Africa with an average of 1090 kg ha^{-1} compared to 3063 kg ha^{-1} in the USA. One of the major constraints responsible for this difference is insect pests. ICRISAT (one of the project partners) was consulted during project identification, and noted that shoot fly, stem borers and sorghum midge were the priority insect pests of sorghum. Information available from CPP projects (R6581) include PRA activities in Eastern Province of Kenya note stem borers as the key pest of sorghum. Shoot fly was also frequently reported as a constraint to production. Sorghum midge was ranked first as a research priority amongst the panicle pests of sorghum in the intermediate altitudes of Kenya and lowlands of Uganda at the ICRISAT consultative workshop on panicle pests of sorghum in 1993 (Harris, 1995). Chemical control of these three pests is expensive and not practical for the subsistence farmer. Therefore the development of management systems which are not pesticide reliant and are economical, environmentally safe and socially acceptable was seen as a practical approach. The economic importance of these three insect pests in Kenya is partially documented in previous research (particularly for stem borer). At project inception it was anticipated that pest management measures identified in Kenya would be applicable in similar agro-ecologies elsewhere in Eastern Africa, and beyond.

1.4 Previous research on the insect three pests

Stem borers:

Previous surveys on stem borers have shown that in Eastern Province, Kenya, *Chilo partellus* is the dominant stem borer on sorghum with an incidence of 82%. In Western Kenya *C. partellus* followed by *Busseola*, *Eldana* and *Sesamia* species were the dominant stem borers (Seshu Reddy, 1983). Work in W. Kenya has shown that *C. partellus*, *Busseola*, *Eldana* and *Sesamia* were able to survive as pupae in facultative diapause in dry stalks until the next season, thus serving as a reservoir source of carry-over to initiate next season's infestation (Seshu Reddy, 1981). Trash burning (Duerden, 1953; Ingram 1958), spreading the stover thinly in the sun (Harris, 1962, Olufadi, 1978 and Ajai, 1978), or partial burning (Adesiyun and Ajayi, 1980) have been shown to cause significant reductions in the incidence of stem borers in the following season's cereal crops. Other methods identified as reducing carry-over are removing volunteer and alternative hosts (Teetes, 1995; Leuschner, 1985; Seshu Reddy and Omolo, 1985), removal of deadhearts (Seshu Reddy, 1981) and crop rotation (Ingram, 1958). In general, the life cycles of stem borers last 30-50 days under field conditions. The pre-oviposition periods are 24-48 hours and oviposition periods are 1-3 days. Therefore any delay or interference during the latter two periods would reduce the survival rate and colonisation success of stem borers since it is the ephemeral females from the carry-over which initiate the next season's population (Ingram, 1958). Intercropping sorghum with cowpea has been shown to significantly delay colonisation by *C. partellus*, especially within the 42 days after crop germination (Amoaka-Atta *et al.*, 1983; Minja, 1990). The use of the so called "push-pull" system, in the lake zone of Kenya, where maize was intercropped with sudan grass, *Sorghum sudanesis*, and silverleaf *Desmodium uncinatum* reduced stem borer damage by half and the striga rating to 5% (Khan *et al.*, 1997; Pickett, 1999).

Other research has investigated the role of parasites (Mohyuddin and Greathead, 1970), light traps (Ho and Seshu Reddy, 1983) and pheromones (Campion and Nesbitt, 1983) in the control of stem borers. These measures could have a future role in the control of stem borers, but taking into consideration the economics of the farming systems and the present level of knowledge many of these technologies are not presently compatible with smallholder farming practice. To become acceptable these tools either require further intensive research, or outlays of cash beyond the scope of the average smallholder farmer and/or outside intervention in the supply of the required inputs.

Sorghum midge:

Sorghum midges (*Stenodiplosis sorghicola*) carry over from one season to the next by the larvae entering diapause inside the attacked spikelet. In the next season their emergence coincides with the first appearance of the flowering heads of sorghum (Harris, 1985). A new generation of adult midges is produced every 2-3 weeks, resulting in the population increasing during the season and late sown sorghum is therefore more severely damaged than early sown sorghum. The severity of midge attack is mainly determined by the extent to which midge populations have built up on earlier flowering sorghums.

The most effective cultural practice presently available for reducing losses from sorghum midge is by avoidance using uniform, regional planting of sorghum early in the growing season. However, such planting is rarely possible within semi-arid tropical farming systems due to planting periods being delayed or extended in response to erratic rainfall.   Other cultural methods which have been effective in

Texas, USA, are reducing carry-over by destroying old seed heads and trash, cutting down self-sown or ratooning plants which flower earlier than sown crops, and the elimination of wild sorghum grasses (Young and Teetes, 1997). Biological control has not been attempted, for although research has identified parasitoids these do not appear to provide significant suppression of midge populations (Teetes, 1995).

Shoot fly:

Female shoot flies (*Antherigona soccata*) start laying their eggs on sorghum seedlings 8-30 days after germination. Individual eggs are laid on the underside of leaves and a maggot emerges two days later. The maggot crawls up to the leaf whorl and penetrates down the leaf sheath, where it cuts the growing point and feeds on the decaying tip resulting in deadheart symptoms. Pupation may occur either in the plant or in the soil. The life cycle is completed in 15-24 days (Harris, 1962). The fly can kill small plants, while larger plants compensate by tillering. In Kenya, during dry periods *Sorghum arundinaceum* was identified as a major source of carry-over, while larval or pupal aestivation was dismissed as a source of extensive carryover (Delobel and Unnithan, 1981).

In Kenya, Wheatley (1961) reported that losses in yield due to shoot fly were only significant in late- sown sorghum, and thus recommended sowing within a two week period. However, this recommendation has the same problems as mentioned earlier under sorghum midge. Sowing a high seed rate (10-15 kg/ha) and then uprooting and destroying infected plants showing the deadheart symptoms has been recommended in India (Vedamoorthy *et al.*, 1965) and Africa (Breniere, 1972). However, other researchers (Mowafi, 1967; Davis and Seshu Reddy, 1980) have shown that there is a positive correlation between higher plant density and numbers of plants attacked.

Other methods which have been recommended as possible control methods but that have not been tested are: removal of alternative hosts in the dry season (Davis and Seshu Reddy, 1980), and use of fish meal traps (Meksongsee *et al.,* 1981). Many parasites and predators have been recorded at different developmental stages of the shoot fly. In Kenya shoot fly eggs, first and third instar larvae are parasitised by chalcids, *Trichogramma kalkae,* and *Tetrastichus nyemitawus* respectively, while adults are eaten by coccinellid beetles, *Scymnus tepidulus*. However none of these agents have been utilised for biological control.

1.5 Appropriate pest management strategies:

Taking account of the above review of previous research, two main strategies, varietal resistance and low cost cultural practices, were identified during project formulation and inception meetings and then explored through field trials. The use of resistant varieties has been cited as a major means of reducing crop losses in sorghum due to stem borers (Minja, 1990), sorghum midge (Harris, 1995) and shoot fly (Jotwani, 1982). Varieties which show varying degrees of resistance to the pests have been developed by researchers, particularly at ICRISAT (various Annual Reports). Varieties to be tested on-farm in combination with cultural control methods were identified in consultation with sorghum breeders and entomologists based in ICRISAT and KARI. These were further screened using farmer panels and on-farm trials following the mother-baby approach, with particular attention to the resistances required for the particular area (i.e. resistances to shoot fly and midge in the west of Kenya and resistance to stem borer in the east).

Though several lower cost (non-chemical) pest management methods are reported in literature, few of these have been tested on farm and even fewer have been accepted by farmers. The project worked to identify low cost technologies that were compatible with the farming systems in the main sorghum producing areas of Kenya. This involved controlled experiments in order to validate the more promising control measures along with on-farm trials to assess these methods with farmers. This two-pronged approach guided the project team in its efforts to determine, with the use of analysis of variance and field site information, whether and under what circumstances the proposed management methods may be better than farmers' practices. The participation of local farmers enabled system compatibility and farmers’ risk considerations to be considered.

1.6 Project response to specific challenges of working on sorghum

This project targeted a crop and its complex of pests which is of strategic importance in the region. However, both sorghum and its main insect pests are not necessarily of immediate priority concern to the farmers growing it, or to development agencies providing services to these farmers. While sorghum is an important food crop in drier areas of East Africa, in diagnostic studies (surveys and PRAs covering cropping enterprises) sorghum pest control rarely figures as a high priority to farmers. In such studies sorghum often ranks below maize and other important food and cash crops (such as cotton, cowpeas, grams, beans, groundnuts and exotic vegetables) with regard to pest management issues. Hence, in the popular drive for demand-driven research over the past decade, sorghum and its associated pests has been neglected by researchers. This presented challenges for the research team, both when attempting to fully engage farmers in the research process and also in identifying uptake pathways for promising research findings. It was felt that promotion of research outputs based on sorghum pest management alone were unlikely to sufficiently engage potential uptake agencies. This challenge was brought to the attention of CPP programme management eighteen months into the project, and in order to address promotional challenges a further output and related activities were identified. This output focused on characterising the demand for crop protection advice in the semi-arid farming systems in the context of livelihoods of the rural poor, inventorising the supply of crop protection related technology for these systems, and identifying opportunities for promoting research products and knowledge which would might improve the livelihoods of small-holder farmers.

1.7 The Livelihoods context for crop protection in semi-arid areas of East Africa

The drier and semi-arid areas of Eastern Africa have over the past 50 or more years undergone a steady transition of land use: from hunting (including fishing) and agro-pastoralism to settled mixed rainfed farming. Population pressure in the adjacent higher potential higher rainfall uplands has resulted in a steady stream of human migration into the drier lands. In these areas human population densities are rising as a result of improvements in water, sanitation and health care provision, along with food relief. Land for grazing and also cropping is increasingly limiting, with increasing dependence on semi-permanent cultivation of rainfed crops as the major source of rural livelihood for most families. Pests and diseases pose an increasingly important risk to reliable crop production for the adapted semi-arid crops; food legumes, cereals and for other emerging cash crops (e.g. mangos and vegetables).

DFID and other agencies have invested into agricultural research for the semi-arid areas. Within DFID Crop Protection Programme (CPP), this has included research into crop protection issues relating to sorghum, finger millet and groundnuts. Most of this research has been conducted along a particular technical theme, with limited attention to the wider livelihood and policy context. Without this contextualisation:-

- the relevance and potential impact of technical research upon livelihoods of the rural poor cannot be adequately assessed,
- development of a well focused uptake strategy for research outputs becomes problematic,
- the packaging of technical information, in a form suited for dissemination to the intended users cannot be done effectively.
- The identification of future research priorities tends to be driven by researchers' perceptions rather than by the analysis of constraints and opportunities in semi-arid livelihoods,

Midway through the project, this contextualisation was undertaken for Eastern Kenya as part of an additional output to provide a characterisation of agriculturally based livelihoods, including the emerging trends and opportunities. Analysis, synthesis and updating of this information was judged to be needed in order to assess the opportunities of promotion of the research outputs from this project and also to assist the prioritisation of future research activities relating to crop protection (see 1.6 above).

2.0 PROJECT PURPOSE

The project addressed two of the CPP programme outputs; **SA2a**: *Strategies developed to reduce the impact of pests and stabilise crop yields in semi-arid cereal-based cropping systems for the benefit of poor people*, and **SA2b:** . *Promotion of strategies to reduce the impact of pests and stabilise yields in semi-arid cereal-based cropping systems, for the benefit of poor people*.

To address the first output, the project had three outputs which aimed to document farmer management practices, verify levels of the key insect pests and validate pest management strategies suited to the two farming systems. The aim was to develop and test technologies for the control of stem borers, shoot fly and sorghum midge and to generate knowledge on their efficacy and acceptability to smallholder farmers from the semi-arid zones in Western and Eastern Kenya. It was anticipated that the work undertaken in Kenya would also apply to other countries in East Africa with similar environmental and socio-economic conditions and perhaps beyond. The second output was addressed through the review of opportunities for the promotion of crop protection research results, including the technical results from this project, in semi-arid Eastern Kenya. Looking further ahead, the project also undertook to identify future crop protection related research opportunities for improving livelihoods in semi-arid areas in Eastern Kenya.

3.0 RESEARCH ACTIVITIES

The project operated in Kenya's two main sorghum producing areas, semi-arid Eastern Kenya and drier (sub-humid) Western Kenya[1].

Implementation was through multi-institutional collaboration. In both Eastern and Western Kenya local leadership was provided by KARI scientists. In Eastern Kenya KARI staff undertook the on-station technical research while extension agents undertook the major part of the on-farm research activities. In Western Kenya KARI staff undertook the major part of both the on-station and the on-farm research.[2] ICRISAT provided pest resistant planting materials for both sites and entomology

[1] While these are the principal sorghum growing, areas smaller quantities of sorghum are also grown in the dry highlands and the wet upland and coastal areas.

[2] This was mainly for logistical reasons. In Eastern Kenya the main sorghum growing area was four hours away from the research centre, and the on-station activities could be conducted at the main sorghum research sites (Kiboko and Katumani). In Western Kenya the on-station activities could not be conducted at Kisii Research Centre and had to be undertaken at a sub-centre (Homa Bay). Reaching the sub-centre involved the KARI researcher travelling though the sorghum growing areas which were used for the on-farm trials.

support for Western Kenya, while NRI provided overall leadership and technical support for on-station and on-farm activities in both sites in terms of crop protection, socio-economics and participatory research methods.

A similar research approach and activities were used in both Eastern and Western Kenya, but with some variations tailored to the different circumstances and situations in each site (see Figures 1 and 2). In both sites, stakeholder workshops were held in the first year to refine research priorities and build ownership of the project. End of project workshops were held to share the results and agree on the way forward[3]. In both sites on-station and on-farm experimentation was undertaken in parallel, with one informing the other; the more complex experimentation being done on-station. Both sites used a mother-baby design for participatory on-farm screening of sorghum varieties.

In Eastern Kenya, two growing seasons (one very short but reliable, one longer but unreliable) for sorghum enabled the on-farm and on-station trials to be repeated three times, while the one (long and reliable) growing season in Western Kenya only allowed for trials to be done twice within the three years. In Eastern Kenya the long distance (4-6 hours drive) from the on-farm sites from the on-station site resulted in many more on-farm sites (6) and farmers (50-60) being involved due to the devolution of research activities to local extension staff working with farmers. In Western Kenya the close proximity of on-station and on-farm sites (15 minutes drive) enabled closer interaction between the main local researcher and a much smaller number of farmers (10-15). To compensate for the narrower geographical focus of trials in Western Kenya, more resources were invested into surveying the context. Focused PRAs were undertaken in three locations prior to the design of on-farm trials. In order to provide a stronger basis for extrapolation of the results a formal survey was conducted over two districts covering 4 divisions and 8 locations mid-way through the trials. A focused study on panicle management was undertaken following foiled attempts to characterise the process of sorghum midge carry over through on-station trials in Western Kenya. In Eastern Kenya, additional focused socio-economic studies were undertaken in 5 of the 6 sites in order to provide the livelihoods and crop management context for the technologies being developed. These studies were used to inform the review of crop protection issues in semi-arid Eastern Kenya which was based mainly on a review of published and grey literature and key informant interviews.

Research Methods/Tools

[3] The way forward involved consideration of the wider context for crop protection research outputs, including the demand for crop protection information among the main stakeholder groups and a review of what was currently available in terms of research products to meet this demand. This is reported in summary for in the workshop reports (Annex).

A wide range of methods and tools were used to produce project outputs. While there was some sequencing of activities, the research approach was not a linear one (for example starting with on-station trials before moving to on-farm ones, or starting with diagnostic surveys before doing on-farm trials). Due to the limited time available, and to enable read- across of results to modify research activities for the subsequent seasons, on-farm and on-station research activities were followed in parallel. Table 1 outlines the main research tools used, and the main purposes of each.

Table 1: Research Methods used and Purpose of these

METHOD/TOOL	MAIN PURPOSES
Focused PRAs with sorghum growers at start of project and later on	Understand systems context for sorghum, Document farmer knowledge of pests and management strategies,
Formal questionnaire survey of sorghum growers	Quantify key facts on sorghum management and pests, and validate them over a wider area
Field observations through farm visits at different stages of the season	Verify important pests Understand systems context for sorghum, Document farmer knowledge of pests and management strategies,
Workshops/meetings at start, Middle and End of project	Confirm key pests, location/s and priorities for research Share interim results and realign research Share findings and decide way forward
On-station experiments – Randomized Compete Block Designs	To develop/validate pest management strategies under controlled conditions
On-farm trials - mother-baby design for varietal tolerance and with/without observation plots for other strategies.	Validate technology on-farm, Involve farmers and extension staff and build their research capability,
Farmer panels – meeting every season and using scoring, voting, ranking and discussion.	Collectively learn about and evaluate pest management technologies, Benchmark results across sites
On-farm pest monitoring- based on the trials – visual observation and stem-borer damage scoring.	Quantify damaging insect pests in each season and stem borer damage levels

Calendar of research activities

A pre-project advance enabled an initial visit by NRI staff to Kenya in March 2000 which included a rapid appraisal of sorghum pests with farmers in Western Kenya. The project effectively started in Eastern Kenya October 2000, after issue of the contract. The main activities undertaken are indicated in the Table 2a and 2b in relation to the sorghum growing seasons for Western and Eastern Kenya.The planned field surveys of pest damage on sorghum in the two sites were not undertaken due to resource limitations (transport, expertise and finance). A more cost-effective approach was used instead, which involved monitoring of pest damage through the on-farm trials and capturing farmers' knowledge of damage through the PRAs, formal surveys and end of season meetings and farmer filled questionnaires. This approach provided information at key growth stages over at least two seasons, which was considered more useful than the snapshot picture at a particular growth stage that a field survey would have given. Further details on the various methods used are described in documents listed under section 7

Table 2a Sorghum Pest Project - Eastern Kenya, Calendar of Activities

	START Oct 2000 →	2000/01 Nov Season	2001 April Season	2001/02 Nov Season	2002 April Season	2003 **END**
PRA/Surveys		Focused PRA	Farm visits	Farm visits	Formal survey	Focus groups
Meetings		1st Stakeholder workshop		Mid-project Review		Final workshop
		Farmer panels Started	Farmer panels 2nd meeting	Farmer panels 3rd meeting	Farmer panels 4th meeting	
On-farm trials and monitoring						
Mwingi		1st variety obs.	Mother baby variety trails	Mother baby varieties	Mother baby varieties	
				Stover management	Inter-cropping & Buldock effect	
			Pest monitoring	Pest monitoring	Pest monitoring	
On-station trials						
Kiboko			Varieties, intercrop	Varieties, intercrop	Intercrop	
Katumani			Stover management	Stover management	Stover management	

Figure 2b Sorghum Pest Project – Western Kenya, Calendar of Activities

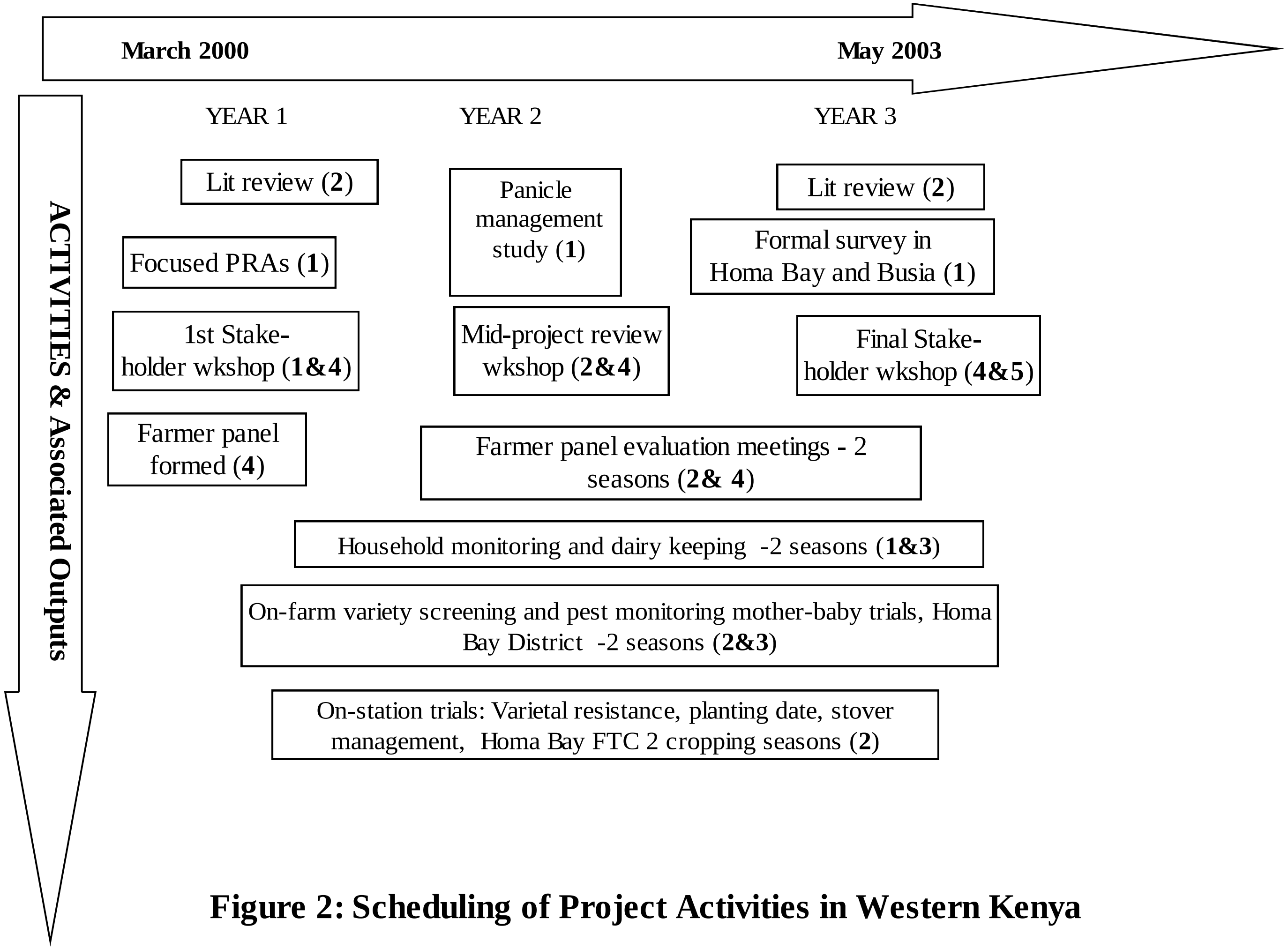


Figure 2: Scheduling of Project Activities in Western Kenya

(Figures in brackets refer to the outputs addressed by each activity listed)

4.0 OUTPUTS

The research results and products achieved by the project. Were all the anticipated outputs achieved and if not what were the reasons? Research results should be presented as tables, graphs or sketches rather than lengthy writing, and provided in as quantitative a form as far as is possible.

The four research outputs listed in the original project PMF are;

1. *Documented farmer knowledge on sorghum pest control and the rationale behind their current strategies.*
2. *Ecozone-specific sorghum pest attacks in relation to cultural practices monitored,*
3. *Existing promising technologies for control of sorghum midge, shoot fly and stem borers identified, catalogued, screened and field-tested for efficacy, system compatibility and farmer acceptability.*
4. *Local uptake pathways identified and capacity in pest management research and control methods developed with partner stakeholders (farmers, extension, national researchers and NGOs).*

As explained above (section 1.6), in the course of the project a further output was added to address wider issues relating to crop protection in semi-arid areas of Eastern Kenya which was:-

5. *Analysis documented of the role of cereals, legumes and emerging cash crops in semi-arid rural livelihoods in Eastern Kenya and the implications for CPP dissemination and research opportunities assessed*[1]*.*

The above outputs were all achieved within the three year project. The project results are presented below under the main output headings. For the sake of consistency, in most cases the results under each output are presented from Eastern Kenya followed by results from Western Kenya.

[1] The fifth output supplemented and expanded output 4. It involved literature review in the UK and Kenya, key informant interviews in Kenya, fieldwork in Kenya and validation of the review findings for Eastern Kenya at the end of project stakeholder workshop. For Western Kenya at the workshop crop protection issues for the drier areas were reviewed. In both workshops demand for crop protection research outputs was identified among key stakeholders present and outline strategies were identified for promotion of sorghum pest project research outputs.

4.1 0 Output 1: Farmer knowledge and practices on pest management

Information on farmer knowledge and pest management strategies was collected from a range of sources including literature review, PRA, formal surveys, during visits to on-farm trial sites and end of season evaluation meetings with expert farmer panels.

Farmer knowledge of the insect pests is related to their knowledge of:-

- The causes of crop damage in the field,
- Identification of the pests,
- Knowledge of the life cycle of the pests,
- Knowledge of factors that can increase or reduce the damage caused by the pests

4.1.1 Causes of damage in the field

- Information gathered from the various sources indicate that in both Eastern and Western Kenya farmers knowledge of the key pests is partial, and varies in relation to the size of the pest and its economic importance. In both sites farmers are very aware of damage caused by stem borer, the largest of the pests and also a pest that consistently reduces crop yields. Symptoms associated by farmers with stem borers were: leaf feeding damage, chaffy heads, stem tunnelling and broken stems (lodging). Farmers relate high levels of stem borer damage to dry periods and continuous cropping. The next largest insect, shoot fly, causes significant damage in both sites of Kenya but less consistently than stem borer. Farmers are generally less aware of shoot fly than stem borer, and in Eastern Kenya farmers are less aware than those in Western Kenya about shoot fly damage. In Western Kenya there are Luo words used specifically for shoot fly (*Lwangi, thuogni* and *thal)*, but there is no equivalent specific word commonly used in Eastern Kenya. Two women farmers interviewed during a focused PRA in Western Kenya and a larger group of women at the PRA group discussions explained the differences between dead hearts and excessive tillering caused by stem borer and shoot-fly damage and the presence of bad (fishy) smell at the base in the case of shoot-fly dead heart. In Eastern Kenya some farmers interviewed were aware of the fishy smell associated with dead hearts, but not of its cause. The smallest of the three insects, sorghum midge, is know to cause widespread damage in some years in Western Kenya, but is not much known as a pest in Eastern Kenya[2]. Farmers in Western Kenya are very aware of

[2] At the stakeholder planning workshop and the PRA activities in Eastern Kenya, midge was not mentioned. However, a presentation made by an experienced sorghum researcher who was unable to attend the planning workshop, attended the end of project workshop where he presented an overview of sorghum crop protection

the symptoms (empty panicles) of midge damage and have a specific name for it (*oongwe*). They can differentiate between damage caused by birds and that caused by midge. However, very few of these farmers know that an insect is the cause of the damage and some attribute midge damage to drought. In Eastern Kenya farmers in the study area were not aware of midge and midge damage was not seen during field visits and PRA activities.[3]

In both Eastern and Western Kenya farmers were comfortable to list and rank sorghum pests in their region in terms of their economic importance (see Table 1). In Eastern Kenya, farmers had somewhat different perceptions compared with extension and researchers of the importance of birds as a pest (Table 2).

Table 1: Major pests of sorghum, ranked by farmers in Western Kenya

PEST (Lou name in brackets)	Ndhiwa Location	East Kanyaluo Location	Kalanya Kanyango Location
Striga (*Kayongo*)	1	1	1
Stalkborer (*Kundi*)	3	2	2
Shootfly (*Lwangi*)	4	3	4
Weevil (*Thuth*)	2	4	
Smut (*Ochondo*)	8	6	6
Midge (*Oongwe*)	6	7	3
Aphid (*Onimbo*)		5	
Birds	5		5
Head bugs	7		
Army worms			7

constraints which identified sorghum midge as a significant pest in parts of Eastern Kenya (see Report on Final Workshop in Eastern Kenya).

[3] However an experienced sorghum researcher attending the end of project workshop reported that sorghum midge is a problem in the more sub-humid parts of Eastern Kenya (Lower Meru and Nithi Districts).

Table 2: Major pests of sorghum, ranked in Eastern Kenya at First Stakeholder Workshop Project

Farmers views	Extension views	Research views
1. Stem borers 2. Fly (iki) – after flowering 3. Termites 4. Chafer grub 5. Aphids 6. Stink bug (ivivi) 7. Smut (cover kernal smut) 8. Weevils	1. Stem borers 2. Birds 3. Shoot fly 4. Stink bug (ivivi) 5. Aphids 6. Chafer grub	1. Birds 2. Weevils 3. Stem borers 4. Moths –storage 5. Aphids 6. Chafer grubs 7. Shoot fly 8. Stink bugs 9. Bollworm 10. Grasshoppers

4.1.2 Pest identification

In terms of pest identification, all farmers in both sites were able to identify stem borer lava. Most farmers could also identify shoot fly lava when show a picture. Although farmers in Western Kenya could identify the 'small insects' that fly around the panicle during flowering but and could easily identify the symptoms of midge damage, they did not relate the two.

4.1.3 Knowledge of life cycle

The most significant gap in farmer knowledge in both sites related to the life cycle of the main insect pests. They could not explain how any of the three main insect pests carry over from one season to another. There were some mistaken ideas in Eastern and Western Kenya that stem borers are soil born pests[4].

4.1.4 Knowledge of associated factors

In both sites farmers associated pest outbreaks with the weather patterns. For example farmers in Western and Eastern Kenya associated severe stem borer attacks were associated with dry conditions during the growing season. Farmers did not however make the connection between rainfall and the washing of eggs laid on the leaves which is the probable cause of less shoot fly

[4] This could be due to the fact that they are associated with continuous cropping of sorghum – hence farmers see fallowing and crop rotation as management strategies.

and stem borer damage when rains are well distributed during the earlier stages of the growing season. In Western Kenya, farmers linked shoot fly and midge damage with dry conditions, late planting, and with a late onset of the rains.

In summary, perceptions of the relative importance of the main pests in the two sites largely justified the focus in the original call, which stipulated stem borer, shoot fly and sorghum midge – although farmers generally underestimated the economic importance of midge and stem borer.

4.1.5 Farmer pest management strategies

Investigations into farmer knowledge showed a moderate level of farmer awareness of the damage caused by the main insect pests, particularly in Western Kenya. By contrast, very few farmers indeed reported taking reactive measures; i.e. action to control these pests once there was an outbreak. The main reasons for this relate to; the status of sorghum as a crop for the farmers involved; limitations on farmers' knowledge of pest management; and the high cost of crop protection chemicals. Firstly, sorghum is mainly a staple food crop which is not sold, and therefore farmers find it hard to justify spending money on controlling pests on a crop that they do not usually sell. Secondly, while farmers would like to reduce sorghum crop losses from pests, they are not fully aware of reactive measures which might work for these pests[5]. Thirdly, sorghum has a very low market price and therefore is a low priority compared to other higher value crops when it comes to expending extra labour on manual control measures or extra cash on pesticides in order to reduce pest damage.

The main sorghum pest management strategies used by farmers are preventative rather than reactive. In Eastern Kenya extensification is a common strategy to minimize the effects of pest damage. By planting an extensive area and thereby reducing the overall effect of bird and insect damage farmers said that this ensured enough food “so that God’s creatures have their share”. Extensification is for many farmers the least burdensome strategy to manage pests, particularly in circumstances where land and draft power are available, and the actual risks (in terms of which pest may come and to what extent) are not known at the start of the growing season.

[5] The main exception to this is the practice of transplanting sorghum as a response to reduced plant stand caused by shoot fly (Western and Eastern Kenya) and chafer grub (Eastern Kenya).

In Western Kenya, early planting when possible is a key strategy used to avoid damage from sorghum midge; if the rains come too late some farmers either do not plant sorghum at all, or reduce the sorghum area relative to maize. For the other pests, the major control method is roguing of the infested plants and use of ash, pepper and cow dung.

In both sites, planting sorghum in the shorter drier rain season is either avoided, or done on a smaller scale. While the main reason given relates to rainfall, pests, particularly birds, are also mentioned by farmers as a factor considered. Moreover, farmers are aware that stem borers are associated with drier weather, and so know that the risk of a severe stem borer attack is higher in these drier seasons. More specifically, some farmers interviewed explained that pest attacks were reduced by certain cultural practices and in some cases they used explicit management strategies to reduce insect pest damage (Table 3).

Table 3: Cultural practices linked to reduced damage by Important Insect Pests of Sorghum by farmers in Western Kenya Eastern Kenya

Stem Borer	**Shoot Fly**	**Chafer Grub**	**Head Bugs**	**Midge**
Crop rotation/fallowing	Plant at high densities	Avoid use of manure	Fumigation with local herbs	Early planting
Burning stover	Roguing of affected plants	Ploughing before planting		Use of early maturing varieties
Avoid ratooning of sorghum	Transplanting/gapping			
Early planting	Use of varieties that produce viable tillers			
Intercropping				

In addition to the above, farmers in both sites follow a wide range of cultural operations which, based on research elsewhere (see section 1.5), are likely to have an effect on the management of pests. These operations include:-

- inter-cropping systems (these are complex and differ from location to location and across the seasons) which tends to reduce the level of pest challenge on sorghum relative to a sole planted crop,
- Dry planting which is done to allow the crop to make full use of available moisture and soil nutrients; improving chances of escape from damage caused by pest build-up during the season,
- Early planting - for the same reasons,
- Planting at high densities followed by thinning and transplanting in order to compensate for damage caused to plant stand at seeding stage,
- Crop rotation (more often associated with mono-cropping), which is believed by farmers to reduce pest and disease carry over,
- Fallowing of land (mainly associated with soil fertility and weed control, but also linked to insect pest and disease build-up),
- Chemical control of stem borer, aphids and bollworm in sorghum using karate- but very few have adopted this due to the high cost relative to the value of the crop,

•

In Eastern Kenya some farmers also mentioned specific management strategies for stem borers which include burning of trash, early planting and rotation/fallowing. Three areas of farmer knowledge and practices relate specifically to the sorghum pest control interventions addressed in the trials in Eastern Kenya; management of sorghum varieties, management of sorghum intercropping and management of crop residue.

4.1.6 Farmer knowledge and management of varieties

Eastern Kenya

The main sorghum varieties grown in the east are Muveta and Serena/Seredo. Other local varieties include Mughuu, Muruge, Mukomo (Gooseneck), Kisanui (Open panicle), Katumila and Gaten'gu (short stemmed varieties). Other recently introduced "modern" varieties are Gadam El Hamam, KARI Mtama 1, PGRCE 216740 and Macia which have been adopted by some farmers. Preference for particular types of sorghum variety does seem related to socio-economic status.

Farm survey responses suggest more "poorer" farmers reported growing the two-season local variety Muruge than the "richer" farmers (Table 4). This could possibly be associated with its ratoonability qualities that enable the "poorer" farmers obtain a second crop after ratooning, especially at times when they lack seed to plant afresh. The "richer" category of farmers in the farm survey seemed to prefer the large seeded single season modern variety, KARI Mtama 1, compared to the “poorer” category, possibly due to its wide utilisation options.

Table 4: Farm survey responses to the question "which sorghum varieties do you grow?"

Sorghum variety	No. of respondents		Total
	“richer” (n = 26)	“poorer” (n = 30)	
Muveta	20	24	44
Serena	14	20	34
Muruge	9	18	27
Gadam	12	15	27
Serado	12	14	26
KARI-Mtama 1	13	9	22
Katumila	10	10	20
Mughuu	3	6	9
Mukomo	3	4	7
Karuge	2	5	7
Kavura	2	5	7
PGRCE	3	2	5
Kateng’u	3	1	4
Kasarina	1	1	2
Kamutululu	0	2	2
Mahube	1	1	2
Macia	1	0	1
Muvovi	0	1	1

Pest and disease tolerance is an important criterion in seed selection in Eastern Kenya, particularly for the “poorer” farmers, as is drought tolerance (Table 5). This reflects the importance of sorghum for “poorer” farmers' household food security.

Table 5: Mwingi District Farm survey responses to the question "what do you look for in selecting sorghum seed?"

Criteria	*No. of respondents using criterion*		
	“richer” (n=26)	**“poorer” (n=30)**	**Total**
Pests and disease tolerance	17	23	40
Big head	20	15	35
Drought tolerance/ escaping	14	20	34
Big seed (seed size)	18	11	29

There is an association between the “richer” farmers and variety selection/ adoption criteria of “big seed” and “big head”. Chi-Square tests on these criteria (χ^2 = 5.916, p-value = 0.015 and χ^2 = 4.308, p-value = 0.038 respectively) show an association. This suggests that the “richer” farmer category are more concerned with the labour saving (bigger heads and seeds make easier harvesting and threshing), processing (bigger seeds make easier de-hulling and pounding) and utilisation qualities (bigger grains can be used as a substitute for rice and maize), than with food security.

Western Kenya

In Western Kenya, farmers grow several varieties of sorghum in a given location. The varieties grown have certain attributes that are important to farmers. A variety can have several desirable attributes or conversely one vital attribute. From the formal survey, it was found that farmers were growing eleven different named varieties in Busia and Homa-bay Districts of Western Kenya. These were *Gopari, Andiwo* and *Obamo* in Homa-bay District and *Nagugu, Nakhalori, Nakhadabo, Olusi, Nabuluru* and *Ikhumba* in Busia district. Farmers in both districts grow ‘modern’ research varieties *Serena* and *Seredo*. Reasons for growing these varieties were also obtained. It was found that the most important attribute was the maturity period, as 43% of the farmers indicated that the reason for preferring to grow the variety(ies) was because they mature early. The second most important attribute was yield (20%) and the third, taste (14%). Others were bird damage resistance (7%), drought resistance (6%), colour (6%), threshability (5%), and marketability (4%). The fact that farmers grow several varieties for different reasons may mean that they are well equipped to evaluate new varieties, but at the same time it may be hard to find varieties that are better than their local options. Farmers in Western Kenya are aware that some varieties are more susceptible/tolerant to stem borer attack than others.

4.1.7 Stover management by farmers:

In both Eastern and Western Kenya farmers have systems for managing stover, but these systems are not explicitly operated with a view to minimising pest carry over.

Eastern Kenya

In Eastern Kenya, farmers are aware that burning of the crop stover will reduce pest carry over, particularly of stem borer, but they do not like to practice this because they value the crop stover as livestock feed and for soil and water conservation. Their stover management practises differ between the two dry seasons, one being a short dry season and the other a long dry season.

Short dry season (late Jan to early March)-after Oct-Dec rains

There is less conservation of stover by "richer" farmers after harvest in February because animal feed is available at this time. Most commonly farmers use this stover for soil conservation (by making trash lines), to improve soil fertility (by cutting and spreading), or simply leave it standing so that it interferes less with ploughing .

Table 6: Farm survey responses to the question *"What do you do with your maize and sorghum stover after October-December rains harvest?"*

Practice/ Activity	TOTAL	**No. of respondents practising**			
		"richer" (n=26)		**"poorer" (n=30)**	
		Maize	**Sorghum**	**Maize**	**Sorghum**
Remove and store	10	7	0	3	0
Tie and sell	1	0	0	1	0
Make trash lines	44	8	14	13	9
Cut and spread	21	6	2	6	7
Leave standing	25	4	6	6	9

Longer Dry Season (July to October) after March – May rains

At the end of the March-May rain season, the "richer" farmers mostly conserve maize stover for livestock feed particularly the draught animals for use during land preparation and planting prior to the October-December rains. Between early September and early November, "richer" farmers experience animal feed shortage and some buy stover from poorer farmers. The richer prefer to use sorghum stover for soil conservation, and maize stover for animal feed either stored or grazed in situ, while the poorer are more likely to use maize stover for a variety of uses, particularly to sell it. In both seasons, slightly more of the poorer farmers practice cutting and spreading of the stover, probably due to the beneficial effects on soil fertility. This practice also reduces stem borer carry over (see section 4.2). Sorghum stover is mostly used to make trash lines because it was mentioned that certain ants found in sorghum stover affect and may kill cattle.

Table 7: Farm survey responses to the question "What do you do with your maize and sorghum stover after March-May rains harvest?"

Practice/ Activity	TOTAL	**No. of respondents practising**			
		"richer" (n=26)		**"poorer" (n=30)**	
		Maize	**Sorghum**	**Maize**	**Sorghum**
Remove and store	26	19	0	6	1
Tie and sell	10	0	0	9	1
Make trash lines	24	0	11	5	8
Cut and spread	11	0	4	4	3
Leave standing	34	6	9	9	10

Findings from 16 in-depth cases studied gave a better understanding of maize and sorghum stover management. These suggest that after harvesting the October-December crops in mid-February, maize and sorghum stover is usually left standing in the field. This happens because both categories of farmers are busy harvesting other crops and have to complete harvesting before they turn to managing the stover. A few "richer" farmers indicated that they have changed their stover management practices in recent years; cutting and preserving the stover as animal feed to reduce the problem of feed shortage during the long dry period (Mid-July to late October). They no longer let the animals into the cropping fields soon after harvest because their cropping fields have been terraced. Other respondents indicated that they have not changed their stover management practices over the years. From February to early March harvesting is completed, maize stover is either ploughed under, especially when the rains start in early March, or is cut and spread on the ground when the rains start in late March/ early April. The sorghum stover is removed and placed on trash-lines to conserve soil and water as land preparation starts. Farmers who have terraced their farms usually remove and place the stover on bench terraces to strengthen them. Minimal use of maize and sorghum stover as animal feed was reported during this time of the year because at that time there is no pronounced animal feed shortage. The two-season sorghum variety stover is normally cut to produce a ratoon crop. The cut stems are placed on trash-lines, especially by the “poorer” farmer category as a means of soil and water conservation, or are ploughed under to add to soil fertility. The resource-poor farmers tend to leave maize and sorghum stover standing in the field at the end of October-December rains in order to complete harvesting all the crops (Box 1). Stover that is left standing in the field is likely to increase the carry-over of stem borer.

Box 1: How Timuki, a “poorer farmer”, manages her maize and sorghum stover in different seasons

Tumuki experiences labour shortage in her farm. This forces her to complete harvesting all her crops before managing her stover at the end of October-December rains harvest. She says she cannot turn her attention to stover management when her food is still in the field where an unexpected rainstorm can damage it. After Timuki has completed harvesting her crops, removal of maize and sorghum stover commences.
Initially, after March-May rains harvest Timuki used to leave maize and sorghum stover standing in the field and would occasionally let her few animals feed on the stover in-situ during the long dry period (late July through greater part of October). Timuki mentioned of having sold her few animals to pay school fees. At the time of this study, Timuki had terraced half of her farm. Timuki now cuts and sells some of the maize stover to the “richer” farmers as animal feed. She has been participating in both sorghum ratoon and sorghum pest projects. Timuki concludes by saying that she has adopted cutting sorghum stover just before the on-set of March – May rain season to obtain a ratoon crop.

Western Kenya

During the PRAs farmers mentioned the following management options: cutting stems after harvest and taking them home for other uses such as fuel wood and making of granaries, fences etc; mulching, leaving stems standing in the field for cattle to graze and lastly, burning. Burning was not a popular choice. This information was verified during the formal survey from which it was noted that a good number of farmers lay their stover in the farm after harvest (see Table 8). In addition it was found that some farmers use stover for making trash lines to prevent soil erosion, a practice that had not been mentioned during the PRAs.

Table 8: Stover management practices reported by farmers in Homa-bay and Busia Districts of Western Kenya

	Percentage of farmers (n=125)	
Stover management option	Homa-bay District	Busia District
Burning	11	12
Leave standing in farm	29	3
Cut and lay in farm	44	61
Take home for other uses	6	3
Trash lines	10	21

4.1.8 Inter-cropping:

Eastern Kenya

- Farmers practise a wide range of inter-cropping systems that differ from season to season Cropping patterns in relation to sorghum

Intercropping is more common with dry planted crops, or with crops planted with the onset of the rains. Cereals are inter-cropped in alternate lines or mixed in the same line with maize, sorghum or pearl millet. Grams or cowpeas are sometimes intercropped within the row or between rows of sorghum or maize. Sorghum is most commonly intercropped with pearl millet in drier areas (LM5), and with maize in wetter areas (LM4). Sorghum that is planted more than two weeks after the onset of rains is usually planted in pure stand, drilled behind the plough or by re-planting an area with poor stand using a hand hoe.

- Farmers see intercropping as a risk spreading strategy, and one that maximises use of land and labour when these are limiting as they often are for the poorer households (Table 9). Sorghum and millet inter-crop assumes that, with low rainfall, legumes may be attacked by aphids, but sorghum and millets will give a yield.

Table 9: Farm survey responses to the question “why do you inter-crop?"

Reasons	*No. of respondents reporting*	
	“richer” (n=26)	**“poorer” (n=30)**
Maximise use of small cropping land	10	18
Spread risk of crop failure / low rainfall	10	15
Labour shortage	2	1
Lack of know-how	1	3
Lack of own oxen	0	2
Less stem borer attack on sorghum-millet inter-crop	1	0
Maize-cowpeas inter-crop does better	1	0

Intercropping patterns of sorghum are similar for richer and poorer households, the more common being intercropping with millet, followed by intercropping with cowpeas (Table 10). Both intercrops are food crops, but surpluses are sold. Fewer richer farmers intercrop sorghum with millet in the short rains (the main millet season and the most reliable season), as they are more inclined to grow millet as a cash crop, and so prefer pure stand to maximise yields.

Table 10: E. Kenya common sorghum inter-crop practices during long rains (April) season and short rains (November) season

Inter-crop combination	**LONG RAINS**		
	“richer” (n=26)	**“poorer” (n=30)**	**Total**
Sorghum-millet	11	13	24
Sorghum-cowpeas	7	6	13
	SHORT RAINS		
Inter-crop combination	**“richer” (n=26)**	**“poorer” (n=30)**	***Total***
Sorghum-millet	8	14	22
Sorghum-cowpeas	7	9	16

4.2 Monitoring of Sorghum Pest Attacks

OUTPUT 2:*Ecozone-specific sorghum pest attacks in relation to cultural practices monitored*

Rationale

Sorghum is affected by so many pests, and one challenge in undertaking pest management research is to be sure of focusing on the most important of these. Knowing which are the most important is a challenge because information on economic damage levels usually based on opinion and rarely supported by strong empirical evidence, particularly evidence collected under representative field conditions. Pest surveys go some way to addressing this challenge. However, they are not only very expensive undertakings, but also fraught with methodological challenges and pitfalls[6]. Researchers' knowledge of crop field pests is often limited geographically because (for sound experimental reasons) nearly all their research on pest management has been undertaken under on-station research conditions where the pest population is likely to be quite different from that in farmers fields. Researcher perceptions of pests is likely to be particularly biased for the semi-arid field pest complex because most experimental stations use irrigation and practice continuous cropping, which is very different from farmer practice. The fourth output aimed to make a modest contribution to redressing this bias, by providing some empirical evidence of pest damage to sorghum under on-farm conditions. The resources available for this output were limited, both in terms of finance and in terms of trained human capacity. In place of field pest surveys, pest monitoring was incorporated into the programme of on-farm and also on-station experimentation in Eastern and Western Kenya. Results from the on-farm monitoring in Eastern Kenya are summarised below along with a short summary of results from monitoring of the on-station trials in Eastern and Western Kenya.

Objectives

The aim of on-farm pest monitoring was to verify the main insect pests of sorghum in semi-arid Eastern Kenya.and the drier areas of Western Kenya, and to assess the extent of the damage

[6] Unless repeated at regular intervals and undertaken with extreme rigour they are likely to provide a very partial picture of the situation in the field. In determining crop pest research priorities in the tropics much weight has been placed on expert opinion. This is approach is likely to be most useful when the expert has already undertaken field studies of the pest/s in question. Much pest research in Africa has focused on the migrant pests (locusts, army worms, quelea) which have highly visible and sensational effects on crops. Expert opinion on these pests has been based on extensive studies of the pest in its natural habitat. In contrast to the large amount of research on migrant pests, relatively limited research has been undertaken on insect pests which are endemic to cropping systems and have much less dramatic (but perhaps more serious) effects on crop production.

they cause. It was taken as given that this information would relate to the sorghum growing seasons covered by the project, which may, or may not, be "typical".

Eastern Kenya

Sources of data

Information on pest damage in Eastern Kenya came from three main sources:-

- Observations by field extension officers and "mother trial" farmers' at key growth stages,
- Observations recorded by "baby trial" farmers,
- Observations by researchers during field visits to these farmers.

Method

Over four growing seasons, pest observations under on-farm conditions were collected using a mix of methods (Table 11).

Table 11: On-farm Pest Monitoring Methods Used in Four Growing Seasons

Season / **Method**	Oct 2000	March 2001	Oct 2001 and March 2002
Researcher field observations	√	√	√
Visual assessment at growth stages: (extension & farmers)	√ (2 stages two mother sites x 15 plots)	√ - 5 mother sites x 15 plots and baby sites - (3 growth stages)	√ - 6 mother sites x 15 plots (4 growth stages)
Foliar damage assessment by extension and farmer		√ mother & baby plots	√ mother plots only
Visual assessment of baby plots by farmer- recorded on short questionnaire			√

Observations of pests causing damage to the sorghum crop were made on trial plots of sorghum varieties grown under farmer management. During the March 2001 growing season detailed assessments of pest damage, including foliar damage scoring[7], were made at all (mother and baby) on-farm sorghum plots where data was collected (28 farmers in all who had sufficient

[7] Foliar damage scores are a measure of the amount of leaf damage caused by stem borer at the 6-8 leaf stage of crop growth. Extension staff were trained to score using a scale of 1-7, where one is the least severe and seven the most severe level of damage. 0 is no damage.

vegetative growth for recording purposes - on driest farms planted later the crop failed to develop beyond seedling stage). During the two following seasons (Oct 2001 and March 2002), continuing with a mother- baby approach to the on-farm trials, these detailed assessments were only made at the mother trials. Mother sites were held on 6 farms in each season with between 16 and 17 variety plots at each site. The sites were all in Mwingi District, spread over three Divisions and were selected to represent a cross section of soil types, rainfall, land use intensity and cereal cropping priorities (Table 12).

Table 12: Mwingi District On-farm Pest monitoring sites and most relevant attributes

	Soils	***Rainfall***	***Land-use***	***Cereal crop priorities***
Kiomo	Clay loam	Higher	Most intensive	Maize, sorghum,
Kathiani	Clay loam	Higher	More intensive	Maize, sorghum, millet
Tii	Sandy	Low	More Extensive	Maize, sorghum, millet
Katse	Stoney loam	Low	More Extensive	Maize, millet, sorghum
Twimewa	Sandy mixed	Lowest	Most extensive	Millet, sorghum, maize
Kakuyu	Sandy loam	Highest	More intensive	Maize, sorghum, millet

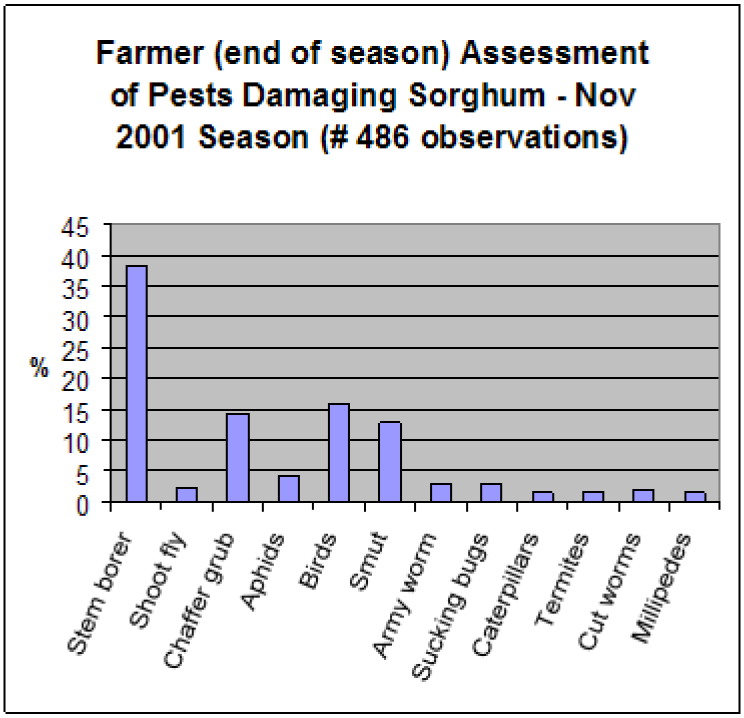
Plot observations were made on each plot at four growth stages; seedling, 6-8 leaf stage, milk stage and crop maturity. Baby plot farmers were provided with a form translated into the local language (Kiswahili and Kikamba) and asked to make a note of the pests causing damage on each of the variety plots. In each season out of about 50 farmers with baby plots about 30 filled in the form containing this information.

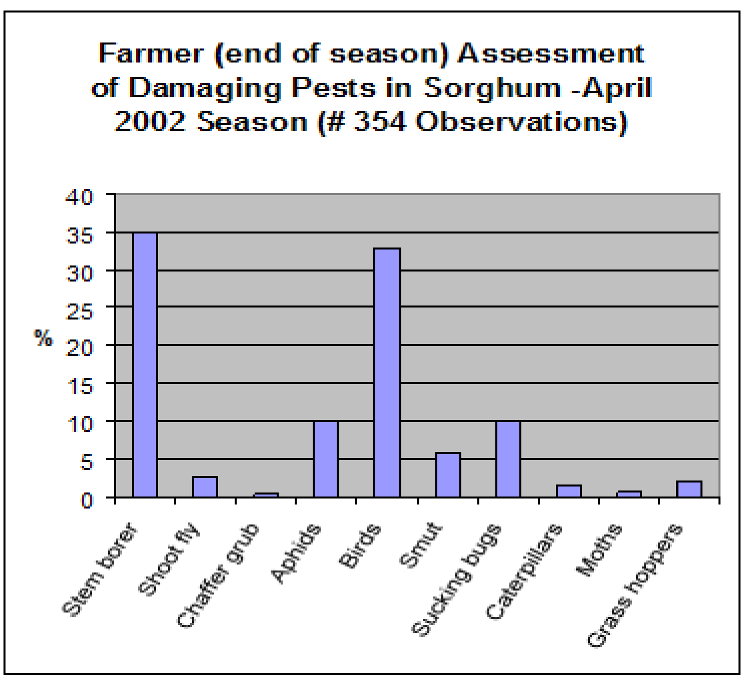
Data on pest observations was coded and entered into an Excell worksheet, before being analysed with SPSS (frequencies only). SPSS tables were imported back into Excell which was use to generate charts, with observations presented on a % basis for purposes of comparison.

General Pest Damage

The on-farm monitoring confirmed that a broad spectrum of pests caused damage to the sorghum crop and that the incidence most of these pests varied from one season to the next. Charts 1 and 2 below compare farmers' observations of sorghum pests during the November 2001 and April 2002 growing seasons. Stem borer, and to a lesser extent birds are pests that figure strongly in both seasons.

Charts 1a and 1b: Pests Observed by Baby Trial Farmers: - November 2001 and April 2002 Seasons.





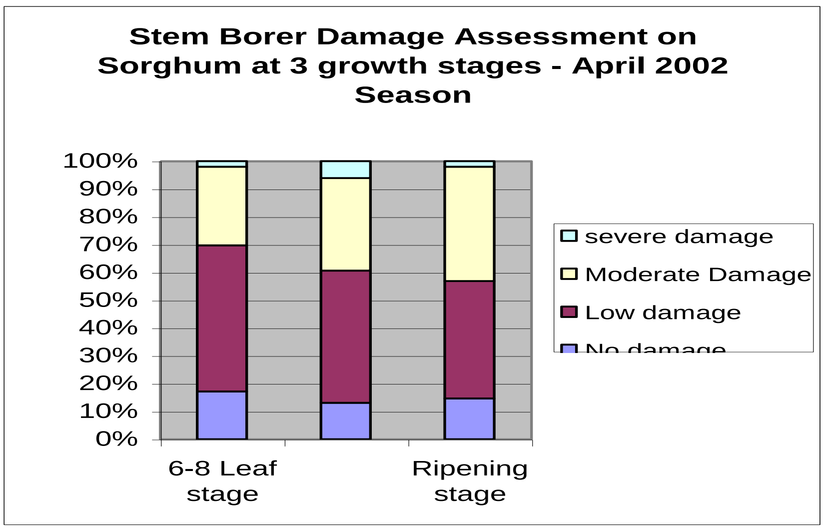
Stem borer damage levels

Further monitoring data on the importance and pattern of stem borer damage, relative to other pests, highlights how import stem borer is as a pest of sorghum in Eastern Kenya, both at early stages of crop growth, and as the sorghum crop reaches maturity.

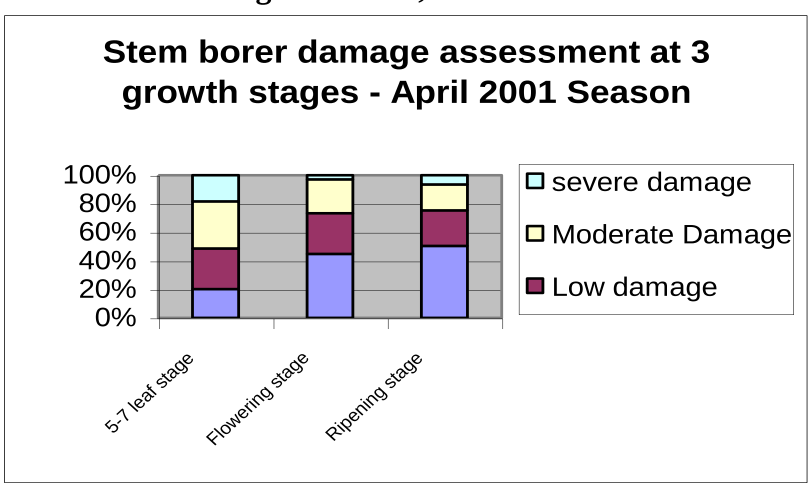
The effect of rainfall on patterns of stem borer damage is clear when the results for three seasons monitoring are compared.

Charts 2a, 2b and 2c, : Comparison of Stem Borer Damage Levels at Three Growth Stages over Three Cropping Seasons:-

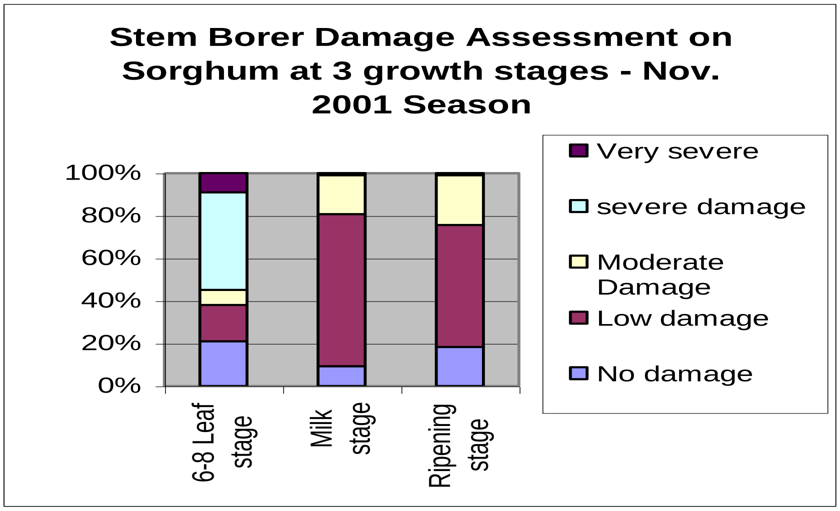
- **April 2001 a drought season,**



- **followed by November 2001 a good season,**

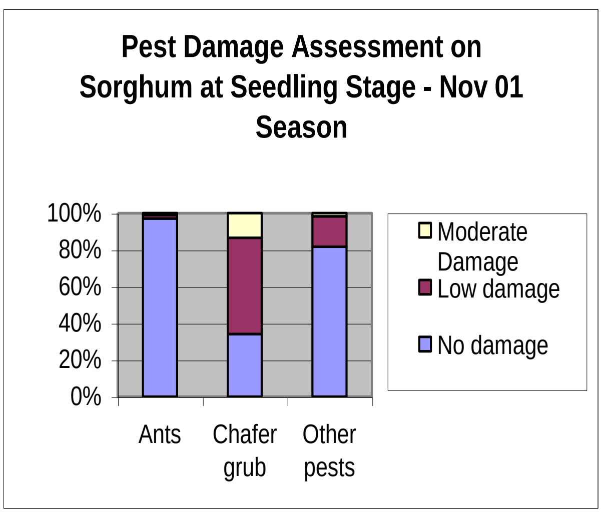


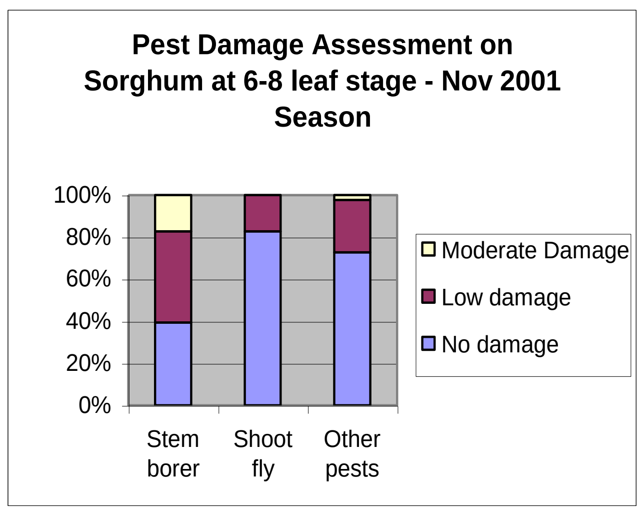
➢ **followed by April 2002 an average season for farmers planting with first rains.**

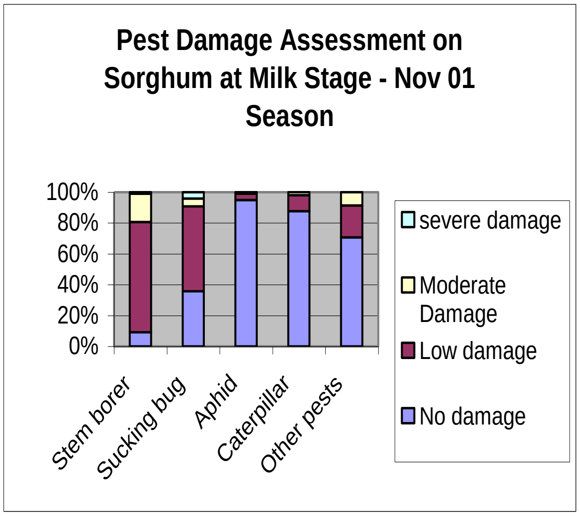


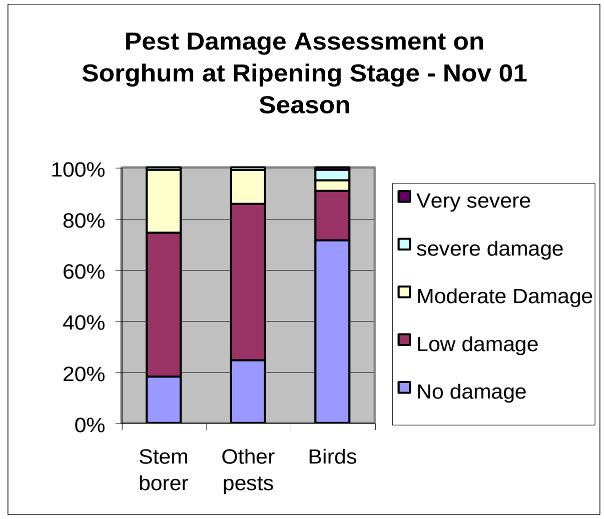
In terms of damage at particular crop stages, over three seasons, stem borer was notably more damaging than other pests at the 6-8 leaf stage and also at milk stage. This was the case even in the November 2001 season when rains were good and stem borer damage levels were low compared to the other seasons.

Charts 3a, 3b, 3c and 3d: Pest damage assessment at various stages of crop growth, Nov 2001 seasons (good rainfall season)









Loss assessments as indicated via chemical control on-farm and on-station

The extent and effect of stem borer damage under on-farm conditions is further illustrated by the results from using chemical control in an on-farm observation plot planted in the April 2002 season in Kiomo location of Mwingi Central Division. This plot of three popular varieties was established to get an indication of the effects of stem borer (and also late shoot fly attack) on yield and also on the "production" of stem borer. While the yields were much lower on-farm compared with the on-station yields reported below, the effect of chemical pest control were very clearly shown. Two applications of Buldock resulted in a doubling of yield and a very high level (97%) reduction of stem borer lava remaining in the stem at harvest time.

Three seasons of trials at Kiboko Research Station showed the potentially devastating effect that insect pests, particularly shoot fly, can have on yield. The most dramatic effect of pests on yield was shown in the April 2001 season, which was particularly dry, although supplementary irrigation was used on this trial, when application of chemical controls resulted in a more than threefold yield increase for a range of sorghum varieties. By contrast in the following season, when rainfall was good, insect pests had hardly any effect on the yield of most of the varieties. The results suggest that under optimal conditions, with adequate soil fertility and soil moisture, shoot fly and stem borer have very limited effect on yield, whereas when the plant is struggling to gain adequate water and nutrients the effect is much more marked. The on-station results cannot be easily extrapolated to on-farm conditions, because of the different micro-climate and pest population which results from continuous cropping under irrigation.

Conclusion

The results of pest monitoring over three cropping seasons over a range of sites confirm the importance of insect pests as a serious sorghum production constraint, being particularly serious when rainfall and soil fertility are sub-optimal. The on-farm findings tend to confirm the results of the stakeholder workshop; that stem borer is the most serious pest of sorghum in semi-arid eastern Kenya. In all three seasons it was reported by farmers as the most serious pest, and it was the most serious pest at the three later stages of growth in all seasons, apart from one when shoot fly was more serious at the 6-8 leaf stage (suggesting shoot fly can be a serious pest in some seasons). This means that the on-farm focus on stem borer by the project was justified. Other insect pests of importance in most seasons are chafer grub, sucking bugs and aphids. Caterpillars and army worm are also important pests in some seasons. Other damaging insect pests noted by some farmers were grass hoppers, cut worms, termites and millipedes.

The on-station results indicate that when the micro-environment changes, then shoot fly can also be a very serious pest.

Using farmer managed variety trial plots as a basis for monitoring pests on sorghum proved to be a lower cost approach than undertaking extensive surveys, and was a means of involving farmers more in the monitoring of pests. The array of pests on these plots were most likely the same as the array of pests on the rest of the sorghum crop in the field. Further observations by farmers during the monitoring and evaluation of variety trials indicated which of the varieties they felt were more badly affected by certain types of insect pest.

Western Kenya Results

Pest monitoring for Western Kenya was incorporated into the analysis of trial results summarised under output 4.3 which indicate the pest levels on-station and on-farm for the two main sorghum cropping seasons covered. The main pests identified by the farmers, extension agents and the researcher were shoot fly, stem borers, midge and *Helicoverpa* spp. Damage caused by shoot fly, stem borer, and *Helicoverpa* spp was assessed as low for both seasons while midge damage was perceived to be very high during the long rains season 2001 and low during the long rains season 2002. The monitoring of actual pest damage in Western Kenya was instructive in clearly showing that key informants consulted at the start of the project had underestimated the economic importance of the sorghum midge, and probably over-emphasised the importance of stem borer.

4.30 IMPROVED PEST MANAGEMENT STRATEGIES DEVELOPED AND TESTED

Output 3 : Existing promising technologies for control of sorghum midge, shoot fly and stem borers identified, catalogued, screened and field-tested for efficacy, system compatibility and farmer acceptability.

On the basis of literature review, diagnostic surveys and stakeholder consultations, a set of trials was designed with a view to testing the validity of the most promising management strategies for the key insect pests identified for Western and Eastern Kenya. The trials were planned and designed separately, although there was significant overlap in terms of main strategies addressed (Table 13).

Table 13: Pest Management Strategies Evaluated in Trials - Eastern and Western Kenya

EASTERN KENYA	WESTERN KENYA
4.3.1 Varietal resistance to stem borer and shoot fly 4.3 2 Stover management to reduce stem borer carry over 4.3.4 Intercropping to reduce stem borer damage and carry over	4.3.1 Varietal resistance to sorghum midge, stem borer and shoot fly 4.3.2 Stover management to reduce stem borercarry over, 4.3.3 Panicle management to reduce midge carry over 4.3.5 Earlier planting as a pest damage mitigating strategy

Summaries of the trial results relating to the above strategies are reported separately for Eastern and Western Kenya.

4.3.1 Varietal resistance to stem borer and shoot fly, stem borer and midge

Rationale and Objectives

Varietal resistance/tolerance to insect pests as a strategy to minimise crop losses from these pests is arguably easier to disseminate and adopt in low external input small-holder farming systems than other pest management strategies. At the start of the project, resistance/tolerance of the available sorghum varieties was not well documented for either Eastern or Western Kenya. In Eastern Kenya the tolerance/resistance of the available material (local and improved) was not known at all, but "elite" short duration varieties developed for other Southern and East African countries were available for testing from KARI/ICRISAT. In Western Kenya, some on-station work on pest resistance had been undertaken at KARI/ICRISAT's Alupe site. The resistance (particularly to midge) of the local and improved varieties needed to be further assessed under a wider range of conditions. A number of promising lines developed on-station at Alupe were available for testing on-farm.

4.3.1.1. Varietal Resistance and Farmer Acceptability in Eastern Kenya

In Eastern Kenya candidate elite varieties from ICRISAT's regional trials were selected mainly on the basis of yield, drought tolerance, early maturity, grain colour and grain quality. The performance of these varieties was assessed both on-station, at Kiboko Research Centre and on-farm in Mwingi District, where they were compared with the most popular local variety (Muveta) and also released varieties familiar to farmers (Seredo and KARI Mtama 1) as benchmarks. The evaluations on-farm and on-station was done in parallel. In the on-station trials the focus was mainly on resistance to insect pests. In the on-farm trials, the focus was on overall performance, but with specific attention to insect pest tolerance.

On-station results - Kiboko

Sorghum lines were screened for insect pest tolerance at KARI-Kiboko Research Station during the April 2001 season, the Nov 2001 season and the April 2002 season under protected and unprotected field conditions.

Analyzed data across the three seasons at Kiboko station revealed significant differences between varieties for shoot fly incidence under unsprayed conditions across the seasons. Differences between the varieties in yields across the seasons under both the situations were found to be significant. The data on stem borer incidence was non significant under both the conditions across the three seasons (Table 14). Based on the damage measures used, this suggests that shoot fly resistance is something which can most easily be screened for under the conditions prevailing at Kiboko.

Table 14. Performance of elite sorghum lines against shoot fly and stem borer and their yields across the seasons at Kiboko

Sorghum line	Insect pest damage (%)				Grain yield (t ha^{-1})	
	Shoot fly		Stem borers			
	S	U	S	U	S	U
Gadam el Hamam	0.8	48	1.0	17	2.40	1.49
IESV 92098 DL	0.0	37	0.0	17	3.37	2.01
IESV 92165 DL	0.6	30	2.6	22	3.77	2.82
PGRCE 216740	0.0	36	4.0	17	3.25	2.31
SDS 1948-3	0.0	38	4.0	13	2.25	1.51
Sudan 142	0.0	33	1.7	18	3.63	2.65
IS 15127	0.0	38	4.7	16	2.88	1.76
IS 23509	0.0	44	2.4	16	4.05	2.70
Macia	0.3	38	3.5	21	2.52	2.16
Mahube	0.3	47	10.7	18	1.53	0.76
ZSV-3	0.3	43	1.6	15	2.93	1.71
KSV 12	0.4	28	6.7	21	3.37	2.42
Kiboko 2 (Local check)	0.4	38	1.4	24	2.65	1.89
F. Prob	**0.62**	**<0.001**	**0.28**	**0.57**	**<0.001**	**<0.001**
Mean	**-**	**-**	**-**	**-**	**2.97**	**2.01**
SE±	**0.41**	**4.6**	**3.59**	**4.51**	**0.271**	**0.256**

On-farm results – Mwingi district

Between 15-18 varieties of sorghum were evaluated on-farm over four growing seasons; two long (April) rain seasons and two short (November) seasons (Table 15).

Table 15 : Eastern. Kenya sorghum varieties contained within the on-farm variety trials-

1. KSV12	10. ZSV3
2. IS15127	11. SDS 1948-3
3. ISSV92165	12. MAHUBE
4. IESV92098 DL	13. KARI MTAMA 1
5. IS23509	14. KAT 412**
6. MACIA	15. IS76#23**
7. SUDAN 142	16. IS23526**
8. GADAM EL HAMAM	17. SERENA++
9. PGRCE 216740	**18.** LOCAL

++ Nov 2000 and April 2001 seasons only

** Nov 2001 and April 2002 seasons only

Farmer Evaluation Criteria

Discussion of good and bad points, helped to generate evaluation criteria. Farmer ranking of the evaluation criteria was relatively consistent from one farmer panel to another. Germination, taste, drought resistance and earliness are very important (Table 16). Of the pests, stem borer tolerance was clearly the most important to farmers, while bird and head bug resistance is ranked consistently low in importance. Farmers explained that head size, vigour and stem strength are all proxies for yield.

Table 16: Farmer ranking of 16 Criteria used for Sorghum Variety Evaluation - (average rankings from 4 farmer panels- February 2002)

QUALITIES LISTED	Overall rank of criteria	Range of ranking	Average rank score
Germination	1	1-7	1.75
Grain taste	2	2	2.00
Drought resistance*	3	2-5	3.30
Early maturity*	4	3-7	3.70
Vigour	5	2-11	5.00
Head size*	6	5-7	6.00
Stem strength	7	4-10	6.40
Disease resistance	8	1-13	6.80
Stem borer resistance	9	3-11	7.40
Grain size	10	6-12	9.00
Dead hearts resistance	11	4-12	8.00
Tillering qualities	12	5-13	8.10
Aphid resistance	13	1-12	9.40
Plant Height	14	5-13	9.40
Bird Resistance	15	6-13	9.50
Head bug resistance	16	6-13	11.0

** Criteria used by breeders (head size being a proxi for yield)*

The range of variety evaluation tools provided an overall assessment of the varieties by farmers. Some differences in results according to the method used underline the value of using more than one method. Comparing the top ranking varieties, some clear favourites emerge (Table 17). Many of the candidate varieties did well compared with the released variety, KARI Mtama 1. There were differences of opinion between farmers within a single panel, and between panels. Some varieties that scored low overall were favoured by some farmers within a panel and the results from the voting showed quite big differences between panels. This indicates that a continuation of the variety validation and dissemination programme over a wider area may be the best way forward, to enable farmers to select from a range of the most promising 7-8 varieties.

Comparing the on-station scoring of stem borer tolerance with the on-farm evaluation by farmers, the results are broadly similar. The three varieties which showed resistance/tolerance under on-station conditions were also noted by farmers to have good tolerance to stem borer.

Comparing the results of the voting with the results of the scoring relating to stem borer tolerance, most of the varieties which score quite well on tolerance also score well in terms of farmers wanting to continue with them. This is an encouraging finding, given that the main objective of these variety trials was to identify material that has some tolerance to stem borers.

Table 17: Performance of Candidate Varieties as judged by a mix of evaluation methods, relative to Released Variety - KARI Mtama 1

Variety	Rank Based on votes	Total average votes	Good and bad points balance score	Matrix scores farmers 6 top criteria	Matrix scores on 3 stem borer tolerance criteria
KSV12	1	3.1	1.5	-1.1	0.5
GADAM EL HAMAM	2	0.4	1.7	1.1	-0.5
KARI MTAMA 1	**3**	**0**	**0**	**0**	**0**
ZSV3	4	-0.7	0.2	-1.1	-1
SUDAN 142	5	-0.8	0.6	-0.4	-0.2
IESV 92098	6	-0.9	-0.4	-1.2	-0.5
IS 23509	7	-1.1	0.3	0.2	-0.7
MACIA	8	-1.1	1.1	-1.3	0.7
IS 23526	9	-1.9	-0.6	-0.3	-2.5
IS 76#23	10	-2.7	0	0.1	-1.2
IESV 92165	11	-3.2	0.9	-2.3	-0.5
IS 15127	12	-3.3	0	-2.9	-1
MAHUBE	13	-3.8	1.1	-2.8	-1.7
SDS 1948-3	14	-3.9	-2.5	-4.4	-2.2
KAT 412	15	-4.4	0	-0.1	-1.5
PGRCE 216740	16	-4.9	-0.4	-1.1	-1.2

4.3.1.2 Varietal Resistance and Farmer Acceptability in Western Kenya

On station trials- Alupe

In Western Kenya 12 advanced sorghum lines were evaluated under protected and unprotected field conditions for resistance/tolerance to key insect pests at KARI, Alupe during the 2001 cropping season. Stem borer damage assessments on the advanced midge lines screened under unprotected field conditions at Alupe showed that the best grain yielders were IS 21055, 8884, 21006 and Wagita in that order (Table 18). The best lines for insect pest tolerance were Wagita, IS 21055, 3461, 8884 and 21006. The performance of these lines in trials in south-western Kenya (Homa Bay district) was similar to the observations at Alupe. In response to experimenting famers' request for more breeder seed of Wagita during a field day at Homa Bay, a 0.15 ha plot was established at Alupe in September. Twelve participating farmers established two small plots, each of IS 8193 and Wagita in the 2002 cropping season.

Table 18. Advanced sorghum lines evaluated under protected and unprotected field conditions for resistance/tolerance to key insect pests at KARI, Alupe in western Kenya during 2001 cropping season.

VARIETY	% SF DMG		MDG SCORE		% TUNN		YIELD t ha^{-1}	
	SPRAY	UNSP	SPRAY	UNSP	SPRAY	UNSP	SPRAY	UNSP
IS 21006	26.1	49.6	2.0	2.0	17.8	21.1	1.1	2.3
IS 21055	14.3	13.2	1.8	2.0	11.2	12.3	3.3	2.5
IS 3461	46.4	50.3	1.5	1.5	4.1	10.1	0.7	0.9
IS 8193	34.8	32.3	6.0	7.3	13.4	17.5	2.1	0.8
IS 8884	26.3	34.9	1.5	1.5	11.0	25.7	1.9	2.4
KARI/M 1	31.8	19.0	3.0	8.3	14.6	15.1	2.3	1.1
NAKHADABO	36.8	22.3	3.3	6.8	10.4	16.3	2.4	0.6
SEREDO	26.9	20.0	3.3	7.3	40.5	24.1	2.6	1.3
SRN 39	58.8	49.3	4.5	9.0	43.0	27.8	0.7	0.7
WAJITA	25.0	14.6	1.3	1.5	23.6	13.2	3.9	2.4
MEANS	***32.7***	***30.5***	***2.8***	***4.7***	***18.9***	***18.3***	***2.1***	***1.5***
G/MEAN	**31.6**		**3.8**		**18.6**		**1.8**	
LSD @ 5%	**10.7**		**1.1**		**11.3**		**0.6**	
% CV	**23.9**		**21.3**		**42.8**		**23.3**	

Midge score on a scale of 1-9 (1=1-9 where 1 = <10%, 2 = 11-20%, 3 = 21-30%, 4=31-40%, 5 = 41-50%, 6 = 51-60%, 7 = 61-70%, 8 = 71-80%, and 9 = >80% damaged spikelets)

Also at Alupe 57 promising sorghum lines were tested under unprotected conditions for tolerance to pests at KARI-Alupe research station during the 2001 season. Observations on the sorghum stem borer (*Chilo partellus*) revealed the presence of 3-4 larvae/pupae plant^{-1} in sorghum at harvest time. The incidence of stem borer through visual observation showed substantial variation among selected lines. Other observations on the influence of stem tunnelling and the incidence of fungal damage of the stalk showed these to be high in sorghum compared with maize stalks. Shoot fly incidence during this season at Alupe was severe, causing maximum dead hearts of 52% in IESV 94102-SH while Wagita had a minimum damage of 13% . Testing of advanced sorghum lines against midge damage indicated a range of 1.67 - 4.33 midge rate against 9 scale where 1 = <10% damage and 9 = >80% damage. Observations on grain yield of these 50 selected lines showed a range of 0.41 – 3.68 t ha^{-1} at Alupe farm.

Varietal tolerance results- Homa-bay

On-farm trial yields

Significant differences in grain weight per plot were noted between varieties (P=0.025). Improved varieties produced significantly higher yields than the local varieties. There was a large variation between the varieties due to different farmer management practices as evident from the large standard error and standard error of the difference (Table 19). In the LR 2002 the yields were much higher than those of the LR 2001. There were highly significant differences between varieties (P<0.001) and between long and short maturing varieties (P<0.001) but no significant differences between local and introduced varieties (P=0.069).

Table 19: Mean grain yield (kg/ha) for sorghum varieties in on-farm trials Homa-bay District, long rains 2001 and 2002

Varietal category	Variety	Yield (kg/ha) 2001	Yield (kg/ha) 2002
Long maturing	Nyachong rawo	11	1038
	IS 21055	41	1028
Short maturing	Gopari	22	1362
	IS 8193	21	1462
	Seredo	71	1723
	s.e.d.	22.6	168
	s.e.	16.0	120

On-station trials

There were highly significant differences (P<0.001) between varieties for mean grain yields (Table 20). Short maturing varieties had significantly higher mean yields than long maturing varieties (P<0.001). There were no significant differences between the two seasons (P=0496).

Table 20 Mean grain yields (kg/ha) for sorghum varieties at the Homa-bay FTC, Long Rains 2001 and 2002

Variety	***Long rains 2001***	***Long rains 2002***	***Mean Yield***
Seredo	2702	2613	2658
IS 8884	2871	1422	2147
IS 8193	2383	1867	2125
Wagita	2711	1404	2058
Gopari	1473	2524	1999
IS 21055	2513	1156	1834
KAT 369	1286	2116	1701
AF 28	1172	1244	1208
Nakhadabo	367	1671	1019
Nyachong Rawo	482	1173	828
IS 3461	904	676	790
IS 21006	474	27	250
Mean	1612	1491	

s.e.d. for variety means =430 on 46 d.f
s.e.d. for year means = 176 on 46 d.f.
s.e.d. for variety x year means = 608 on 46 d.f.

Sorghum shoot fly tolerance

Differences between the varieties in shoot fly damage were found from both the on-farm and on-station trials. Although the long and short maturing varieties showed significant differences in percentage of deadhearts, this did not follow a particular trend (over seasons and between on-farm and on-station results) and so definitive conclusions on this cannot be made on the basis of these results alone. It is likely that both the different resistance mechanisms and rainfall patterns, affected the response to shoot fly of the varieties tested on-farm and on-station.

Stem borers tolerance

There were no significant differences between varieties for stem borer number of exit holes, foliar damage and number of live larvae in the on-station trials. In both years, stem borer populations were low and this may have made it difficult to detect any significant differences. In the LR 2001 in the on- farm trials only stem borer foliar damage counts were undertaken and these were found not to be significant. In the LR 2002, when a range of damage measures were used there were significant differences between varieties for all the stem borer damage parameters. The findings from the on-farm trials are different in some respects from the on-station ones, which may be because the on-farm results are from one season only. In both the on-station and on-farm trials, short maturing varieties had significantly lower damage means than the long maturing varieties. This is because the stem borer populations infesting the long maturing varieties may have built up in the short maturing varieties or the pests may have come in when the short maturing varieties has passed the susceptible stage.

Sorghum midge resistance

Due to late planting on-farm, there was a severe midge attack on all the varieties in the LR 2001. The scores were an average of 9 for all the varieties and farmers, meaning that more than 90% of the sorghum spikelets were midge-damaged. This may be an indication that none of the varieties were tolerant to the sorghum midge in this season, as the following season showed significant differences. This phenomenon has been explained by Teetes 1995, who found in Texas USA that when sorghum midge infestation levels reach very high levels the resistance level is not high enough to provide protection in all situations. There were no significant differences between all varieties in general. Similarly, in the on station trials, there were no significant differences between the varieties for midge damage. In both trials however, there were significant differences between long and short maturing varieties for midge damage. In the LR 2002 there were lower levels of midge damage because the planting was undertaken earlier due to the earlier on-set of rains in this season' s planting time.

Evaluation Results from Farmer Field Days

Evaluation of sorghum varieties by was undertaken by farmers during the growing season through farmer field days. A summary of the variety evaluation results for both years is given in Table 21. Variety Wagita was ranked best for resistance to midge attack followed by IS 8884, AF 28 and IS 3461, respectively. Varieties IS 8884 and Wagita were ranked best for resistance to bird attack followed by AF 28. Varieties IS 8884, Seredo and KAT 369 were ranked best for maturity period as they had reached physiological maturity when the field days were held. KAT

369 and AF 28 were ranked best for colour followed by Wagita and Gopari, both brownish in colour. KAT 369 and Wagita were ranked best for panicle shape. Seredo, KAT 369 and IS 8193 all short-stature varieties were best for plant height. Yield was estimated visually by looking at the amount of seed on the panicles. Wagita and Seredo had the highest amount of seed while KAT 369 and Gopari were ranked second best in this category. KAT 369, Seredo and Wagita were ranked best for seed size. Wagita then Seredo and KAT 369 ranked best for head size. Wagita was ranked first overall followed by Seredo and KAT 369. Next were Gopari, IS 8884 and IS 8193. The varieties that ranked poorly for most attributes were Nyachong Rawo, IS 21055, Nakhadabo and IS 21006, in that order. Statistically there were highly significant differences ($P<0.001$) between the varieties for the each attribute and for the overall ranking ($p<0.001$).

Utilisation workshops to evaluate the culinary attributes of sorghum varieties

A summary of the evaluations for culinary attributes for the LR 2001 and 2002 is given in Table 22. Varieties KAT 369, AF 28 Gopari and Wagita were ranked best for seed, size, colour and taste. Most of the varieties were ranked good or moderate for flour texture while varieties KAT 369, Wagita, AF 28 and Gopari were ranked best for flour colour. KAT 369, AF 28 and Wagita were ranked best for *Ugali* (stiff porridge) and Uji (soft porridge) taste and colour. Varieties Nakhadabo, Nyachong Rawo, IS 8884 and IS 21006 were ranked worst for most of the attributes. Varieties KAT 369, Wagita, AF 28 and Gopari had the highest overall scores while varieties, Nakhadabo and Nyachong Rawo IS 21066 and IS 8884 had the lowest overall scores. Statistical analysis showed that there were highly significant differences ($P<0.001$) between varieties for each attribute and for the overall scores. From the utilisation workshop it was noted from discussions by farmers that there is a preference for white/light coloured varieties as can be seen from the higher scores for flour, seed, *ugali*, and *uji* colours. Varieties AF 28, IS 3461, and KAT 369 are whitish in colour. Farmers associate this with the white colour of maize and its palatability. Second in the scoring were light brown varieties such as Wagita, Seredo and Gopari, while dark brown varieties such as IS 8884, Nyachong Rawo and IS 21006 scored lowest for colour attributes. The lighter varieties also scored higher than the darker varieties for taste.

Factors influencing adoption of sorghum varieties in W. Kenya

Based on the various variety evaluation activities described above it was possible to idenfify factors which influence the adoption of sorghum varieties.

Early maturity: Early maturing varieties were found to have less pest damage and higher yields than long maturing varieties. From the formal survey it was found that early maturity is the varietal attribute most important to farmers. The high ranking of this attribute was because early maturing varieties mature at a time when farmers have depleted their food reserves. Just as important, the early maturing varieties evade midge damage as they reach physiological maturity before the drought sets in. From the field day results it was also clear that the farmers preferred early maturing varieties. Introduced varieties IS 21006 and Nakhadabo, which are of long maturity, are therefore unlikely to be adopted by farmers because the trend is slowly shifting from planting long maturing varieties to shorter maturing varieties due to erratic and unreliable rainfall.

Yield: During field day evaluation, farmers did mention yield as a significant factor. The higher yielding varieties were also the farmers' most preferred varieties as was seen from results of all the workshops. Other qualities are linked to yield. For example in both seasons IS 3461 had low stand counts leading to poor yields.

Physical attributes: From the results of the farmer field days, farmers showed a preference for white/light coloured sorghums because of their similarity to maize. This could be seen from the higher ranking for varieties like KAT 369, IS 3461 and AF 28. However KAT 369 was ranked very poorly for bird and midge damage. Varieties Wagita, Seredo and Gopari are light brown in colour hence were ranked second best after the other three. Farmers showed a preference for panicles that are neither too loose nor too compact. Varieties that exhibited these qualities were Wagita, Seredo and KAT 369. There was a clear preference for short stature varieties as seen from the higher scores given for varieties Seredo, KAT 369 and IS 8193. This is because of the ease of harvesting short varieties and the lodging associated with taller varieties. Head size was perceived as a determinant of yield, which explains the higher scores for varieties with large panicles.

Bird resistance: The farmers indicated that the darker varieties have a bitter taste but they grew them because they suffer the least damage from birds.

Best- bet varieties

During the final farmer workshop farmers indicated that the varieties they would take up were Wagita, IS 8193, Seredo, Gopari and IS 8884, in that order. The findings from the trials indicate that these varieties are able to reach maturity before pest populations build up because they are short maturing, which is a key farmer preference attribute. From the farmer field days and utilisation workshops these varieties also ranked highly with an exception of IS 8884, which had poor culinary attributes due to its dark colour. However farmers are likely to take it up as it as they still grow Nyachong Rawo, which has similar attributes (dark colour) and is believed to cure diarrhoea, but yields poorly.

Table 21: Average score per attribute for each variety by farmers at the field days at the Homa bay FTC, long rains 2001 and 2002

Variety	Midge damage	Bird damage	Maturity period	Seed colour	Panicle shape	Plant height	Seed size	Head size	**Yield**	Overall average
Wagita	1.5	1.4	1.8	1.7	1.8	2.2	1.6	1.6	1.5	1.7
Seredo	2.2	3.1	1.7	1.9	2.2	1.6	1.7	2.1	2.0	2.0
KAT 369	2.7	3.6	1.7	1.4	1.7	1.9	1.6	2.1	2.3	2.1
Gopari	2.4	2.0	2.2	1.7	2.1	3.0	2.1	2.2	2.3	2.2
IS 1884	1.6	1.3	1.6	3.0	2.5	2.5	3.1	2.8	2.1	2.2
IS 8193	2.2	1.7	2.0	2.9	2.4	1.9	2.4	2.5	2.7	2.2
AF 28	1.8	1.4	2.1	1.7	3.4	3.5	2.6	3.3	3.0	2.5
IS 3461	2.0	1.5	2.3	1.5	3.3	3.6	2.4	3.3	3.1	2.5
Nyachong Rawo	3.2	2.3	3.3	3.1	2.6	2.9	2.3	2.4	2.5	2.7
IS 21055	3.0	2.0	2.7	2.8	3.6	3.3	3.0	3.2	3.1	2.9
Nakhadabo	2.8	2.2	3.0	3.1	3.1	3.2	2.9	3.2	3.4	3.0
IS 21006	3.6	3.1	4.0	3.2	3.6	4.0	3.7	3.7	4.2	3.7

NB: Scale: 1=Very good 2=Good 3=Neither good nor bad 4=Bad 5=Very bad

Table 22: Average scores for varieties by farmers at the utilisation workshops at Homa- Bay, Long rains 2001 and 2002

Variety	Seed colour	Seed taste	Seed size	Flour texture	Flour colour	Ugali taste	Ugali texture	Ugali colour	Uji taste	Uji colour	Uji texture	Overall average
KAT 369	1.7	2.0	1.5	2.4	1.5	1.8	2.4	1.6	1.7	1.9	2.6	1.8
Wagita	1.5	1.7	1.8	2.1	2.1	2.1	2.3	2.2	2.0	2.3	2.3	1.9
AF 28	1.7	2.1	2.6	2.7	2.3	1.9	1.9	2.1	2.1	2.2	2.5	2.0
Gopari	1.8	1.8	1.6	2.4	2.3	2.6	2.5	2.4	2.1	2.3	2.3	2.0
IS 3461	2.0	2.3	2.7	2.4	2.5	2.1	2.2	2.4	2.4	2.5	2.4	2.2
Seredo	2.0	2.1	2.1	2.3	2.6	2.7	2.7	3.0	2.8	2.6	2.8	2.3
IS 8193	2.7	2.7	2.5	2.2	2.7	2.5	2.3	2.7	2.8	2.8	2.4	2.4
IS 21055	3.2	2.9	3.2	2.4	2.9	2.7	2.7	2.7	2.8	2.9	2.6	2.6
Nakhadabo	3.0	3.1	2.7	2.4	3.0	3.1	2.9	3.1	3.2	3.2	2.8	2.7
Nyachong Rawo	3.4	3.7	3.1	2.0	3.0	3.1	2.8	3.0	3.1	3.0	2.9	2.8
IS 8884	3.9	3.5	3.9	2.4	3.3	3.0	2.9	3.2	3.0	2.8	2.8	2.9
IS 21006	3.8	3.4	3.9	2.1	3.2	3.4	3.3	3.5	3.0	3.0	2.8	3.0

*Scale: 1=Very good 2=Good 3=Neither good nor bad 4=Bad 5=Very bad

4.3.2 Use of Crop Management Practices Against Stem Borers In Sorghum

Introduction

Stem boring larvae or caterpillars are regarded as the most important pests damaging cereals (especially maize and sorghum) in Africa. At Kiboko in 2001 and 2002, replicated plots of 12 ICRISAT elite lines exposed to damage by borers and shoot flies yielded 71% less on average than plots which had been repeatedly sprayed with endosulphan to suppress these pests. The main species of borer in eastern Kenya is now *Chilo partellus*, an asian species which has gradually replaced the indigenous borer species since its accidental introduction in the mid-twentieth century. The second most important borer species, *Sesamia calamistis* typically makes up only a small proportion of the combined population. Damage is caused by destruction of young plants (dead-hearts) and loss of nutrients and water to older plants leading to stunting, tillering and reduced head development. Owing to the expense of using pesticides for these relatively low-value crops, this project concentrated on other strategies for combating the problem.

For resource-poor farmers the most easily available approaches to reduce stem borer damage are forms of cultural control involving crop management. These techniques aim to reduce the stem borer populations in the crop by manipulating the crop environment to make it less attractive or supportive for the pest. The ultimate aim, in addition to saving crop yield, is to reduce stem borer numbers in the mature crop or the post-harvest crop residue to prevent carry over to the next planting.

Research at ICIPE has concentrated on the "push-pull" technique in reducing stem borers in maize. This is a way of attracting the pest towards a trap crop (pull) while deterring it from the main crop (push). Sudan grass (*Sorghum vulgare sudanense*) attract stem borers and allows borer development but encourages natural enemies. In the semi-arid zone of Eastern Kenya, sorghum is widely grown and offers lower risk of crop failure than maize. However, sorghum is more attractive than maize for borers and there is no advantage in using Sudan grass which is a wild sorghum. The project therefore concentrated on two cultural control approaches, which may reduce borer populations while fitting in with farmers' livelihood needs; stover management and intercropping.

4.3.2.1 Stover management in E. Kenya

Residues of maize and sorghum are valuable as forage, for house construction and for crop management through trash lines to prevent run-off and erosion and as fertilizer when incorporated into the soil. In some parts of Africa trash may be burned to destroy pest and diseases while liberating some minerals. This involves a loss of 80% of the fixed nitrogen in the material and sacrifices organic matter which benefits soil structure. In Nigeria partial burning of fresh stover to remove the leaves while heating the stems to kill borers has been recommended. However the technique would require time and skill. In Kenya stover burning is rarely practised.

Several practices relating to maize and sorghum stover management exist in semi-arid Eastern Kenya (see Section 4.1.6 and Kavoi, 2003). These included uprooting and placing maize and sorghum stover on trash lines to conserve soil and water, removing and storing (for preservation either up on a tree or a constructed rack or shed) as well as tying and selling. At the end of March-May rain season, farmers owning livestock, particularly draught animals, conserve maize stover for livestock feed for use during land preparation and planting prior to the October-December rains. There is little stover conservation after harvest in February because animal feed is available at this time. Sorghum stover is mostly used to make trash lines to conserve soil and reduce water run-off and erosion. Other stover management practices include: cutting and spreading on the ground, leaving standing in the field after harvest, ploughing under, and cutting back to obtain a ratoon crop (in the case of sorghum).

The treatment of stover during the dry season can have a dramatic effect on the carry-over of moths to the following rainy season. If stems are slashed at harvest and laid on the ground, the temperature of the stems may be raised to a point sufficient to kill borer larvae. At the same time loss of moisture and deterioration of the stem will trigger larvae to enter a resting stage (diapause) in which they may moult but will not become pupae or emerge as adults until rain comes. Access by ants, termites and other predators into the stems greatly increases predation. In Ethiopia early cutting of sorghum stalks and placing on the soil for four weeks led to complete extermination of borers. The results of our experiments in Eastern Kenya indicated that a similar effect can be achieved.

Experiments on stover management

The experiments were carried out on station at Katumani in the short and long dry seasons of 2001-2002. Some on-farm verification was carried out in two villages in Mwingi District, Mumoni Division (Katse and Kathiani locations) working with farmer field schools. The three treatments compared on farm were, plants left standing, plants placed in trash lines and plants spread thinly on ground. A host farmer provided a sub-plot in an existing field of KARI Mtama 1 (KM1) and participating farmers brought cut sorghum from their own fields for the other treatments.

The hypotheses of the experiments were that cutting and spreading sorghum stems thinly after harvest will lead to increased mortality of borers through overheating and predation. Spreading in trash lines should have a similar effect but less markedly owing to partial shading of lower stems in the pile. The six treatments used for the on-station experiment were:-

- C-SP12: Cut immediately and spread on field for 12 weeks
- C-SP6-TL6: Cut immediately – spread for 6 weeks and placed in trash lines for 6 weeks
- C-TL12: Cut immediately – placed in trash lines for 12 weeks
- ST-12 (Control): Left standing for 12 weeks
- ST6-SP6: Standing for six weeks and spread for 6 weeks
- ST6-TL6: Standing for six weeks and placed in trash lines for 6 weeks

Results

Long dry season Aug-Nov 2001 and Aug-Oct 2002:

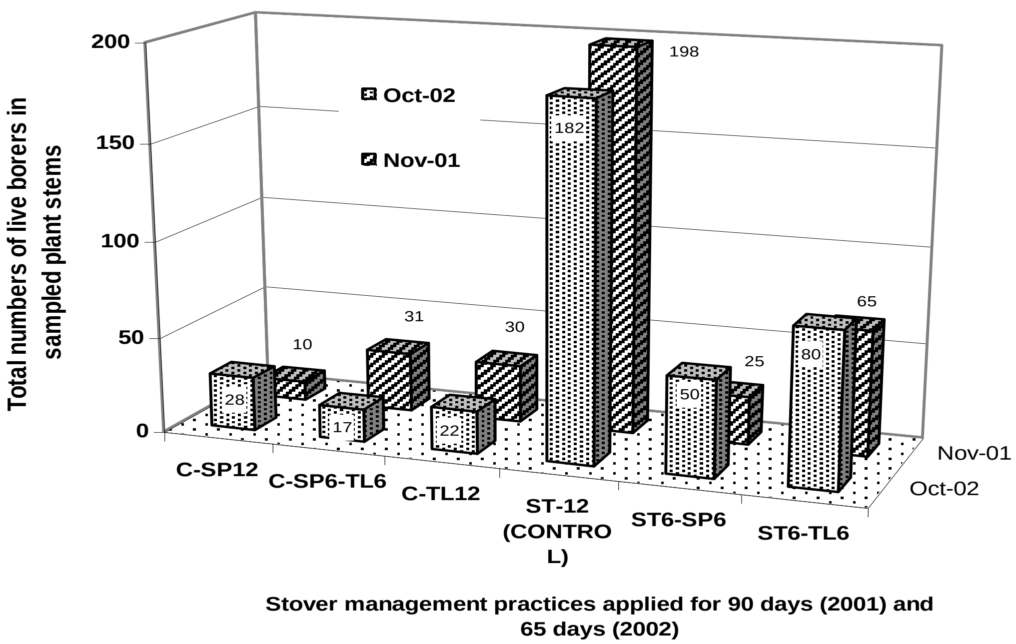
- *Stem borer infestation (Chart 4)*

  Numbers of live borers (larvae and pupae) present in standing stalks were reduced by 85-95% by cutting and spreading stems thinly immediately after harvest for 12 weeks. Placing the cut stems in trash lines for 12 weeks or leaving standing for six weeks then spreading was almost as effective. Leaving plants standing for six weeks before spreading or placing in trash lines supports more live borers than the other treatments but still reduces live borers by 50%. Results were maintained when the period of exposure of the stover was reduced to 9 weeks.

- *Tunnelling and emergence*

  Moth tunnelling and emergence (exit holes) from sorghum are somewhat reduced by cutting after harvest and spreading or placing in trashlines. However results are not conclusive and counting exit holes does not give a good measure of borer reduction.

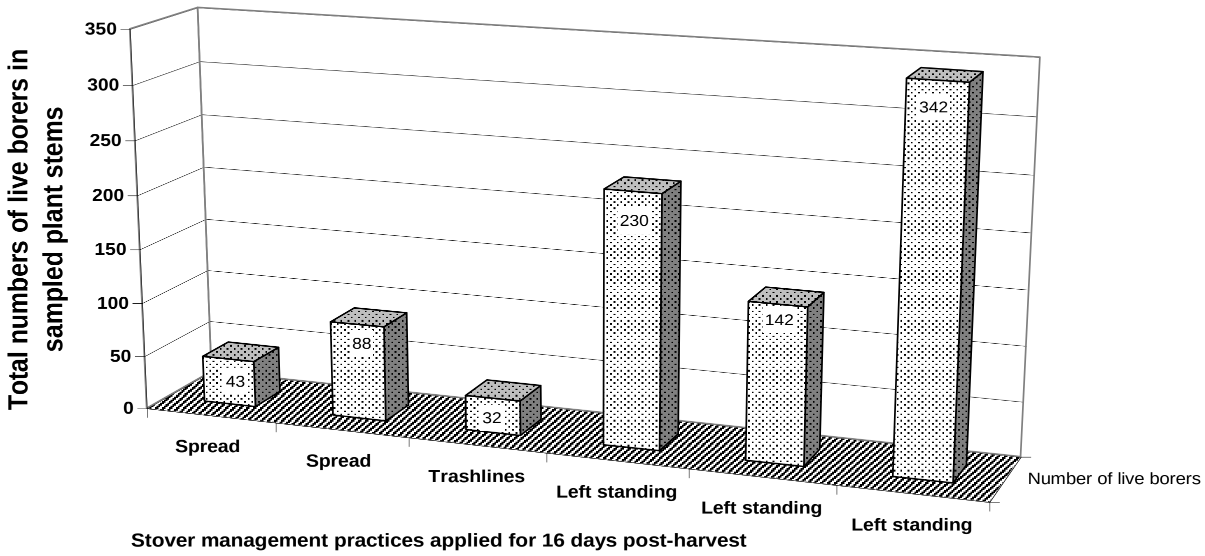
Chart 4. Effect of 9-12 weeks of stover management on survival of borer larvae (all species). NDFRC, Katumani, August – November 2001 and August – October 2002.



Short dry season February to March 2002 (Chart 5)

In this season the rains returned after 16 days and the experiment had to be terminated. Surprisingly, when the three treatments involving cutting are compared with the three left standing, there was still an average reduction of 75% in live borers.

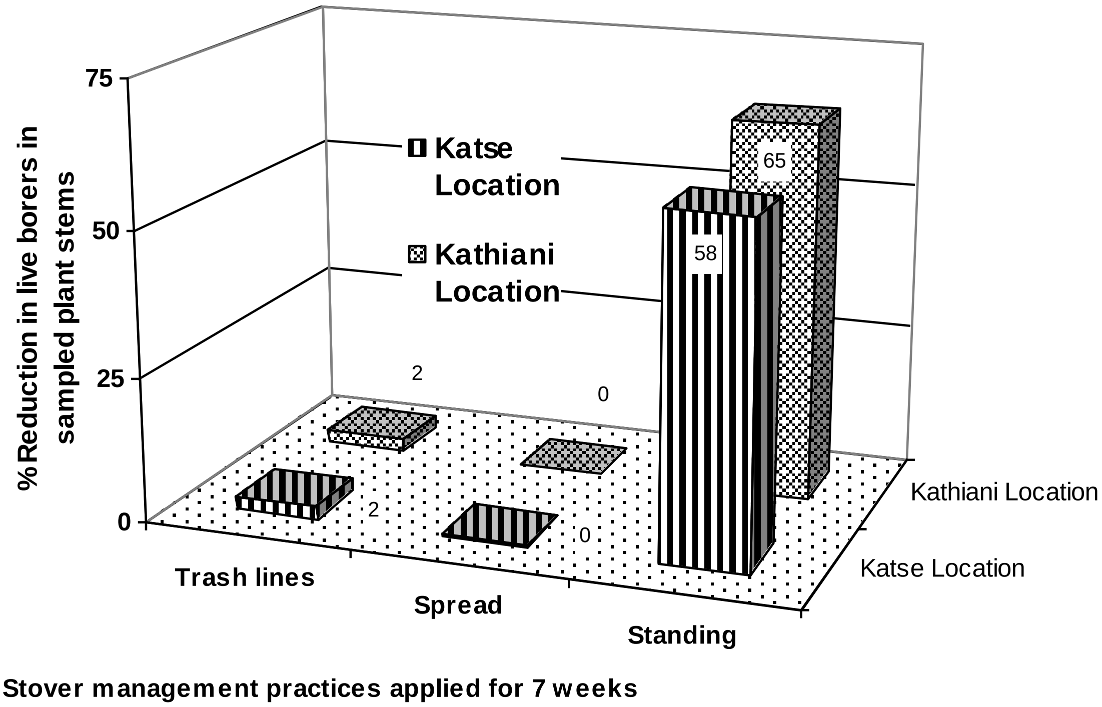
Chart 5. Effect of 16 days of stover management on survival of borer larvae (all species). NDFRC, Katumani, February to March 2002.



Results of farmer verification trials (Chart 6)

On-farm in Mwingi District (Mumoni Division), farmers found that live borers were reduced to around 0-2% of pre-treatment levels when stalks were slashed and spread or laid in trash lines for 7 weeks, compared to around 60% remaining in standing stalks.

Chart 6. Effect of 7 weeks of stover management on survival of borer larvae (all species). Mwingi District, February to April 2002



There is clear evidence that spreading stover can reduce stem borer carry-over, both during the long dry season from August to October and the shorter dry season between February and March. Cutting immediately and spreading or placing in trash lines, for periods of as little as 16 days, still have a noticeable effective in reducing live borer numbers compared to leaving plants standing at harvest. In Mwingi district temperatures are generally higher and conditions are more extreme, leading to almost complete removal of Stem borers.

The short dry season is likely to allow more effective carry-over of borers than the long dry season since there is a shorter period of dry conditions between rainy seasons. In this short dry season only a shorter period of spreading (2-6 weeks) may be possible as the return of rainy conditions will lower temperature and trigger diapause termination. Although more information needs to be gathered in this season, initial results suggest that the investment of time in slashing down plants at harvest will reduce the carry-over of stem borers by up to 90%.

4.3.2.2. Western Kenya experiments on stover management

The stover management treatments for the experiment were based on information from the PRAs about the different ways in which farmers manage their sorghum stover. An on-station trial using Variety Kari-mtama 1 was laid out during the dry season (July to September) in the long rains (LR) of 2001 and 2002 at the Homa-bay Farmers' Training Centre (FTC) under natural infestation. This variety was selected due to anecdotal evidence from other researchers that it was susceptible to the stem borer[8]. The trial was laid out in a randomised complete block design with 6 treatments in 3 replicates. The treatments were as follows:

1. Sorghum stems left standing for 12 weeks after harvest
2. Sorghum stems left standing for 6 weeks and laid out for 6 weeks
3. Sorghum stems left standing for six weeks and bundled for 6 weeks
4. Sorghum stems cut immediately after harvest and laid out for 12 weeks
5. Sorghum stems cut immediately after harvest, laid out for 6 weeks, then bundled for 6 weeks
6. Sorghum stems cut immediately after harvest and left bundled for 12 weeks

Destructive sampling of stem borers in stems was undertaken after harvest at three intervals: in the middle and at the end of the dry season to determine borer survival. Samples of ten stems per treatment were taken each time and the live larvae were counted to determine differential survival under treatments. The numbers of exit holes and pupae were also recorded to help explain the data.

Due to the low populations of stem borers in the year 2001 it was not possible to detect treatment effects. As a result, in 2002, in order to ensure high enough populations for the experiment, inoculation was undertaken using *Chilo partellus* eggs obtained from the National Dryland Research Centre-Katumani. A batch of twenty eggs was inoculated onto each plant 3 weeks after sowing using a pair of forceps because a bazooka dispenser (described by Sharma *et al*. 1992) was not available. Another trial of the same design was laid out under natural infestation.

[8] Subsequent trials conducted by ICRISAT in Eastern Kenya suggest that this variety is reasonably tolerant to stem borer, when compared with other short duration elite sorghum varieties (ICRISAT, 2003).

Results

Using the description by Teetes *et al.* (1983) the stem borer species were visually determined to be *Chilo partellus* and *Busseola fusca.* These two species were combined in the samples for analysis. The results have been reported separately for the trials under natural infestation and under artificial infestation.

Natural Infestation

Live larvae

There were highly significant differences (P<0.001) between sampling times with the highest numbers of live larvae per stem occurring after harvest and reducing considerably at twelve weeks after harvest when the final sample was taken (Chart 7). There also were significant differences between treatments in general (P=0.013), and between the treatments that were left standing for 6 weeks after harvest and those that were either laid out or bundled (P=0.005) (Chart 7). There was a significant variation (P=0.004) between the two seasons with the LR 2001 having a mean live larvae population of 0.4 and the LR 2002 having a mean of 0.2. Analyses for the different sampling times indicated that there were significant differences between the treatments in general at six weeks after harvest (P=0.005) and there were significantly more live larvae in stems that were left standing than in those that were either laid out or bundled (P<0.001). There were no significant differences between treatments in number of live larvae at twelve weeks after harvest.

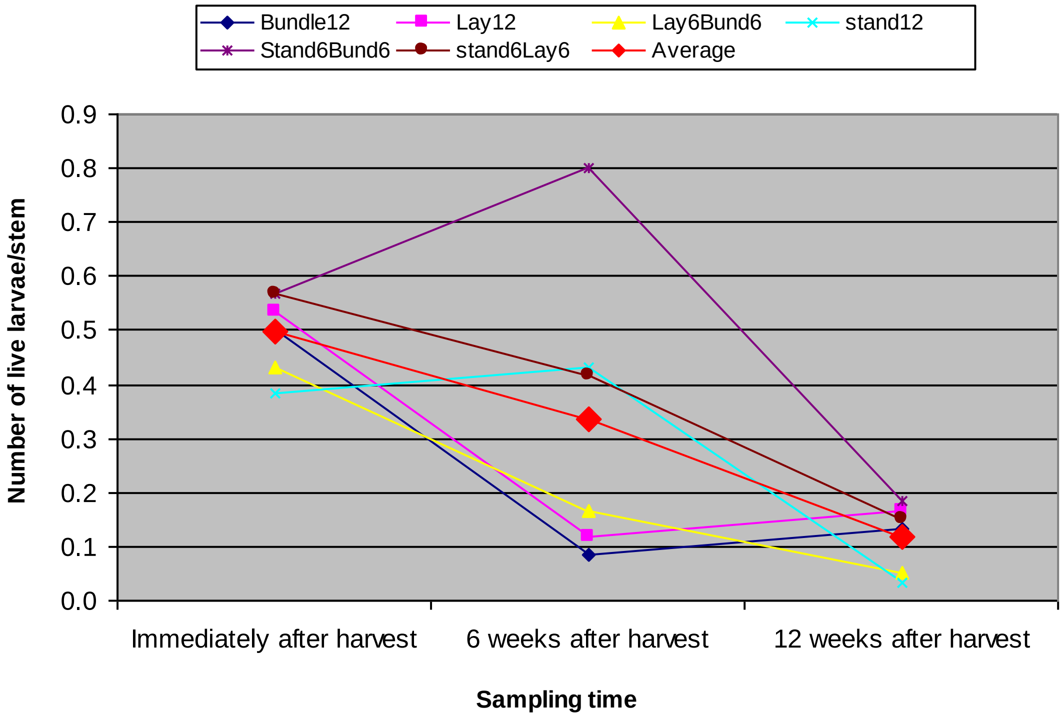


Chart 7: an number of stem borer live larvae in sorghum stems subjected to six different treatments under natural infestation through the dry seasons of the Long rains 2001 and 2002, at the Homa-bay FTC

Exit holes

A significant difference was noted between sampling times for the number of exit holes per stem (P=0.033) and a highly significant difference overall between treatments (P=0.002). The samples taken at six weeks had the highest mean numbers of exit holes while the samples taken at twelve weeks after harvest had the lowest. The treatments under which stover was left standing for the first six weeks had significantly (P=0.002) higher numbers of exit holes per stem than those that were either laid out or bundled. The treatments were highly significantly different at six weeks after harvest (P<0.001). Similarly, the treatments that were left standing had significantly higher mean numbers of exit holes than the ones that were either laid out or bundled (P<0.001). At twelve weeks there was a nearly significant difference between the treatments (P=0.059), while the treatments that were left standing had significantly more exit holes than those that were laid out or bundled (P=0.036).

Artificial Infestation

Live larvae

In the LR of 2002 the results indicated that there were highly significant differences between treatments (P<0.001) for numbers of live larvae found in stems in general and that the treatments that were laid out in the first six weeks (P<0.001) had very significantly fewer live larvae than other treatments over the period of the experiment (Chart 8). Chart 8 shows the steep decrease of stem borer live larvae over sampling occasions, which was also highly significant (P<0.001). There also was a highly significant interaction between time of sampling and treatments (P=0.001). Analyses for the different sampling times indicated that there were highly significant differences between the treatments in general at six weeks after harvest (P<0.001) and highly significant differences between the treatments that were left standing and those that were cut and laid on the ground for the first six weeks (P<0.001).

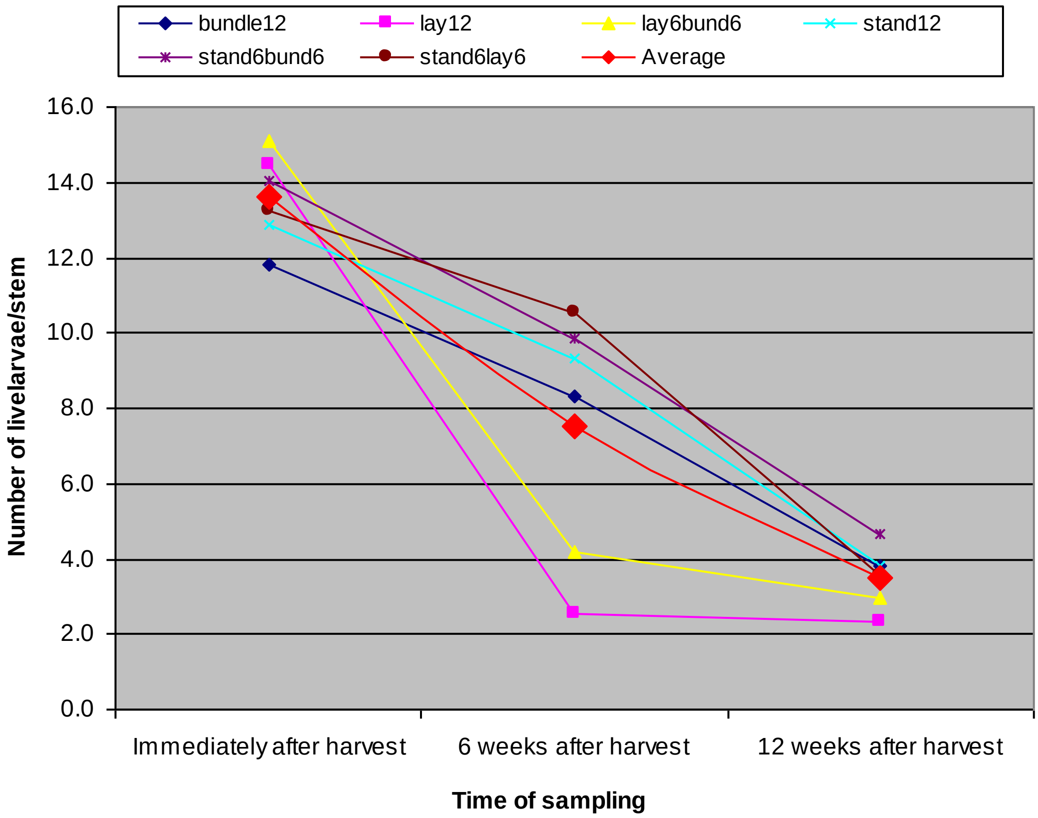


Chart 8: Mean number of stem borer live larvae in sorghum stems subjected to six different treatments under artificial infestation through the dry season of the Long rains 2002

Exit holes

The numbers of exit holes reduced significantly with time (P<0.001). At six weeks the treatments were highly significantly different (P=0.002), while the treatments in which the stover was left standing and the ones in which it was cut and laid or bundled for the first six weeks showed a borderline significant difference (P=0.064). There were no significant differences in number of exit holes at 12 weeks after harvest.

Discussion

In both the LR of 2001 and 2002 the trial results show that under all treatments except leaving standing under natural infestation larvae numbers decreased with time, reaching a minimum at twelve weeks after harvest. In addition, there were significant differences between treatments at six weeks after harvest but not at twelve weeks after harvest. This implies that provided the stems are not left standing, the dry season lasts long enough and is hot enough to kill most larvae in the stems (Table 23).

Table 23. Mean maximum temperatures: Homabay District, July-August 2001 and 2002

	July	***August***	***September***
2001	***30.5***	***31.2***	***32.3***
2002	***30.5***	***31.5***	***32.7***

The highly significant differences between the treatments that were laid out in the sun for the first six weeks and those that were either left standing or bundled means that already at six weeks the desired reduction of stem borers has been achieved so that stems may be used for other purposes. Under natural infestation, it was noted that larvae and numbers of exit holes sometimes increased for the treatments in which stover was left standing for six weeks. After six weeks the treatment in which stover was still standing showed increases in the number of exit holes, indicating that some stem borers had continued to develop and emerge after harvest. This may mean that after harvest moths can still emerge, and perhaps infest other hosts. This implies that leaving stover standing may encourage stem borer carry-over in alternative hosts, and that the two carry over sources should be considered together instead of separately. Cutting and laying stems for six weeks soon after harvest is the best treatment for reducing stem borer carry-over.

4.3.3 Panicle Management to reduce midge carry over – W. Kenya only

Introduction

It has been found that the greatest source of midge carry over is in spikelet residues left on-farm (Kulkarni 1985, Harris 1985). It has therefore been recommended that old seed heads and trash should be destroyed during the dry season (Sharma 1985, Harris 1985, Enserink 1995). It was necessary to clarify the farmers' panicle management practices and perceptions and knowledge on the sorghum midge before a recommendation on panicle management could be put into practice in Western Kenya. This work therefore aimed to identify farmer practices and knowledge gaps with respect to the sorghum midge in Western Kenya and to come up with a conclusion on what action is needed to bridge the knowledge gaps. The specific objectives were to:

1. To investigate and document farmers' panicle management practices and their knowledge on the sorghum midge.
2. To identify those farmer panicle management practices that encourage midge carry-over based on findings from a literature review.
3. To use the information from 1 and 2 above to suggest means of preventing midge carry-over.

Results

From the semi-structured interviews of farmers during the growing season of 2001 it was found that panicles without seed were left in the fields. Farmers' reasons for the causes of blasted panicles included: late planting, little rainfall, *Striga* weed infestation, pest infestation, prolonged drought during flowering, and lack of clean seed for planting. None of the farmers attributed the damage specifically to the sorghum midge and none practiced any control for the damage caused. This information was verified and quantified through a formal survey, during which 100% of the farmers interviewed in Homa-bay District and 90% in Busia District confirmed that midge-blasted panicles were a common occurrence. It was also found that most of the farmers (more than 80%) left the blasted panicles in the farm after harvest, while the rest use them for compost preparation and livestock feed, or burn them (Table 24).

Table 24: Farmer treatment of blasted panicles after harvest in Homa-bay and Busia Districts of Western Kenya.

	Percentage of farmers interviewed (n=125)	
Practice	Homa-bay District	Busia District
Left in the farm	81	87
Livestock feed	6	2
Compost preparation	3	10
Burning	10	2

The formal survey also found that more than 40% of farmers attributed the blasted panicles to damage by the sorghum midge while the rest attributed it to other causes (Table 25).

Table 25: Farmer perceptions of causes of blasted panicles in Homa-bay and Busia Districts of Western Kenya.

	Percentage of farmers interviewed (n=125)	
Perceived cause	Homa-bay District	Busia District
Midge	49	48
Erratic rainfall	2	0
Drought	19	14
Late planting	8	14
Did not know	21	17
Birds	0	3
Smut	2	3

It was not possible to determine whether blasted panicles would produce viable midges, as adults did not emerge from the wetted panicles on all the attempts that were made. This may be explained by Teete's (1995) finding that most midges do not terminate diapause and emerge as adults during the same year as they entered diapause. Harris (1985) further states that midges can carry over for a period of 3 years.

Conclusion

Farmer interviews during formal survey and the trials suggest that midge is the most serious pest of sorghum in Western Kenya. Several authors have indicated how easily sorghum midge damage is confused with other causes of crop loss by both farmers and extension agents (Ratnadass and Ajayi 1995, Nwasike 1995, Harris 1995). However, none of the literature on the sorghum midge suggests bridging this serious knowledge gap. The farmers' practice of leaving blasted panicles in the fields clearly encourages midge carry-over, as spikelet residues left on-farm are reported elsewhere as being the greatest source of midge carry-over (Sharma 1985, Teetes 1995, Harris 1985, Enserink 1995). Farmer appear to be more aware of midge damage than are the extension agents. The extension workers in Homa-bay have admitted that they do not understand the midge problem and at the stakeholders' workshop the extension workers invited from other sorghum growing districts within the Kisii RRC-mandate area did not think that midge was a priority (Wilson and Ritchie 2001).

Until farmers and extension staff have learned to recognise cause and effect, control measures depending on their co-operation may not be successful. The focus on midge damage and carry over for Western Kenya should be towards devising a way of educating them about what promotes midge damage, the effect of the damage and how to reduce carry over. Survey data showed that some farmers use the panicles for livestock feed and composting, while others burn them. These practices may offer opportunities for improved management of panicles, for instance, in composting. However, there is need to establish the feasibility of these options with farmers with regard to costs (labour) and practices (livestock feed), for example.

The information on blasted panicles is based on farmer perceptions and direct observations by the researcher. To further quantify the economic importance of midge damage, it may be necessary to conduct surveys of midge incidence and severity over a number of seasons. Also there is need to establish the extent to which sorghum panicles left in the fields produce viable midges. It would require several seasons and a well tested method for breaking diapause to gain this information.

4.4.4 Use of intercropping practices against stem borers in sorghum- E. Kenya only

Introduction

Intercropping has long been recognised to confer some advantages in relation to pest attack, compared to mono-cropping. For example at ICIPE in the early 1980s, Amoako-Atta and others found that establishment of stem-borers on maize and sorghum could be delayed by intercropping with cowpeas. It has been found that the female borer is confused by the mixed plant population and lays eggs on the legume instead of the host crop. Borer larvae often wander between plants and in an intercrop may be unable to find a suitable host before succumbing to starvation or predators. However in intercrops with sorghum, maize has been found to be more strongly attacked than in monocrop (Ogwaro 1983). This is because the sorghum is highly attractive to female moths and "pulls" the borers into the maize. Millet is a crop which is suitable for borer egg laying but does not support borer larval development well. In West Africa, Adesiyun (1983) found that sorghum intercropped with millet had only 10-30% of the *Busseola fusca* stem borer population of sole cropped sorghum.

Farmers in semi-arid eastern Kenya intercrop mainly to maximise returns from limited land and to spread the risk of crop failure. Occasionally farmers comment that intercropped sorghum suffers less from stem borer attack. Sorghum is mainly intercropped with cowpeas or pearl millet (Kavoi, 2003). Millet is a less suitable host for borers than sorghum but is more attractive for laying. A replicated intercropping experiment was designed to test the hypothesis that intercropping with sorghum may confuse laying moths and reduce successful borer development. The six treatments used of three seasons (Long rains 2001 and 2002, and short rains 2002) were:-

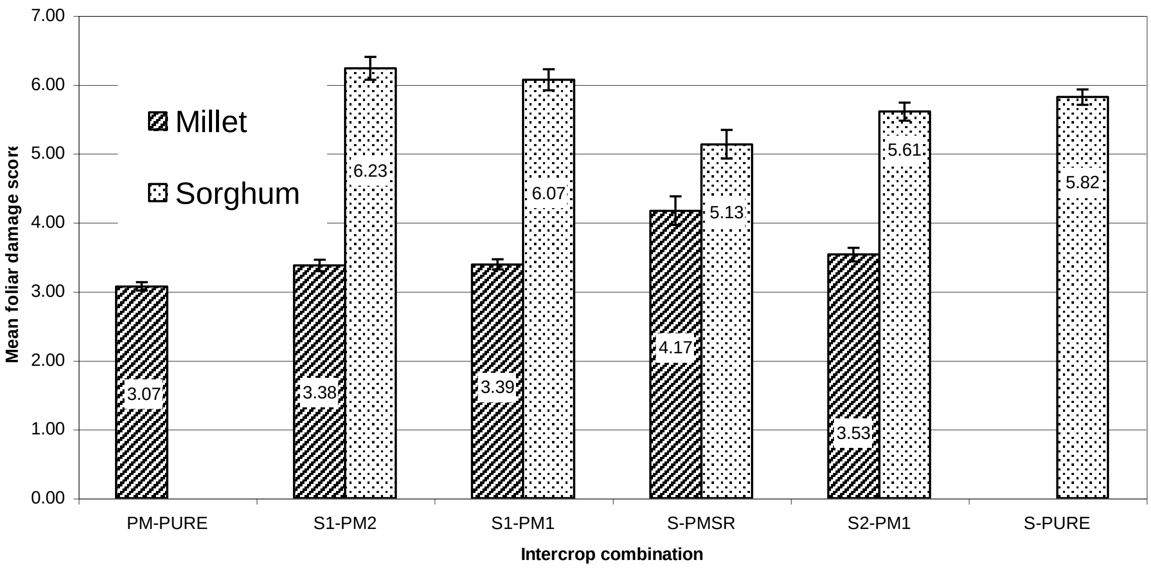
- PM-PURE Sole Crop millet
- S1-PM1 Alternate rows Sorghum and millet
- S1-PM2 1 row sorghum and 2 rows millet
- S2-PM1 2 rows sorghum and 1 row millet
- S-PMSR Alternate stations sorghum and millet, same row
- S-PURE Sole Crop sorghum

Results (long rains 2001 and 2002):

Foliar damage (FD) (Chart 9)

Same row intercropping leads to greater foliar damage in millet compared to other treatments (p=0.045) and sole-cropping (p=0.021). Sorghum intercropped in the same row has less foliar damage but not significantly (p=0.087) compared to other treatments.

Chart 9. Foliar damage scores for intercropped sorghum and millet, long rains, June 2001.



Stem borer population

In July 2001 numbers of live larvae per metre of stem were reduced by 45% - 60% by same row intercropping & 1 row sorghum to 2 of millet, compared to sole-cropped sorghum. Moth emergence (exit holes) from sorghum were reduced by 25% by the same treatments. In the following short rains (November 2001 to February 2002) borer numbers were lower and only a marginal reduction (13%) in larval numbers was achieved with same-row intercropping and around 25% for two rows sorghum to one of millet. Alternate rows of sorghum and millet produced a high larval population, not significantly different from pure sorghum, while a single row of sorghum to two rows of millet produced the best reduction in larval numbers (46%). In July 2002 a similar result was obtained to the first long rains season, with intercropping treatments producing reductions of 30% - 66% in larvae per metre of stem.

Chart 10. Number of stem borer larvae per metre of plant stem in sole-cropped and intercropped sorghum and millet, long rains, July 2001.

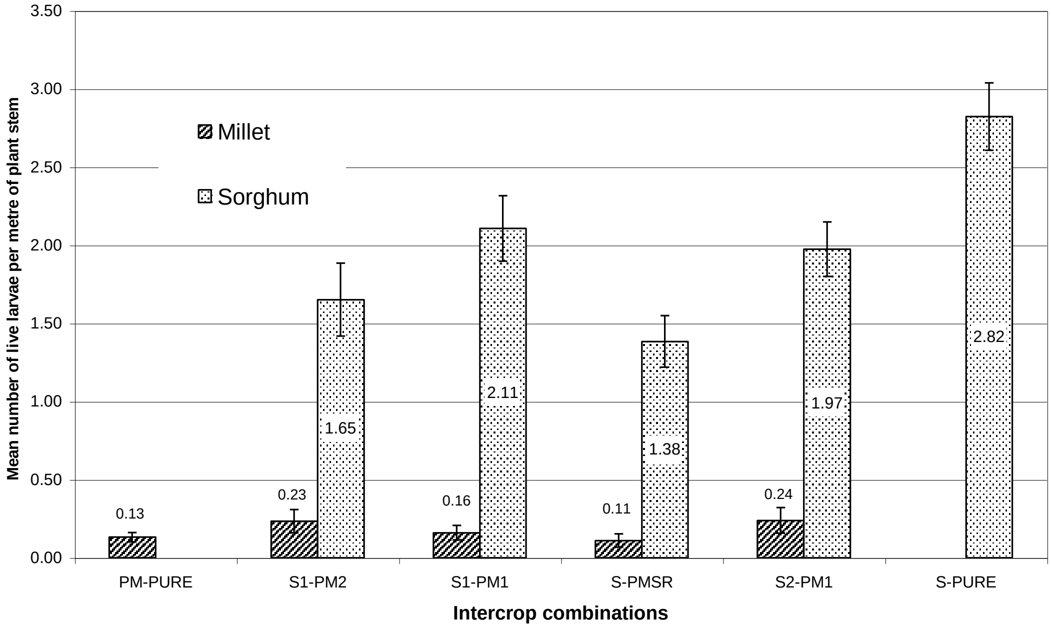


Chart 11. Number of stem borer larvae per metre of plant stem in sole-cropped and intercropped sorghum and millet, short rains, February 2002.

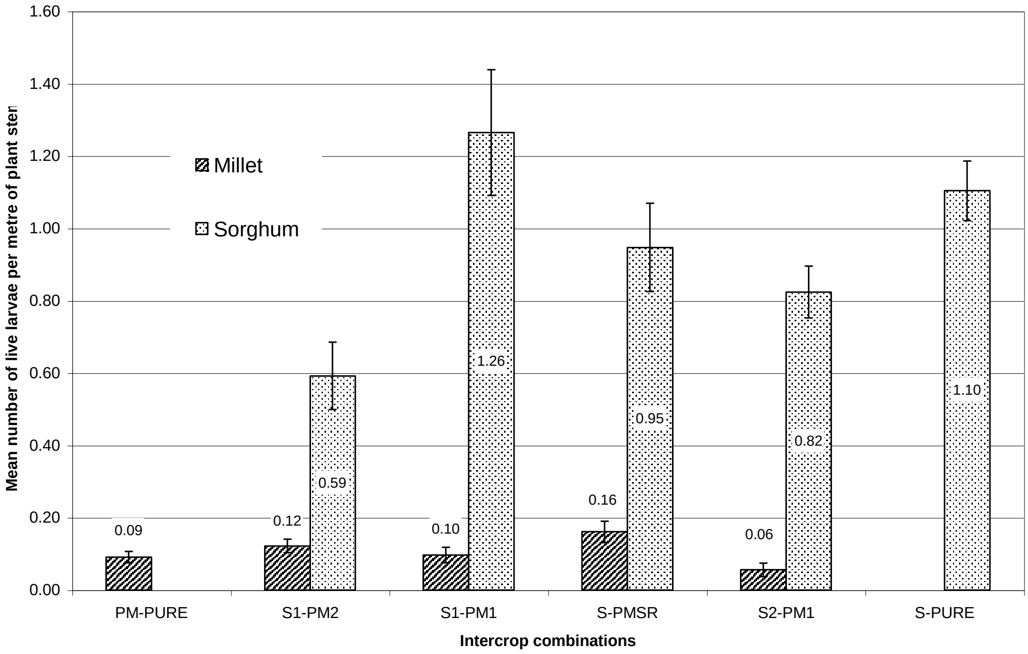
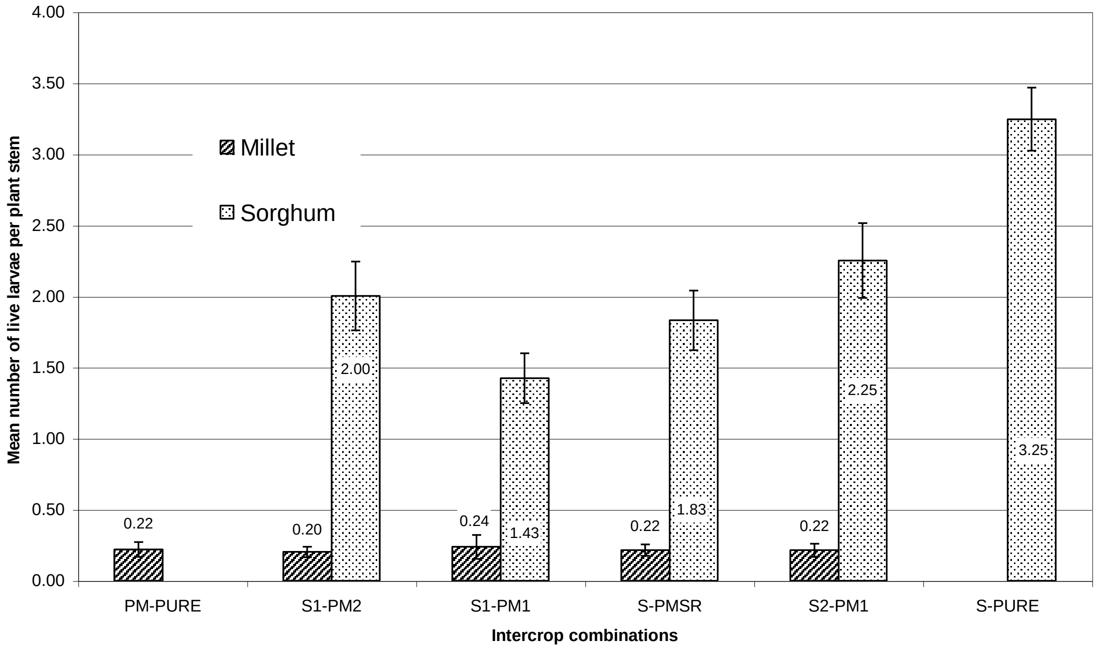


Chart 12. Number of stem borer larvae per metre of plant stem in sole-cropped and intercropped sorghum and millet, long rains, July 2002.



Farmers' observation plots

Three farmers in Mivukoni village, Mwingi District, participated in a small-scale sorghum/millet intercropping trial using observation plots. In separate trials, farmers intercropped local sorghum and also a new variety. The work was implemented and reported by Linus Muthengi, extension worker in Kyuso Division. Results are shown in Table 26, on the basis of scoring and counting and weighing yield. They noted that it reduced the number of plants with dead-hearts and incidence of damage as well as reducing damage levels on damaged plants. The farmers' intercropped sorghum was seeded at 1:2 or 1:4 relative to the millet and was noted as developing more slowly and producing smaller heads than in sole crop. One farmer's yield was eaten by birds.

Farmers believed that intercropping saved labour/time in cultivation and crop protection. They also mentioned the value of two crops from one piece of land. They appear willing to accept lower yields from the intercrop.

Table 26: Results of farmers observation trial, planted at Mivukoni Village April rains 2002. Three farmers participated. Recorder: Linus Muthengi.

	Intercrop with Millet	Sole crop sorghum
Local Sorghum: MUVETA		
6-8 leaf stage		
Stem borer foliar damage rating (1-5)	1, 1, 1 = **1**	2 ,3 ,2 = 2**.3**
Number of Dead-hearts out of 25 plants	4, 4, 4 = **4**	6, 7, 5, = **6**
Number of stem-borer-damaged plants out of 25	9,7,8 = **8**	18, 9, 15 = **14**
Crop maturity stage		
Stem borer damage rating	2, 2, 1 = **1.7**	4, 3, 1 = **2.7**
Number of chaffy heads in subplot	0, 0, 0 = **0**	2, 0, 2 = **1.3**
Yield		
Number of heads in subplot	45, 70, 55 = **57**	90, 96, 75 = **87**
Sorghum yield (Kg) averaged	0.8, 0.8, 0 = **0.53**	1.0, 1.2, 0 = **0.73**
Research Sorghum: KSV12, GADAM		
6-8 leaf stage		
Stem borer foliar damage rating (1-5)	2, 1, 2 = **1.7**	2, 2, 3 = **2.3**
Number of Dead-hearts out of 25 plants	3, 3, 3 = **3**	5, 5, 5 = **5**
Number of stem-borer-damaged plants out of 25	10, 5, 10 = **8.3**	16, 10, 16 = **14**
Crop maturity stage		
Stem borer damage rating (1-5)	1, 2, 1 = **1.3**	2, 4, 2 = **2.7**
Number of chaffy heads in subplot	0, 0, 2 = **0.7**	0, 1, 3 = **1.3**
Yield		
Number of heads in subplot	60, 46, 86 = **64**	86, 102, 98 = **95**
Sorghum yield (Kg) averaged	0.75, 0.5, 0 = **0.42**	1.5, 1.0, 0 = **0.83**

Conclusions

Mixed row intercropping with millet can reduce stem borer larval numbers in sorghum in the long (April) rains, which is the season when then stem borer challenge is most severe. Benefits are less noticeable in the short rains. Millet is a cash crop as well as a food crop, and the possibility of reduced head size of millet when seeds are planted in the same hill in the same row needs to be examined with farmers. The on-station trial used an artificial planting pattern of alternating stations which separates the plants, but this may not appeal to farmers. Using small proportions of sorghum in an intercrop with millet may avoid reduction of millet yield. The performance of the sorghum may be at risk from competition, but stem borers should be reduced, with a benefit both in terms of sorghum yield and a lower borer carry over population. Another possible way of using millet to give protection to sorghum (or maize) on-farm would be to put a ring of millet around a field of sorghum, as has been advocated for maize using napier grass (*Pennisetum purpureum*). This may be worth testing on farm with comparison plots of sorghum imposed on existing fields; particularly if farmers are prepared to sacrifice the millet yield due to probable bird damage when planted in this way in return for less loss from stem borer on their maize or sorghum.

4.3.5 Manipulation of sowing dates of early maturing varieties in W. Kenya

Introduction

In Western Kenya, farmers have developed strategies to get around some of the pest related constraints arising from late planting of sorghum. For example, during the PRA surveys farmers indicated that if they had to plant sorghum late they used early maturing varieties. Also, farmers in Busia, Kenya, have indicated that if they were very late they would avoid planting sorghum completely due to fear of midge damage. Planting early maturing varieties can be an effective means of managing pests of the type that require several generations to build-up dense populations within a season sufficient to cause economic damage. However, the period within which early maturing sorghum varieties can be planted late while avoiding pest damage has not been established. Nor has there been any study to quantify the effects of progressively later planting dates in terms of crop losses incurred due to subsequent pest damage in Western Kenya.

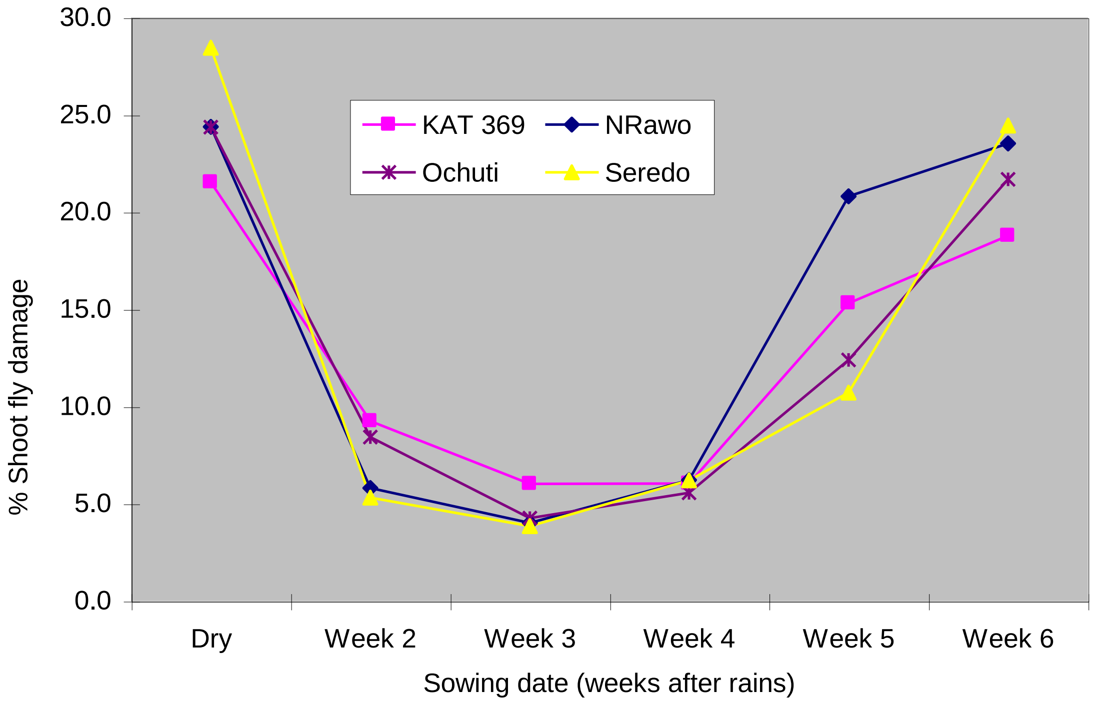
It was therefore proposed that short maturing varieties of sorghum planted on staggered sowing dates might reach maturity at the same date as long maturing varieties planted earlier, and so avoid pest damage. An experiment was designed to test this hypothesis in order to provide additional information for the development of integrated pest management options for smallholders. The specific objectives of the study were to:

1. Validate the hypothesis that late planting leads to increased pest damage
2. Test the hypothesis that pest damage can be avoided by use of early maturing varieties
3. Quantify the effect of planting date on pest incidence and severity and on yield of sorghum

Effect of sowing date on shoot fly damage

Highly significant differences were noted between sowing dates for the percentages of shoot fly dead hearts recorded ($P<0.001$). Dry planting and planting 5 weeks after the rains had the highest percentages of deadhearts recorded. There were no significant differences ($P=0.690$) between varieties (Chart 13), and no significant differences (P=0.475) between long maturing (Nyachong rawo and Ochuti) and short maturing (Seredo and KAT 369) varieties. There was a significant annual variation in shoot fly incidence (P<0.001) with year one having a mean of 19.1 and year two having a mean of 1.6. The dry planted crop having high damage levels may have been because dry-planted sorghum seedlings were moisture stressed and therefore had poor vigour. In addition carry-over from the previous season, with all the diapausing shoot flies attacking the first planted crop may be a factor. Crops planted two weeks after the rains had significantly less shoot fly damage because at that time there was plenty of rain and the crops were vigorous and also because the rain may have washed off the larvae that were to attack the crops.

Chart 13 : Percent shoot fly damage in relation to sowing date in 4 different sorghum varieties at the Homa-bay FTC for long rains 2001 and 2002.

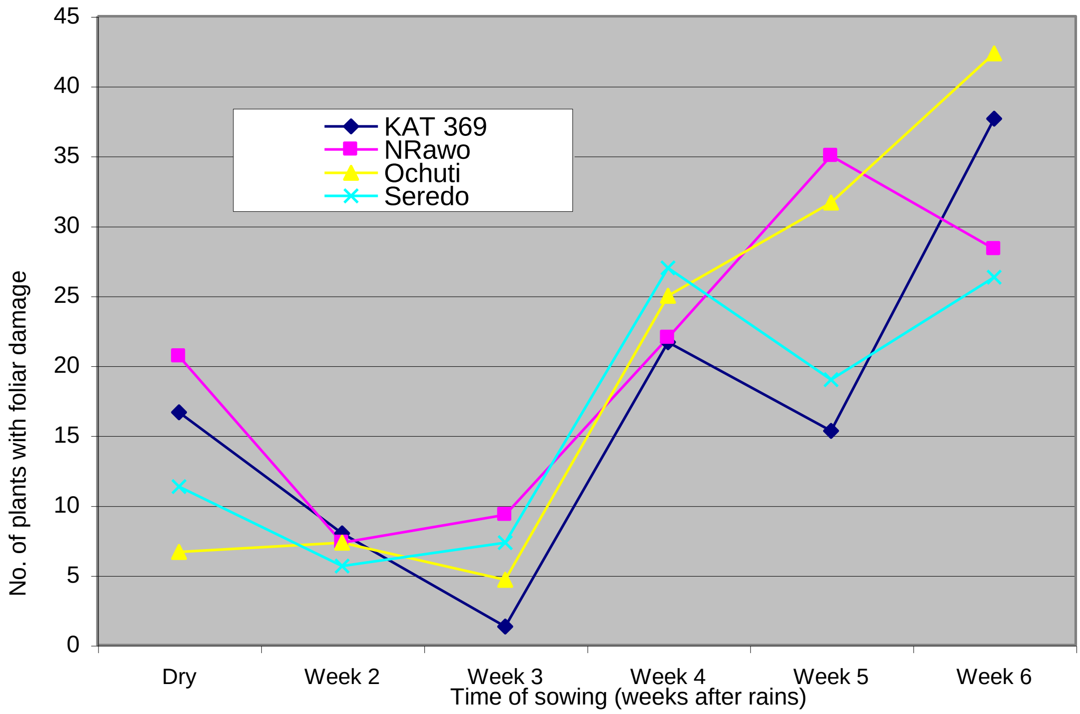


Effect of sowing date on stem borer damage

Highly significant differences were found between varieties for number of plants with stem borer leaf feeding symptoms (P=0.006), and between long and short maturing varieties (P=0.001). The short maturing varieties, KAT 369 Seredo, had lower levels of damage compared to the long maturing varieties Ochuti and Nyachong Rawo (Chart 14). There also were highly significant differences between sowing dates (P=0.001) with significantly lower means (P=0.001) for early sowing dates (dry planting to 3 weeks after the rains) than for later sowing dates (4 to 6 weeks alter the rains) (Chart 13). There was a significant variation between seasons (P=0.007) with the long rains 2001 having a mean count of 12.0 compared to the mean of 18.2 for the long rains in 2002.

Similarly there were highly significant differences between varieties (P=0.001) and between long and short maturing varieties (P=0.001) for the number of exit holes per stem recorded. Short maturing varieties had lower numbers of exit holes than the long maturing varieties. There also were highly significant differences (P=0.001) between sowing dates in general and between early and late sowing dates (P=0.001); early sowing dates had lower numbers of exit

Chart 14: Mean stem borer foliar damage in relation to sowing date in 4 different sorghum varieties during the long rains 2001 and 2002 at the Homa-bay FTC



holes than the late sowing dates. There was no significant annual variation (P=0.210).

Highly significant differences were found between varieties (P=0.001) and between long and short maturing varieties (P=0.001) for numbers of live larvae per stem recorded. Short maturing varieties had lower numbers of live larvae than the long maturing varieties. There also were highly significant differences (P=0.001) between sowing dates in general and between early and late sowing dates (P=0.001). Early sowing dates had lower numbers of live larvae than the late sowing dates. There was no significant annual variation (P=0.118). There were highly significant differences (P=<0.001) between sowing dates for percentage of stem tunnelled. No significant differences were found between varieties (P=0.120) for percentage of stem tunnelled. Similarly, there were no significant differences between long and short maturing varieties (P=0.307).

The significant differences between sowing dates in stem borer damage levels are likely to be related to the effects of rainfall, particularly on conditions for the establishment of a breeding population. Dry planting and planting one and two weeks after the rains had lower foliar damage, exit hole and larvae counts than planting 3, 4 and 5 weeks after the rains. The same was true for percentages of stem tunnelled by the stem borers. It is likely that rainfall washed off the first instar larvae for the first three sowing dates, while earlier plantings serve as a source of innoculum for later plantings.

Short maturing varieties KAT 369 and Seredo had significantly lower amounts of foliar damage, exit hole and larvae counts than the long maturing varieties, Ochuti and Nyachong rawo. This may have been because the early maturing varieties may have passed through the susceptible stage before the stem borer larvae set in. They may also have served as a source of inoculum for the long maturing varieties.

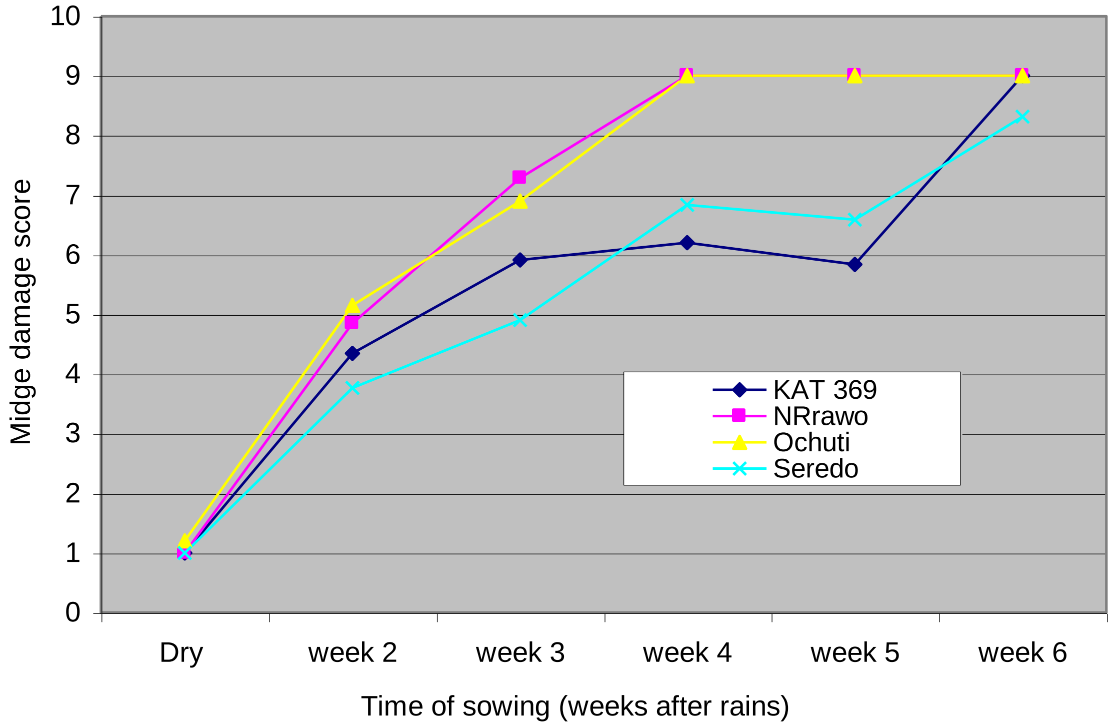
Effect of sowing date on sorghum midge

Highly significant differences were noted between varieties (P=0.001) and between long and short maturing varieties (P=0.001) for midge damage scores. Short maturing varieties had lower damage scores than long maturing varieties (Chart 15). There also were highly significant differences (P=0.001) between sowing dates in general and between early and late sowing dates (P=0.001). Early sowing dates (dry planting to 3 weeks after the rains) had much lower damage scores than late sowing dates (4-6 weeks after the rains). There was a highly significant annual variation in midge damage score (P=0.001) with year one having a mean score of 8.2 compared to year two having a mean of 4.7.

Dry planting and early planting (1 and 2 weeks after the rains) had significantly lower midge damage scores than later plantings (3-5 weeks after the rains). There was also a highly significant annual variation with a severe outbreak in year one. Enserink

(1995) studied seasonal fluctuation in sorghum midge damage in Busia District of Western Kenya and concluded that it related to the local rainfall patterns as these influenced the spread of infestation. In this study it was found that the rainfall patterns were different for the long rains 2001 and 2002 with the former having very little rains at planting time (during the month of March), resulting in a delay in planting. In addition, in the year 2001 there was high rainfall in the month of January, followed by a dry spell, so some farmers planted while others waited until April to plant. This led to the higher incidence and severity of midge in this year as a result of population build up on the earlier planted crop. Short duration varieties showed very significantly lower midge damage scores than long duration varieties.

Chart 15: Midge damage scores in relation to sowing date in 4 different sorghum varieties at the Homa-bay FTC for long rains 2001 and 2002.



Effect of sowing date on sorghum yield

During the first year there were no yields for sowing dates 4 to 6 after the rains due to the severe midge damage. As such the data for yields could not be analysed for the two years together and is presented separately.

Year 1

For grain weight (kg/ha), there were significant differences between sowing dates (P=0.037) and highly significant differences (P=<0.001) between varieties. There was also a significant interaction between sowing date and variety (P=0.041) (Table27). Varieties KAT 369 and Seredo had significantly higher yields than Ochuti and Nyachong Rawo . There was also a significant interaction between sowing dates and long and short maturing varieties (P=0.004). Sowing dates 3, 4 and 5 weeks after the rains had no yields due to midge attack and less rainfall, therefore the stand count at harvest was used as an indication of what the yield might have been.

Table 27: Mean sorghum yields (kg/ha) in relation to sowing date in 4 different sorghum varieties at the Homa-bay FTC for the long rains 2001.

	Variety				
Sowing date	**KAT 369**	**NRawo**	**Ochuti**	**Seredo**	**Mean**
Dry planting	171	545	485	621	456
1 week after rains	675	97	359	946	519
2 weeks after rains	252	58	48	677	259
3 weeks after rains	0	0	0	0	0
4 weeks after rains	0	0	0	0	0
5 weeks after rains	0	0	0	0	0
Mean	366	233	297	748	411

s.e.d for variety means = 112.8 on 22 d.f.
s.e.d. for sowing date means = 97.7 on 22 d.f.
s.e.d. for sowing date x variety interaction = 195.4 on 22 d.f.

Year 2

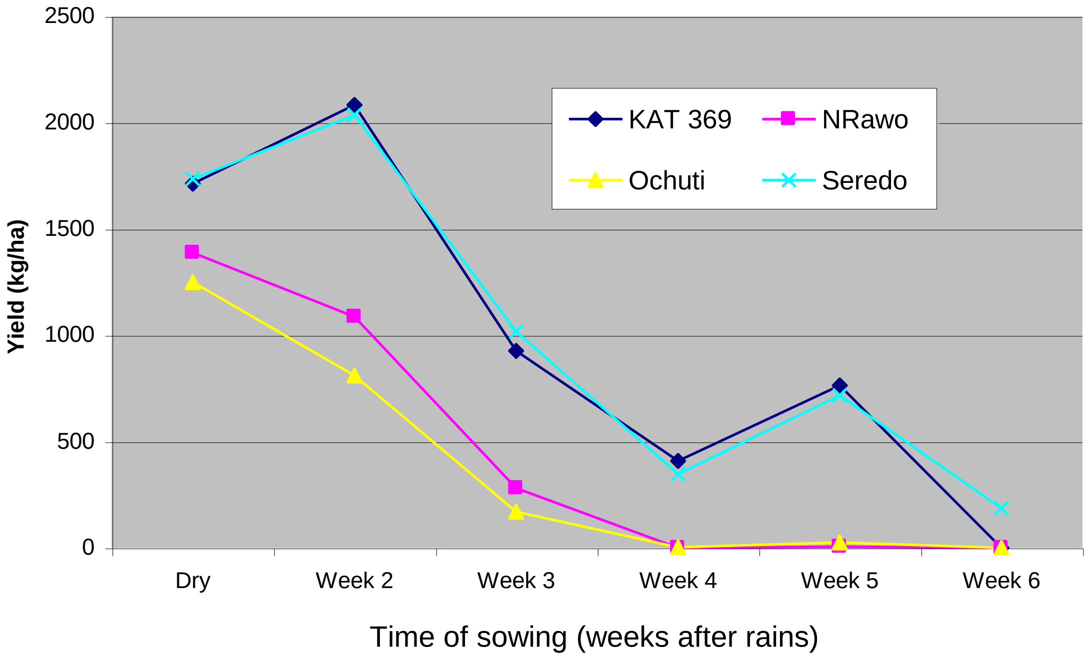
There were highly significant differences between sowing dates in general (P=0.001) and between early and late sowing dates (P=0.001), with the early sowing dates (dry planting to 3 weeks after the rains) having higher mean yields than the late sowing dates (4 to 6 weeks after the rains) (Chart 16). Similarly, there were highly significant differences between varieties in general (P=0.001) and between long and short maturing varieties (P=0.001). The early maturing varieties KAT 369 and Seredo had higher mean yields than the late maturing varieties Nyachong rawo and Ochuti, even when planted up to five weeks late.

Significant differences in stem borer damage levels were observed between long and short maturing varieties of sorghum, with short maturing varieties KAT 369 and

Seredo having significantly lower amounts of foliar damage, exit hole and larvae counts than the long maturing varieties, Ochuti and Nyachong rawo. This may have been because the early maturing varieties may have passed through the susceptible stage before the stem borer larvae set in. They may also have served as a source of inoculum for the long maturing varieties. The same was true for midge damage as short duration varieties showed very significantly lower midge damage scores than long duration varieties.

Linear regression showed strong statistical evidence (r^2= 0.85) that a decrease in grain yield of sorghum strongly correlated a delayed sowing date.

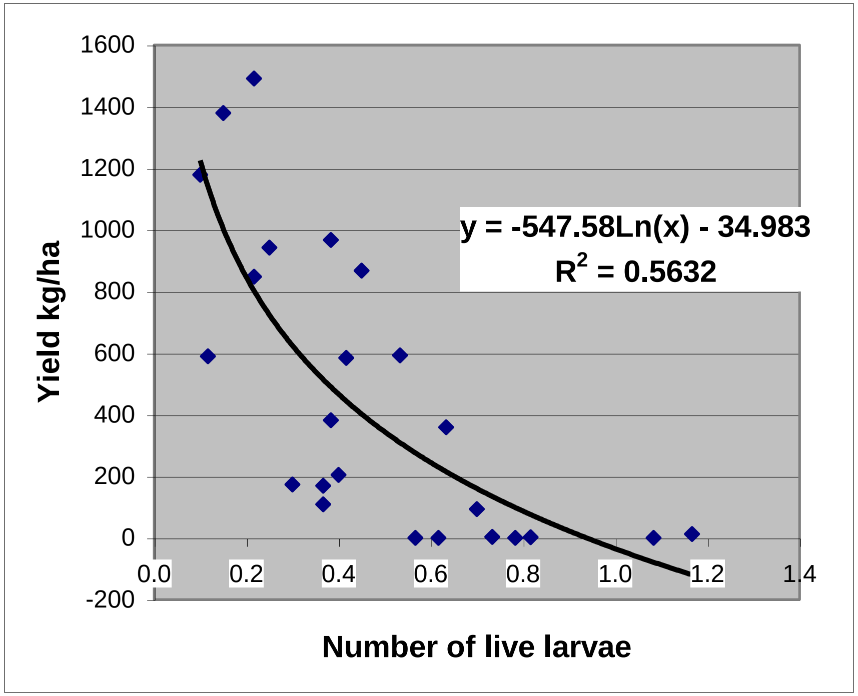
Chart 16: Mean sorghum yields (kg/ha) in relation to sowing date in 4 different sorghum varieties at the Homa-bay FTC for long rains 2002.



Effects of pest damage on yield

Regression analyses between the pest damage and yield showed that there were significant correlations between numbers of stem borer live larvae, stem borer exit holes, midge damage and yield. There were no significant correlations between foliar damage and yield. The scatter plots showing these relationships are presented in Chart 17 below.

Chart 17: Scatter plots showing (Clock wise) the correlations between: Number of live larvae and yield; number of exit holes and yield; midge damage and yield; foliar damage and yield



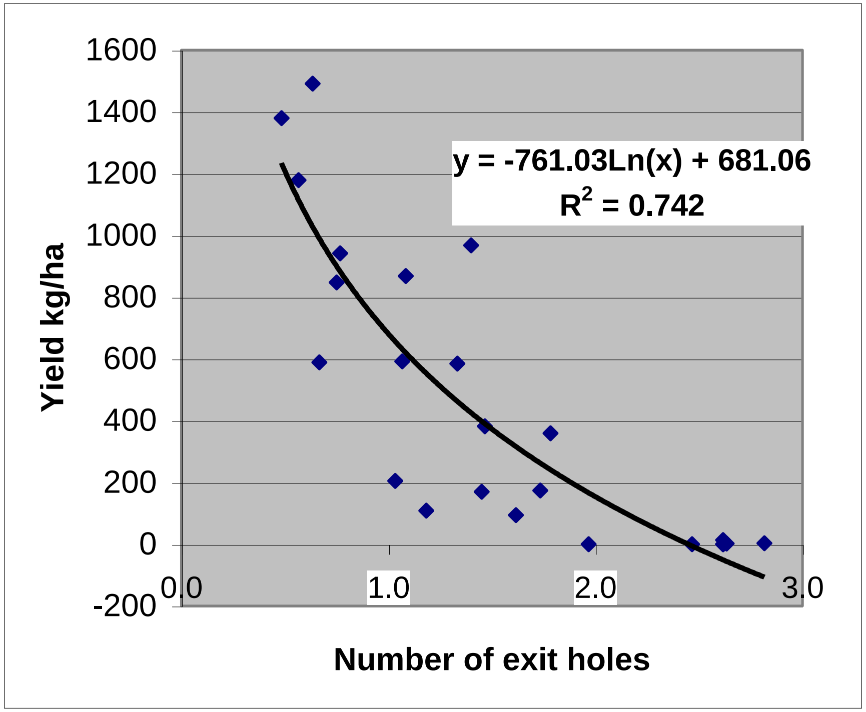
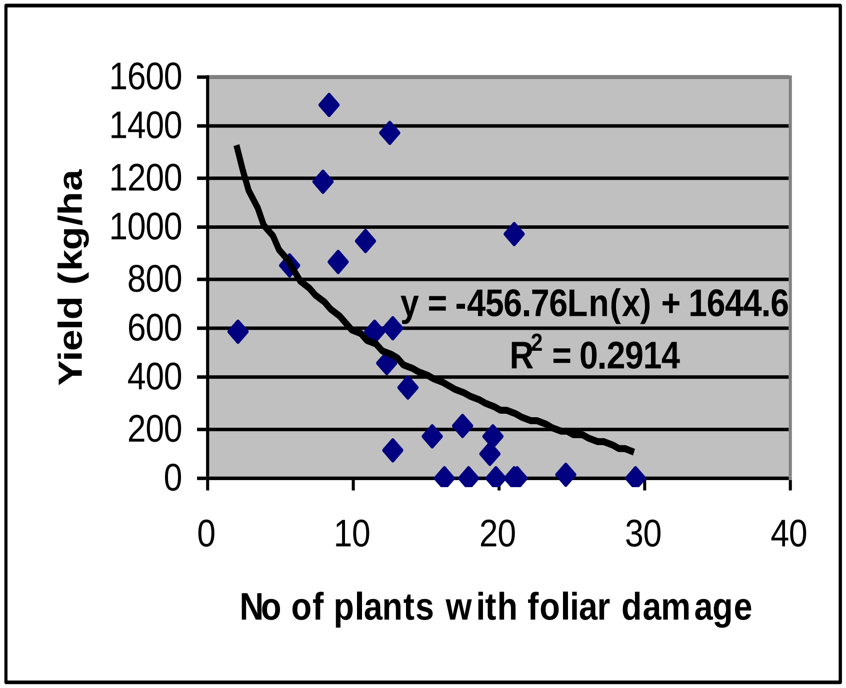
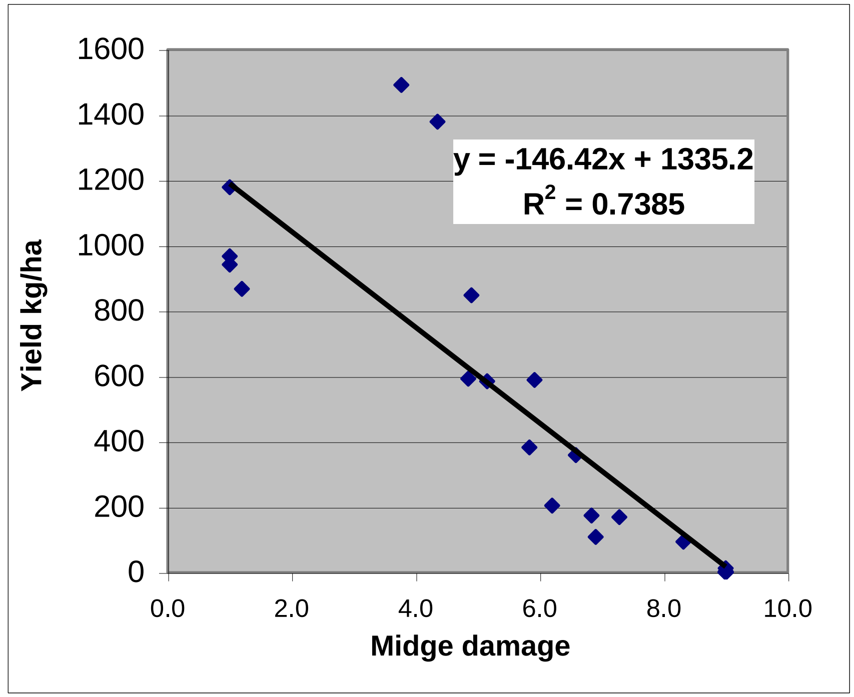


Chart 17 continued..





Conclusions

Overall the results from this trial suggest that damage from the three main insect pests is clearly related to date of planting. Shoot fly damage is most probably related to plant vigour and rainfall. Other things being equal, planting immediately after the onset of the rains is likely to result in less shoot fly damage than either dry planting or more than two weeks after the onset of the rains. Stem borer damage and build-up during the season is also related to rainfall. To reduce levels of stem borer damage in sorghum and also the build up of a large breeding population to carry over into the next season, early planting, including dry planting, would appear to be a sound management strategy. To avoid midge damage, the best period for sowing in Western Kenya is until three weeks after the on-set of the rains. If possible farmers should plant sorghum at a similar time, and should plant the longer maturing varieties before the shorter maturing ones to minimise build up of midge population after the first flowering. The significant differences found between short maturing and long maturing varieties for pest damage and grain yield in both years suggests that the maturity period of varieties is a potentially useful pest management strategy. Notwithstanding inherent pest resistance or tolerance qualities, short maturing sorghum varieties have a valuable role for improved food security in Western Kenya.

4.4 *OUTPUT 4:* Capacity in pest management research and methods developed and uptake pathways identified

Under this output a summary of capacity developed, methodology lessons learned and uptake options and pathways identified is presented.

4.4.1 Capacity developed

This output captures the main "institutional and learning benefits" of the project. CPP projects are commonly implemented through collaborative partnerships between advanced research institutes, national research programmes, extension programmes and farming communities. The project design incorporated mechanisms for building capacity within the partner members as part of project implementation. While this capacity was built in order to enable effective implementation of the project activities, it constitutes a valuable human resource which can be used in future research efforts. The main capacity building aspects of the project relating to various levels of operation are summarised in Table 28 below.

Table 28 - National Capacity Developed Through the Project

LEVEL TARGETED	SKILLS/QUALIFICATIONS DEVELOPED	NUMBERS INVOLVED E. Kenya	W. Kenya
National researcher staff	Field pest assessment	3	3
	Workshop preparation	2	2
	Presentation skills	3	4
	Focused PRA methods	8	1
	Formal survey methods	1	3
	On-farm design & layouts	1	2
	Participatory evaluation methods	4	3
	On-station design and layout	1	1
	Statistical analysis	1	1
	Report writing skills	1	1
	Higher degree qualification	1	1
National extension staff	Field pest assessment	2	4
	Focused PRA methods	6	4
	Formal survey interview methods	10	3
	On-farm design & layouts	1	4
	Participatory evaluation methods	2	4
	Report writing skills		2
Local panels of farmers	Field pest assessment	1	6
	On-farm design & layouts	1	6
	Participatory evaluation methods	1	6

4.4.2 Lessons from methods and approach

Pest monitoring using on-farm trial plots: Farmers assessment of the relative importance of the main insect pests recorded during focused PRAs and formal surveys largely corresponded with the findings from pest monitoring in the on-farm trials. However, damage by smaller pests (shootfly) was underestimated by farmers, both during the on-farm monitoring and during the focused PRAs. Using farmer managed trial plots for pest monitoring provided a fairly cost-efficient mechanism for validating relative importance of the main pests, as an alternative to pest surveys. On-farm observation plots, using chemical control on a mix of sorghum varieties, also provided a cost-effective means for gathering useful information on the economic importance of the main insect pests.

Time needed for farmer evaluation of new varieties: The evaluation of varieties over several seasons suggests that it takes at least three seasons (more in some cases), for farmers to decide which of the new varieties they would like to continue growing. Farmers' preferences for varieties differ from one farmer to another, according to their own preferences and the conditions on their farm (e.g. soil type and fertility). Pest resistance/tolerance is only one of a number of criteria used by farmers when selecting varieties. Therefore varieties need to be tested on-farm over a period of time, and across a range of farmers, soil types and agro-ecologies before conclusions relating to scaling up (what to scale up and how to) of the results can be derived.

Mother and baby trial design The mother baby design was useful for the on-farm variety evaluation when there were more than 15 varieties to test on-farm, providing a workable mechanism for formal evaluation, pest monitoring, and preliminary seed bulking. Selection of a suitable site/farmer for the mother plot is particularly important.

Training and empowerment at field level The hands-on training of field extension staff and farmers during the research process was very effective in terms of building their research capabilities and providing a high quality of data from the on-farm trials. Without this the on-farm research results achieved would not have been possible. In Eastern Kenya the extension staff took initiative, laying out their own trials with farmers and carefully recording the results as part of learning exercises with the established farmer field schools and farmer panels. High quality photographs and descriptions of the key pests proved an invaluable resource for empowering field extension staff and also working with farmers to identify key pests.

Parallel on-station and on-farm research Conducting the on-station and on-farm trials in parallel was a cost and time effective means for reaching conclusions about the main technologies being developed/validated. While on-station researchers had initial reservations about undertaking on-farm pest management trials before on-station results showed promise, the observation trials undertaken served, on the whole, to reinforce the results from the on-station trials.

Farmer field schools which were facilitated by extension staff in the research areas proved very useful for the variety assessments, and for validating knowledge-intensive pest management (e.g. the effect of stover management in the dry season on stem borer carry over)

Pest damage assessment: While the project activities were guided by established methods for assessing pest damage, it was found in practice that not all of the conventional damage indicators are good predictors of actual damage. For example stem borer foliar damage scores taken early in the season seemed to bear little relationship with damage assessed at the end of the season. For large pests, like stem borers, farmers have a way of visually assessing tolerance and resistance which depends on observations made through the season. This form of qualitative assessment can usefully complement form quantitative assessment.

Local uptake pathways identified

The factors that influence potential dissemination and uptake of technologies include the institutional setting, the type of technologies available for uptake, the uptake pathways and communication channels available and farmers' circumstances.

The institutional setting

Findings from this study suggest that the main institutions with potential to be involved in dissemination of findings from this project are the public sector (KARI and government extension), Non-Governmental Organisations (NGOs), the private sector (individual traders and stockists, seed suppliers and oxen rental suppliers), Community Based Organisations (CBOs). Policy makers in these institutions and others also have a contribution to make. Each of these institutions has strengths and weaknesses when it comes to the promotion and uptake of research results. Currently some of these institutions have working arrangements, but this do not always operate optimally. For example there are formal mechanisms for linking research and extension in the mandate areas of the main KARI research centres and also for the coordination of the agricultural programmes of NGOs at district level. Informal links have been established between some private sector players and government agencies, but most of these are not formalised or very well developed. More recently there have been initiatives to bring CBOs more into the process of disseminating research results, to inform and involve the private sector using the results from publicly funded research, and to experiment with new mechanisms for dissemination. The implications of these various initiatives are expanded in the discussion of uptake pathways below.

Technologies available for uptake

The research results summarised about in section 4 were presented in more detail at the end of project stakeholder workshops. Group discussions relating to the relevance and usefulness of the results from this project were held and are presented in detail in the end of project workshop reports.

Western Kenya

In Western Kenya the discussions concluded that the results and technologies were applicable to all the eight Districts of Western Kenya represented at the workshop, and that they were ready for dissemination. The advantages and disadvantages of the technologies were also discussed, and are summarised in Table 29. Overall it emerged that the biggest hindrance to uptake will be the availability of seed, followed by cultural practices and attitudes.

Table 29: Advantages and disadvantages of sorghum pest management interventions for Western Kenya perceived by stakeholders in Western Kenya

Technology	Advantages	Disadvantages
Varietal resistance	• Increased yields • Increased food security • Many varieties to choose from	• Lack of seed • Varying farmer preferences • Bird damage to early maturing varieties
Sowing dates & early maturing varieties	• Increased yields • Reduction of pest damage • More planting date alternatives	• Cultural practices and attitudes • Varying farmer preferences • Lack of seed
Crop residue management	• Increased yields • Alternative source of livestock feed • Improved soil fertility • Reduction of pest populations	• May be labour intensive

Uptake pathways for the technologies

Promotional pathways to target institutions and beneficiaries

Representative smallholder farmers at the project research sites were involved in identifying improved pest management options, but information on these improvements may only reach large numbers of farmers via agencies providing information and advisory services, as listed below. Local development and extension agencies were involved in planning the research activities, extension assisted with implementation, and NGOs attended field days. A wider range of extension representatives and NGOs along with KARI scientists were invited to workshops at which the final results were disseminated and discussed.

The public sector: Studies on uptake pathways in Kenya have shown that the public sector extension is rated highly by the majority of farmers as it is considered accessible and addresses multiple problems and is seen as providing reliable information. "The "focal area" approach under the National Agriculture and Livestock Extension Programme provides a mechanism for bringing together key stakeholders and focusing resources on a particular location within a division. Focal areas shift every year bringing in new CBOs. Provided that the local extension staff focus on their role in facilitating and passing information to other local service providers, and are not driven to deliver information directly to all farmers, there is potential to reach more farmers using indirect methods. This would need adequate training and a high quality of technical information.

The private sector: Agribusinesses and their networks offer some potential, by involving local input suppliers in the supply of sorghum seed. This can be done provided the current regulations on seed quality are met and a viable sorghum seed production scheme is in operation to supply seed to stockists.

Non-governmental organisations: There are a number of NGOs in Western Kenya and also some in Eastern Kenya with experience in knowledge dissemination, training, provision of goods and services, and capacity building at the local level. Although they are faced with a number of limitations which include a low capacity to cover large areas and numbers of people, the interest shown by the NGOs in Western Kenya and also in Eastern Kenya is encouraging and many of the NGOs have the resources with which to deliver extension services. All of the NGOs work closely with the government extension services, and recognise that it is the government extension which is the main repository of technical capacity upon which to draw. The policy of many NGOs is to facilitate farmer groups and CBOs to draw on government extension capacity, instead of employing their own technical specialists.

Community based organisations: In many rural areas self-help and women's groups that are well developed have been federated into CBOs, particularly in Eastern Kenya. These CBOs provide attractive potential entry points for knowledge dissemination and generation. Farmer groups are widely perceived as one mechanism for improving their access to agricultural services. By working together, farmers can realise the scale economies of bulk acquisition and enter into more stable relationships with suppliers. For example pooling resources to invest in seed bulking or to apply for credit from micro-financers gives them a greater chance of success.

Communication channels

The communication channels identified at the stakeholders at the stakeholders' workshops can be summarised into the following categories: mass media, printed matter, FFS, demonstrations/farmer open days, workshops and seed fairs.

Mass Media: Radio programmes on the technologies available from this study would be an attractive communication channel given its broad coverage in Kenya. As noted by Garforth (1998), radio is the most effective mass medium for reaching rural audiences in a form and language they can understand. This medium could be used to raise awareness and signpost where to get information on the technologies that were identified in this study. The radio is not ideal for transferring detailed technical advice as farmers learn by seeing and doing.

Printed matter: The findings generated from this project can be developed into booklets, pamphlets, and/or briefing papers which would be most suitable for intermediate users (extension, other researchers, policy makers, NGOs). Posters may be more suitable for farmers.

Farmer Field Schools: Formal literacy levels in Kenya and the presence of established FFS's make them an appropriate dissemination channel for the dissemination of information on early maturing varieties of sorghum and appropriate stover and panicle management. The IPM capacity of farmers can be developed through FFS and the horizontal diffusion of knowledge can be supported to disseminate findings from this study.

Demonstrations and farmer open days: Working with farmer groups, technologies such as early planting and use of early maturing varieties could be effectively demonstrated during the cropping season and stover and panicle management at the end, making the learning process gradual and progressive.

Seed fairs: Seed fairs provide an opportunity for creating awareness among farmers, researchers, extensionists and other development specialists of new modern varieties and also additional alternative seeds and planting materials from farmers' own sources and additional outside sources. They also enable local researchers, extension and farmer seed experts who do not normally meet, to do so and create working contacts between them which will continue to exist and develop independent of outside facilitators. Seed fairs have already been tried in Eastern Kenya by ITDG, CRS and others, and work well. Introduction of the seed fair concept to Western Kenya would contribute to increased understanding of the local seed network by local and public services and NGOs involved in smallholder seed production and bring the improved short maturing varieties to the attention of many farmers.

Farmer circumstances: The integrated pest management strategies investigated in this project were those thought suited to smallholders as modifications of existing crop management practices. Wealth ranking findings showed that most of the farmers in Western and Eastern Kenya are in the poorer and medium wealth categories while a very small percentage fall into the richer category. Nonetheless, the findings from this study indicate that with the combined presence of a strong social capital base, appropriate technologies, uptake pathways and suitable communication channels there is scope for dissemination of the sorghum pest management technologies for improved livelihoods of poorer smallholders in Western Kenya and other similar areas.

4.50 Output 5: Crop protection dissemination and research opportunities and rural livelihoods in Semi-arid Eastern Kenya

The findings under this output, which relate to crops and technologies beyond those explored under the previous outputs, are based on literature review, expert consultation and field visits to interview local experts in various districts, and are presented in a report already presented to CPP (Kavoi and Sutherland, 2003). The main findings are summarised below:-

1. Semi-arid and arid areas cover about 80% of Kenya (583,000 Km^2) and 50% of the country's arable land. Semi-Arid Eastern Kenya (SAEK) is a challenging environment for its more than 3 million inhabitants. Households depend largely on agriculture to meet their basic needs, and for the majority of households crop production is the most important livelihood strategy. There are more livelihood opportunities in the more densely settled higher potential areas of SAEK closer to markets than in the less densely settled drier and remoter parts which account for most of the area.

2. A gradual decline in the per capita level of food crop production in most areas can be attributed to changing weather patterns (declining annual rainfall amounts), declining soil fertility and increasing pest and disease risks. Areas planted to maize and beans (food crops) have expanded at the expense of more drought tolerant staple crops, although food legumes (grams, pigeon peas, cowpeas, chickpeas, dolichos) and also small grains (millet and sorghum) are important cash earners for poorer households. Horticultural crops are on the increase in all areas, and particularly the areas with better market access and water availability.

3. Both field and horticultural crops are important for cash income, particularly grain legumes (green grams, cowpeas and pigeon peas) fruits (grafted mangos, pawpaw and citrus) and vegetables (kales and tomatoes). For these crops, insect pests and diseases are a major and an increasing constraint. Aphids, pod suckers, pod borers, kiwi beetle, thrips and in certain seasons bollworm are all serious insect pests. Farmers go to considerable lengths (within their means) to try and manage these pests using local concoctions, cultural practices and pesticides. Diseases such as scab and mildew affect Green grams. Mangos suffer flower abortion and mango weevil. Diamond Back Moth (DBM) and aphids affect kales. Both early and late blights and other pests affect tomatoes.

4. For the main food crops (maize, beans, sorghum, millet) weeds pose the biggest potential constraint (especially for women), but most farmers are able to effectively control weeds in most seasons. Insect pests pose a significant constraint, especially stem borer, chafer grubs, sorghum shoot fly, and bean fly. Charcoal rot and anthracnose diseases are serious in beans, birds are a major disincentive to uptake of pearl millet and to some extent sorghum, and cover kernel smut is the major disease affecting sorghum. Farmers have low external input strategies to manage these pests, the most common ones being to expand the cultivated area, use high seed rates, practice inter-cropping in order to hedge risks and in a some cases fallowing and crop rotation.

5. Storage of dual-purpose food and cash crops (cowpeas, grams, pigeon peas, sorghum, pearl millet, maize, and beans) is constrained by storage pests, especially bean bruchids, common maize weevil, Larger Grain Borer (LGB) and common warehouse moth. While farmers try and manage these storage pests, they have been greatly frustrated in recent times by the sale of "fake" storage chemicals. Low and unpredictable prices have also been disincentives to on-farm storage for many farmers.

6. Some, but not all of the serious crop pests have been addressed through research funded through CPP, the Kenyan Government, DFID and other sources. Major weeds have been identified, their potential effect on yield assessed and use of various weeding tools and herbicides has been explored. Most of the major field and storage insect pests have been identified, but in some cases assessment of their effect on yield and grain loss and their distribution (spatial and temporal) has not been fully assessed and documented. Control measures for stem borer on maize have been researched, but the results not well disseminated; research into BT resistance in maize to stem borer is ongoing. Some screening and characterisation of existing maize and sorghum varieties for tolerance to insects is ongoing; maize to stem borer (CIMMYT backed) and of sorghum to stem borer, shoot fly and midge (CPP funded). Control measures for chafer grub have been identified. Some preliminary research been conducted on aphids, bean fly and bollworm control but the management of other field insect pests, particularly those affecting food legumes, has not been well researched. Effective control measures for charcoal rot in beans and cover kernel smut in sorghum (by CPP) have been developed and promoted on a small scale. Controls for the main storage pests using chemicals, local materials and physical methods have been developed and tested.

7. While relevant crop protection research has been undertaken, and some key messages are available, rather little has been done to promote publicly funded research for the benefit of farmers in SAEK. Products (tolerant varieties) and knowledge (management methods) developed have not been widely disseminated beyond the immediate area where the research has been conducted. Chemical companies have been relatively more effective in promoting their own products and messages for control of field pests. However, consultations with extension agencies identified a demand for up to date and independent advice and information on crop protection, and indicate low use of chemical controls among the majority of the resource-poor farmers.

8. The interest of farmers and development agencies in crop protection is largely related to the extent to which improvements in crop protection translate into visible improvements in income and food security. At present farmers are discouraged mostly by very low and unpredictable farm gate prices. Future promotion or CP research outputs must be closely linked to initiatives which enhance market opportunities. Crop production by some farmers is also discouraged by food relief programmes which keep local food prices low and lower incentives to produce food. Relief programmes which transfer more responsibility for food security back to local farmers will provide a more favourable environment for promoting improvements in crop protection of the food crops in SAEK.

9. Effective promotion of the existing research outputs rests on understanding the challenging environment for both crop production and uptake. There are promising opportunities for scaling out technologies and methods that have been

developed under on-farm conditions in specific areas, including appropriate validation prior to widespread dissemination. There are also good opportunities for linking promotional activities to other development initiatives in marketing, relief provision and knowledge transfer (e.g. farmer field schools). Because the environment for uptake is challenging a clear strategy is needed for promoting research outputs in order to capture the benefits from relevant research funded by CPP and others. Such a strategy would involve clear targeting of key agencies (public and private) in order to raise awareness, nurture commitment, foster participation and build technical capacity where needed. It is recommended that promotional activities place more emphasis on developing a promotional strategy that is sustainable for the Semi-arid systems, than on short-term mass dissemination of proven technologies.

10. Future research must be informed by an understanding what currently drives decision making in crop production for the majority of households in SAEK who are poor. Food security is a strong driver, but farmers are very limited in the cash (and to some extent labour) available to invest in food crops. Research to support food security should therefore focus on breeding/selection of varieties of the main food crops for tolerance to the main environmental challenges (weeds, insect pests, low soil fertility, diseases). Research may also look at low input pest management practices such as seed management, appropriate forms of inter-cropping, field sanitation, crop rotation and use of locally available botanicals for food crops. . To retain a variety of adapted crops in order to hedge risks, crop utilisation issues also need to be addressed in parallel with CP research. For higher value crops (vegetables, fruits, green grams, pigeon peas), IPM including more effective use of chemicals and local botanicals (for production and storage) is a research area which can be developed in partnership with agencies supporting marketing activities in SAEK.

5.0 CONTRIBUTION OF OUTPUTS TO DEVELOPMENTAL IMPACT

As the identified uptake pathways to target institutions and beneficiaries are discussed under output 4.5 above this section focuses on how the outputs will contribute towards DFID's developmental goals, final beneficiaries, project publications, plans for further promotion and dissemination and further research issues identified.

5.1 Contribution to Millenium Goals

Specifically, the project sought to enhance food security for small holders through identifying options for reducing their sorghum crop losses caused by key insect pests at different stages of crop development:-

1. Crop losses at establishment caused by sorghum shoot fly (*Antherigona soccata*).

2. Panicle damage caused by sorghum midge (*Stenodiplosis sorghicola*).

3. Losses due to feeding activities associated with infestation of stalks by members of the stem borer complex (primarily *Chilo partellus* and *Busseola* spp.).

The project's working assumption was that improved pest management results in reduced crop losses and higher yields which in turn translates reduced vulnerability and improved household food security for producers. In good seasons there is a surplus for sale, providing for the needs of those in urban and other rural areas who process and/or eat sorghum, or sorghum products, but do not produce it. Sorghum is an important food crop within Africa's low input cereal-based farming systems, where 41 % of the worldwide area is grown. Prior to this project, very little was documented regarding the susceptibility of the modern sorghum varieties available in ICRISAT programmes, and also of local varieties, to the main insect pests in East Africa. Moreover, there was very limited information on proven sorghum pest control options suited for resource poor smallholders in East Africa. The projects' two main pest management strategies, tolerant varieties and affordable crop management methods both showed promise for the two distinctive sorghum production systems used to test these. This was an encouraging result, given the current and future potential contribution of sorghum to household food security in areas of unreliable rainfall within Africa. There is an additional spin-off for the work on stover management, because yields of maize which is also affected by stem borer can be improved by using the recommended crop hygene practices to reduce carry over of stem borer.

Final beneficiaries

The ultimate intended beneficiaries are smallholder farmers, particularly women who are the principal farmers, in Mwingi District Eastern Province of Kenya and Lake Zone of Western Kenya. Immediate direct benefits from adopting the strategies are a significant reduction in the currently experienced losses of sorghum due to major insect pests. This contributes to stabilising food production so releasing income for other uses such as the payment of school fees and the purchase of medicines. The project outputs also address food security and hence social stability in poor communities which rely on sorghum-based cropping systems (otherwise household members are forced to out-migrate in search for food). An indirect benefit to participating farmers is the experience of working with research and extension staff to seek solutions to problems. Such interactions may lead to further initiatives by farmers and local extension staff as they gain the confidence to experiment and to drive forward their own agendas. Both the pest management strategies and the participatory research methods used are relevant to sorghum and other semi-arid cereals throughout eastern Africa.

5.2 Reporting and dissemination of findings

A list of reports and documents produced by the project is attached as Appendix 1 to this report. The findings documented in this report were documented in more detail and disseminated as handouts on specific topics at two end of project workshops to ensure that the results where known about by extension providers operating in all of the drier districts of both Eastern and Western Kenya.

Follow up promotional activity (publications and dissemination plans)

Based on past experience, it is know that the dissemination of technical results via workshops and publications is not adequate to ensure uptake by the recipient agencies. The project proposal envisaged a promotional phase, “in which the methods and technologies developed and promoted in the first phase will be further refined in response to farmer feedback. These developed and tested technologies will then be promoted to a broader target group.”

Farmers with similar socio-economic and environmental circumstances within Kenya may be targeted via extension providers through specific promotional activities. At the workshops held to discuss the research results, recommendations about which of the results to disseminate and how to promote these were discussed. These options are presented in Table 30 below

Table 30: Proposed Promotion in Kenya for Project outputs

Pest management output	Western Kenya	Eastern Kenya
Pest tolerant/escaping varieties acceptable to farmers in research sites	Promote new early varieties Wagita, IS 8193, Seredo, Gopari and IS 8884. with breeders increase seed for wider testing.	Promote released varieties (Gadam, KM1) Other popular varieties (KSV12, ZSV3, Sudan 142), with breeders increase seed for wider testing including post-harvest qualities.
Improved stover management	Need further discussion – but can emphasise value of field hygene	Involve farmer groups/FFS demonstrations and field days, including data collection on effects. Include FFS results from Mwingi in promotional material.
Improved panicle management	Develop and test promotional material on panicle management for mide	
Intercropping with millet		Find appropriate entry point locally and use demonstrations.
Ratooning	Needs further discussion as there are different views among extension.	Decision tree to guide extension Target areas with appropriate rainfall and soils. Use Demonstrations
Early planting	Promote early planting of mid-season varieties and later planting of early varieties	

While not discussed at the final workshops, it is intended that the wider research and crop protection community will be targeted through submission of articles by the technical researchers on the project for publication via appropriate journals, newsletters and web-sites. The expectation is that the readers may pass this information on to extension programmes within their countries (perhaps including adaptive trials to verify the results, or activities initiated through farmer field school or similar learning based group extension activities).

The inclusion of appropriate training within the project enabled one local scientist to be trained in entomology and participatory techniques, and another to be trained in crop protection related socio-economic research concepts and methods, which will be transferable to future projects.

5.3 Further research

Based on discussions at the end of project workshop in Eastern Kenya, some possible areas for further research were noted, while the lead research in Western Kenya also noted related research issues.

Eastern Issues Noted

Varieties

- Need to agree with breeders on unreleased varieties to increase the amounts of the seed of e.g. KSV12, ZSV3, Sudan 142.
- Need for taste preference (palatability) data on varieties for testing in other areas.
- Breeders to make screening for insect pest resistance routine for more advanced material.

Intercropping

- Calculate economics of the technology.
- Explore if same results achieved when intercropped traditionally (sorghum and millet in same hill) or intercropped with alternating plant spacing.

Stover management

- Presently the technology has been tested only on sorghum. In many areas maize plants form the majority of the stover. Validating the technology on maize or mixed stover would be useful.

- The time taken to kill the majority of larvae varied between the on-station and on-farm trials. This was probably related to the different temperatures experienced in the two areas. Further trials would enable a refinement of the number of days required to make a significant kill under specific agro-ecological zones.

Ratooning

- Identification of existing short duration varieties that will respond to ratooning.
- Encourage breeders to consider ratooning in the breeding programme.

Western Kenya

Sorghum Midge

- Verification of the mechanism of midge damage levels and carry over through pest surveys on incidence and severity over several seasons and years in Western Kenya.
- Assess the feasibility of alternative methods of panicle management based on farmer practices and establish the effect of these on production of viable midges.

6.0 REFERENCES

Adesiyun, AA and Ajayi, O (1980). Control of the sorghum stemborer, *Busseola fusca*, by partial burning of stalks. *Tropical Pest Management* 26(2), 113-117

Ajai, O (1978). Control of sorghum, millet and wheat field insect pests. *Samaru Conference* Paper 24, Ahmadu Bello University, Zaria, Nigeria.

Amoaka-Atta B, Omolo EO and Kidega EK (1983). Influence of maize, cowpea and sorghum intercropping systems on stem-/podborer infestations. *Insect Science and its Application*. 4, 47-57.

Breniere J (1972). Sorghum shoot fly in West Africa. *In Control of sorghum shoot fly, eds. Jotwani MG and Young WR. New Delhi, India:* Oxford and IBH Publishing Co. pp129-136.

Campion DG and Nesbitt BF (1983). The utilization of sex pheromones for the control of stemborers. *Insect Science and its Application* 4, 192-197.

Davis, JC and Seshu Reddy, KV (1980). Insect pests of sorghum and pearl millet and assessment of insect numbers and losses. *In Assessment of crop losses due to pests and diseases: proceedings of a workshop, 19-30 Sept 1997, Bangalore, India* UAS Technical series no. 33 Bangalore, Karnataka, India: University of Agricultural Sciences, pp 232-239.

Delobel AG and Unnithan GC (1981). The status of *Sorghum arundinaceum* as a host of *Antherigona soccata* Rondani (Diptera: Muscidae) in Kenya. *Insect Science and its Application* 2, 67-71.

Duerden, JC (1953). Stemborers of cereal crops at Kongwa, Tanganyika, 1950-1952. *East African Agricultural Journal*, 19, 105-119.

Enserink, H.J. (1995) *Sorghum agronomy in West Kenya: Investigations from a farming systems perspective.* Amsterdam: Royal Tropical Institute.

FAO, (1980). *Elements of Intergral Control of Sorghum Pests*. FAO, Rome Italy.

Garforth, C. (1998) *Dissemination pathways for RNR research. Socio-economic Methodologies. Best Practice guidelines.* Chatham UK: Natural Resources Institute

Harris, KM (1962). Lepidopterous stemborers of cereals in Nigeria. *Bulletin of Entomological Research* 53, 139-171.

Harris, KM (1985). Lepidopterous stemborers of sorghum. In *Proceedings of the International Sorghum Entomology Workshop*, 15-21 July 1984, Texas A&M University. ICRISAT Patancheru, India.

Harris, KM (1995). World review of recent research on panicle insect pests of sorghum and pearl millet. In *Proceedings of an International Consultative Workshop 4-7 Oct 1993*. ICRISAT Sahelian Center Niamey, Niger. ICRISAT pp 7-25

Ho DT and Seshu Reddy KV (1983). Monitoring of lepidopterous stemborer populations by pheromone and light traps. *Insect Science and its Application* 4, 19-23.

Ingram, WR (1958). The lepidopterous stalk borers associated with Gramineae in Uganda. *Bulletin of Entomological Research* 49, 367-383.

Jotwani, MG (1981). Integrated approach to the control of sorghum shoot fly. *Insect Science and its Application* 2, 123-127.

Kavoi, J.M. (2003) *Crop protection contribution towards improved livelihoods in Semi-Arid Eastern Kenya: Challenges and Opportunities.* MSc Thesis. Chatham, UK: University of Greenwich.

Khan, ZR, Ampong-Nyarko, K, Chiliswa, P, Hassanali, A, Kimani S, Lwande W, Overholt WA, Pickett JA, Smart LE, Wadhams LJ and Woodcock CM (1997). Intercropping increases parasitism of pests. *Nature 388, 631-632*

Kulkarni, K.A. (1985) Screening sorghums for midge resistance. Pp 265-274. In: *Proceedings of the international sorghum entomology workshop*, 15-21 July 1984, Texas A&M University, College Station, Tx, USA. ICRISAT Patancheru, A.P., India

Leuschner K (1985). Sorghum Entomology Research: Programs and need in the developing world. In *Proceedings of the International Sorghum Entomology Workshop 15-21 July 1984*.

Meksongsee B, Chawanapong M, Sangkasuwan U and Poonyathaworn P (1981). The biology and control of sorghum shootfly, *Antherigona soccata* Rondani, in Thailand. *Insect Science and its Application* 2, 11-116.

Minja, EM (1990). Management of *Chilo* spp. infesting cereals in Eastern Africa. *Insect Science and its Application* 11, 489-499.

Mohyuddin AI and Greathead DJ (1970). An annotated list of parasites of graminaceous stem-borers in East Africa, with a discussion of their potential in biological control. *Entomophaga* 15, 241-274.

Mowafi K (1967). Preliminary studies on the dura shoot fly *Antherigona indica infuscata* (Emden) (Anthomyiidae: Diptera). B.Sc. Dissertation, University of Khartoum, Sudan.

Nwasike, C.C. (1995) Breeding for resistance to sorghum midge in West Africa. Pp 211-212. In: *Panicle Pests of Sorghum and Pearl Millet: Proceedings of an International consultative Workshop,* 4-7 Oct 1993. ICRISAT Sahelin Center, Niamey, Niger. Nwanze, K.F. and Youm, O. (eds). Patancheru, A.P., India: International Crops Research Institute for the Semi-arid Tropics.

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.

Olufadi, AO (1978) Control of sorghum and millet field insect pests. In *Proceedings of the NAFPP workshop on sorghum, millet and wheat* pp 86-89.

Pickett, J (1999). Pest control that helps control weeds at the same time. *BBSRC Business April 1999* pp 16-17.

Ratnadass, A. And Ajayi, A. (1995) Panicle Pests of sorghum in West Africa. Pp 29-38. In: *Panicle Pests of Sorghum and Pearl Millet: Proceedings of an International consultative Workshop,* 4-7 Oct 1993. ICRISAT Sahelin Center, Niamey, Niger. Nwanze, K.F. and Youm, O. (eds). Patancheru, A.P., India: International Crops Research Institute for the Semi-arid Tropics.

Seshu Reddy, KV (1981). Pest management in sorghum-II. In *International Symposium, Sorghum in the Eighties*. ICRISAT, India, 2-7 November 1981, p30.

Seshu Reddy, KV (1983). Studies on the stem-borer complex of sorghum in Kenya. *Insect Science and its Application* 6, 3-10.

Seshu Reddy KV and Davis, JC (1979). Pests of sorghum and pearl millet and their parasites and predators recorded at ICRISAT Centre, India up to August 1979. *Cereal Entomology Department Progress Report 2*, ICRISAT, Patancheru, AP India, 23pp.

Seshu Reddy, KV and Omolo, EO (1985). Sorghum insect pest situation in Eastern Africa. In *Proceedings of the International Sorghum Entomology Workshop*, 15-21 July 1984, Texas A&M University. ICRISAT Patancheru, India, pp 31-36.

Sharma, H.C. (1985) Screening for sorghum midge resistance and resistance mechanisms. Pp 275-292. In: *Proceedings of the international sorghum entomology workshop*, 15-21 July 1984, Texas A&M University, College Station, Tx, USA. Patancheru, A.P., India: International Crops Research Institute for the Semi-arid Tropics**.**

Sharma, H.C., Taneja, S.L., Leuschner, K. And Nwanze, K.F. (1992) *Techniques to screening sorghums for resistance to insect pests.* Information Bulletin no 32. Patancheru, A.P., India: International Crops Research Institute for the Semi-arid Tropics.

Teetes, GL (1995). Integrated pest management of sorghum midge in USA. In *Proceedings of an International Consultative Workshop 4-7 Oct 1993*. ICRISAT Sahelian Center Niamey Niger. ICRISAT pp 253-262.

Teetes, G.L., Seshu Reddy, K.V., Leuschner, K. And House, L.R. (1983) *Sorghum insect identification Handbook.* Information Bulletin No. 12. Patancheru, A.P., India: International Crops Research Institute for the Semi-arid Tropics.

Vedamoorthy G, Thobbi VV, Matai BH and Young WR (1965). Preliminary studies with seed and seed furrowing applications of insecticides for the control of sorghum stem maggot, *Anthergona indica* Malloch (Anthomyiidae). Indian Journal of Agricultural sciences 35: 14-28.

Wheatley, PE (1961). The insect pests of agriculture in the Coast Province of Kenya. Maize and Sorghum. *East African Agricultural and Forestry Journal* 27, 105-107.

Young, WR and Teetes, GL (1997). Sorghum entomology. *Annual Review of Entomology* 22, 193-218.

Wilson, K.S. L. And Ritchie, J.M. (2001) *Sorghum Stakeholders' Workshop Report, KARI RRC-Kisii Kenya.* 5th February 2001. Unpublished

7.0 Appendix 1: List of project reports and documents

Technical Reports

J. Kavoi, (2002) UK Based Literature review of crop protection issues in semi-arid Eastern Kenya, in the context of sustainable livelihoods

Kavoi, J. (2003) Farmer Knowledge On Sorghum Pest Control in Eastern Kenya (Workshop handout)

J.Kavoi and A Sutherland, (2002) Review of crop protection issues in Semi-Arid Eastern Kenya in the context of sustainable livelihoods: A working paper Kenya Agricultural Research Institute/ Natural Resources Institute

EM Minja and AB Obilana (2001) Management of key insect pests of sorghum in southern and eastern Africa: Developing IPM approaches with expert panels. ICRISAT-Nairobi

EM Minja and AB Obilana (2002) On-station screening of sorghum lines for resistance/tolerance to biotic and abiotic stresses at Alupe and Kiboko in Kenya ICRISAT-Nairobi,

Nyang'wara, M. (2001) Sorghum pests project - Farmer field day report, W. Kenya

M Nyang'wara (ed) (2003) Demand For Crop Protection Advice In The Drier Areas Districts In Western Kenya – As Identified By Workshop Participants

Page, B. and Sutherland A. (eds) (2000) Report on Surveys conducted in Western Kenya during March 2000 as part of inception for the Sorghum Pest Project

Ritchie, M., and Songa, J., (2002): Effect of intercropping sorghum and millet on stem borer damage to sorghum, in: Sutherland, J. and Songa, J., (2002): Sorghum project mid-term review report, Natural Resources Institute, Chatham, UK. Pages 10-12.

Ritchie, M., and Songa, J., (2002): Sorghum stem borer variety resistance screening, Kiboko, Eastern Kenya, in: Sutherland, J. and Songa, J., (2002): Sorghum project mid-term review report, Natural Resources Institute, Chatham, UK. Pages 21-23

Songa, J. (2002): Effect of stover management practices on stem borer carry-over in sorghum, in: Sutherland, J. and Songa, J., (2002): Sorghum project mid-term review report, Natural Resources Institute, Chatham, UK. Pages 8-9

Dr Josephine Songa and Dr Mark Ritchie (2003) Use Of Crop Management Practices Against Stem Borers In Sorghum, *Kenya Agricultural Research Institute, NDFRC, Katumani*

Songa, Dr J. and *Dr Mark Ritchie (2003)* Use Of Intercropping Practices Against Stem Borers In Sorghum, Kenya Agricultural Research Institute, NDFRC, Katumani

Sutherland, A. (2002): Evaluation by farmer panels of mother and baby sorghum variety trials in Mwingi district, Eastern Kenya, in: Sutherland, J. and Songa, J., (2002): Sorghum project mid-term review report, Natural Resources Institute, Chatham, UK. Pages 23-25.

Sutherland, A (2001) Notes on Field Visit to Mwingi District, March 2001 to observe Stover Management, Intercropping Practices, Stem Borer damage and Variety Assessment

Sutherland, A (2001) Sorghum Pest Project: Mwingi Field Visit Report 18-21st November 2001

Sutherland, A (2003) EXTRACTS FROM "Review of crop protection issues in Semi-Arid Eastern Kenya in the context of sustainable livelihoods: A working paper (End of project workshop handout)

Sutherland, A (2003) Sorghum Pest Project Overview of Approach & Methods - Eastern Kenya (Workshop handout)

Sutherland, A. (2003) Opportunities for the promotion and uptake of Crop Protection Research Outputs in Dry areas of Eastern and Western Kenya.

Sutherland, A. Justus Kavoi**,** C. Mugo, Mr L. Muthengi, Mr L. Rindiri (2003) Report Of On-Farm Pest Monitoring On Sorghum –Mwingi District

Workshop Reports

A. Sutherland and J. Songa (eds) (2001) Sorghum Pest Project Stakeholder Workshop Sorghum And Its Pests In Mwingi District Potential Issues For Research Msafiri Hotel, Mwingi 14-15th February 2001

Wilson, K.S. L. and Ritchie, J.M. (eds) (2001) *Sorghum Stakeholders' Workshop Report, KARI RRC-Kisii Kenya.* 5th February 2001.

Sutherland, A. and J. Songa (eds) Report on Mid-term internal review of DFID/NRI/ICRISAT/KARI sorghum pest project in Kenya, 31st January 2002

Sutherland, A and Wilson, K (eds) (2003*) Sorghum Pest Project Dissemination And Crop Protection Review And Validation Workshop –13-14 March 2003 –Garden Hotel, Machakos WORKSHOP REPORT*

Nyang'wara M. and Sutherland, A (eds) (2003) Sorghum Pest Project Dissemination And Crop Protection Review And Validation Workshop – March 17-18 2003, Kisii WORKSHOP REPORT

Trial Protocols

M. Ritchie and J Songa, Experiment 1: Varietal tolerance of improved sorghum lines to Stem borers (*Chilo partellus*)

J. Kavoi, J. M. Songa, A. J. Sutherland, K. Wilson (2001) On-farm Trial 1 : Evaluation of improved short duration sorghum lines, including tolerance to common sorghum pests, with a focus on Stem borers (*Chilo partellus*)

K Wilson and A Sutherland (2001) Mwingi District On-Farm Trials – Sept 2001 to Sept 2002.

*On-farm evaluation of Sorghum Pest Management Options (Tolerant Varieties, Intercropping and Stover management***)**

M. Ritchie and J. Songa (2001) Trial Protocol - Effect of stover management on stem borer carry-over in sorghum

Dr J.M. Songa and Dr J.M. Ritchie (2001) Sorghum Pest Project Proposed on-station experiments: Long rains (March – July) 2001

Theses

J. Kavoi (2003) KAVOI, J.M. (2003) *Crop protection contribution towards improved livelihoods in Semi-Arid Eastern Kenya: Challenges and Opportunities.* MSc Thesis. Chatham, UK: University of Greenwich.

Nyang'wara, M. K. (2003) Improving Livelihoods through Farmer Participatory Evaluation of Integrated Pest Management (IPM) Strategies of Sorghum in Western Kenya. Ph D Thesis. Chatham UK: University of Greenwich

Visit reports

A.J. Sutherland and K. Wilson, Visit No: 7823 Sorghum Pest Management Project: Visit to initiate project activities in Eastern Kenya, November 9-23rd 2000

J.M.Ritchie and K.S.L.Wilson. (2001) Visit number 8059 Sorghum Pest Management Project: Visit to western Kenya. 02/02/2001 to 10/02/2001.

A.J. Sutherland, Mark Ritchie, Kate Wilson, (2001) Visit No: 8095 Sorghum Pest Management Project: Visit to Eastern Kenya, February 11th -23rd 2001, Natural Resources Institute

A Sutherland (2002) Visit Report to sorghum pest project: Eastern and Western Kenya during April 2002.

17-22ND April 2002 Eastern Kenya- Report on Progress on Project Activities