Post-harvest research: An overview of approaches to pest management in African grain stores that minimise the use of synthetic insecticides

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Abstract

Food insecurity is chronic and recurrent amongst many households in sub-Saharan Africa. Despite the apparent effectiveness of pesticide application, synthetic pesticides pose serious and increasing risks. Recommended insecticides for use on grain such as organo-phosphates are associated with health and environmental problems. They are not cheap and insecticide treatment failures in grain stores have frequently been linked to under-dosing due to cost constraints. While improved practice may limit pesticide misuse, safe alternative measures appropriate to the needs of poorer households do exist. The Natural Resources Institute (NRI), through the UK Government sponsored Crop Post Harvest Programme (CPHP), has been supporting research into a range of alternatives, many of them blending science with traditional/indigenous knowledge. These include the use of inert dusts, locally available botanical materials, solarisation, targetted pesticide treatment to reduce costs and a risk assessment system to optimise pest management against the Larger Grain Borer *Prostephanus truncatus*. These research projects will have come to an end by the close of 2002 and by that time it is intended that there will be a range of options developed that can be used by small-scale farmers. It is not intended that these methods should be seen in isolation but they should be extended as a package of options from which farmers and their advisors can pick and choose according to circumstances and preferences.

Resumé

L' insécurité alimentaire est chronique et récurrente parmi beaucoup de ménages en Afrique sub-Saharan. Malgré l'efficacité apparente de l'application de pesticides, les pesticides synthétiques posent des risques sérieux et croissants. Des insecticides recommandés pour l'utilisation sur le grain tels que les organo-phosphates sont associés à des problèmes sur la santé et l' environnement. Ils ne sont pas bon marché et les échecs de traitement aux insecticides dans des magasins de grain ont souvent éte liés avec sous-dosage dû à des contraintes de coût. Tandis que la pratique améliorée peut limiter l'usage impropre de pesticide, des mesures alternatives sûres et appropriées aux besoins de ménages plus pauvres existent réellement. Le Natural Resources Institute (NRI), par l' intermediaire du Gouvernement du Royaume-Uni a sponsorisé le Crops Post-harvest

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Programme (CPHP), a soutenu la recherche dans un éventail de possibilités, beaucoup d'entre elle associant la science à la connaissance traditionnelle/indigène. Ceci inclue l'utilisation de poussières inertes, des matériels botaniques localement disponibles, la solarisation, le traitement de pesticides ciblés visé pour réduire les dépenses et un système d'évaluation de risque pour optimiser la gestion des parasites contre le grand capucin du maïs, *Prostephanus truncatus*. Ces projets de recherche devráient se terminer d'ici la fin de l'anné 2002 et à ce moment-là il est envisagé d'avoir un éventail d'options développées pouvont être utilisées par des fermiers à petite échelle. On ne destine pas ces methodes à étre utilisées séparément mais plutôt comme un ensemble d'options à partir desquelles les fermiers et leurs conseillers pouvent choisir en function des circonstances et des préférences.

Introduction

The UK's Department for International Development (DFID) implements a wide ranging Crops Post-harvest Research Programme (CPHP) in sub-saharan Africa. A important element of this is directed towards reducing the amount of synthetic pesticide used by small-scale farmers. These farmers store their crops in a wide range of different structures. Stocks are maintained to meet the household's need for a continuous supply of food until the next harvest or to enable the farmer to sell grain at the most profitable time. When storage periods are longer than two or three months, farmers run the risk of grain losses due to insect attack. Such losses are very variable and depend upon the prevailing climatic conditions as well as the pest complex in question. If the complex is dominated by weevils (*Sitophilus* spp.) then grain in storage for about six months will typically lose about 5% of its weight (Adams, 1977; De Lima 1979, Golob, 1981). On the other hand, since the arrival in Africa of the Larger Grain Borer (*Prostephanus truncatus*) losses are potentially higher averaging 10% with some farmers losing as much as 30% by weight (Hodges, 1986; Dick, 1988). Weight losses are a serious matter but when they are as high as this most or even all grain shows insect damage and the market value of grain is reduced, although prices may be less affected when grain is scarce (Compton *et al.*, 1998)

Synthetic insecticides offer the African farmer one means of reducing storage losses due to insects, and in most countries several compounds may be registered for use in this way. Typically these are organophosphates such as pirimiphos methyl (Actellic) or fenitrothion. Occasionally, malathion is listed but many insect strains are now resistant to it. If pest complexes also include *P. truncatus* then a mixture of an organophosphate with a synthetic pyrethroid is required. This is because *P. truncatus*, like certain other beetles of the family Bostrichidae, is easily killed by synthetic pyrethroids but not by organophosphates, the opposite is true of other typical storage pests such as *Sitophilus* spp and *Tribolium castaneum*. To provide the necessary broad-spectrum protection insecticide, companies are marketing mixtures such as Actellic Super (pirimiphos methyl plus permethrin).

Insecticides for the protection of farm stored grain are usually available as either dilute dusts, typically 50g of dust is admixed with 100 kg of grain, or as emulsifiable concentrates (EC). ECs are diluted with water before use and then applied as a spray on grain. If maize cobs are to be stored then they may be sprinkled with insecticide emulsion. This is convenient for the construction of traditional Ghanaian maize cob barns (Fig. 1) where the cobs would in any case be wetted as the barn is built.

Figure 1 - Typical Ghanaian maize cob barn (Volta Region)

Despite the obvious benefits of pesticide application, synthetic pesticides do pose a serious risk. The insecticides recommended for grain use are often organophosphates and these are associated with health and environmental risks (Ecobichon and Joy, 1993). Small farmers may easily be using a number of different insecticides for different crops and it is not uncommon to find that highly toxic pesticides, especially those for crops such as tobacco or cocoa, have been mistakenly applied to grain stocks (Fig. 2). Insecticides are also a considerable expense for many small-scale farmers. Investigation of reports of insecticide treatment failures in grain stores in Zimbabwe have shown that under-dosing, possibly due to cost constraints, has been the cause. With this background it is clear that there are advantages to be gained from limiting pesticide usage on small farms by finding suitable alternative measures. The Natural Resources Institute has a portfolio of projects, funded by the UK's Department for International Development, supporting research with farmers in sub-Saharan Africa to test a number of possibilities. These include the use of inert dusts, traditional plant materials, solar drying and specific targetting of pesticide application.

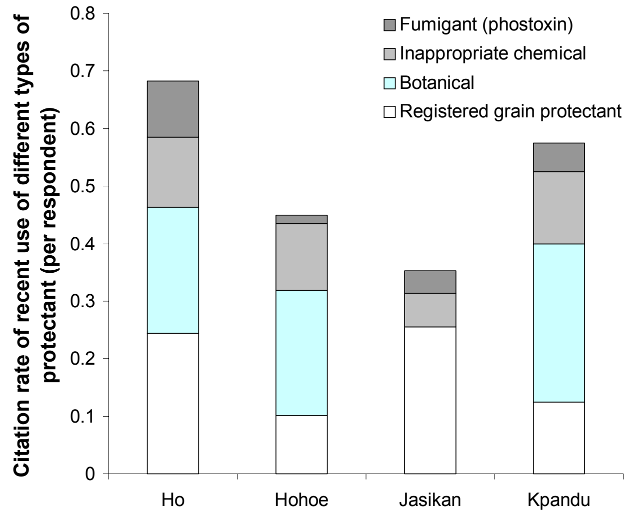

Figure 2: Survey sample of the types of protectants used on maize farm stocks in four different districts of the Volta Region, Ghana (242 respondents)

Project activities

i) Inert dusts

The inert dusts tested were all diatomaceous earths (DEs) compounds. These are the fossils of phytoplanktons (diatoms). When they come into contact with insect cuticle they absorb its water-proof outer waxy layer. Without this layer insects may die from dehydration. DEs have extremely low mammalian toxicity.

The potential for farmers to protect their farm stored grain from insect attack by admixture with two DEs, Dryacide® and Protect-it™ was investigated in three agro-ecological regions of Zimbabwe. We have shown that these DEs offer a realistic alternative to conventional, synthetic organophosphate insecticides, and are effective in controlling storage insect pests in maize (Fig. 3), sorghum and cowpeas for eight months under small-scale farmer conditions in Zimbabwe. Farmers evaluated the DEs during their own trials using parameters such as, insect damage, expected 'sadza' yield and quality, and sale price. The DE treatments outscored their existing grain protection practices and farmers were keen to purchase DEs to protect their future harvest. Laboratory studies have shown that higher concentrations of diatomaceous earths are required to control the bostrichid beetles, *Rhyzopertha dominica* and *P. truncatus*. Field trials in a *P. truncatus* infested area are needed to ascertain optimum rates and application methods of DEs against this devastating storage pest.

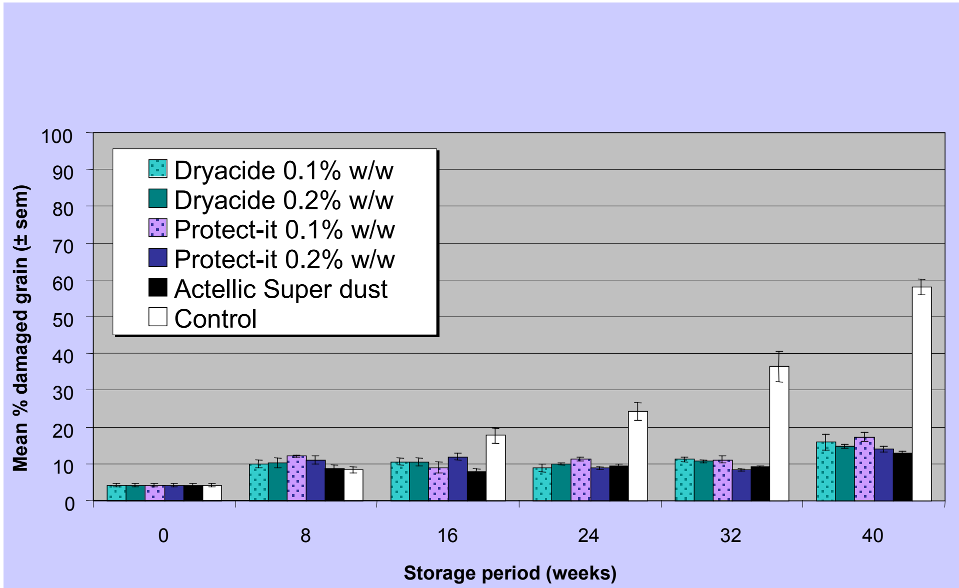

Figure 3: Insect damage to maize grain treated with DEs or Actellic Super dilute dust during the 1998/99 storage season in Buhera district, Zimbabwe(n=4)

Low-cost, local sources of DE exist in sub-Saharan Africa and preliminary tests have shown a raw sample of Zimbabwean DE to be effective against storage pests. The use of local sources of DEs will be a central theme of future work. However, until DEs are registered as grain protectants in Zimbabwe it will not be possible to make a more complete assessment of their acceptability to producers and consumers. Temporary registration is currently being applied for, and a local company (EcoMark) is keen to register and distribute Protect-it, in Zimbabwe.

ii) Traditional plant materials

A number of plant materials have been identified as food storage protectants used by farmers in northern Ghana. Feedback from farmers has indicated that the uptake of botanical pest control is constrained by the variability of control, and this has been confirmed in laboratory and field trials. Some of the plants concerned are shown in Table 1 and an example is shown in Figure 4. We are attempting to identify the factors that contribute to this variability as a means of standardising the usage of plant materials as storage protectants. Increased reliability of botanical insecticides will contribute to their promotion as a cheap and environmentally sustainable alternative to synthetic pesticides. The variability in bioactivity within the plant species has been analysed temporally and spatially using high performance liquid chromatography (HPLC) in parallel with bioassays. For example, in the case of *Cassia sophera*, differences in the chemical profile and bioactivity were very marked so farmers should be cautious about the source of their plant material and be sure that both time and location are correlated with activity. Relevant changes in plants will need to be incorporated into any recommendations to farmers. Besides looking at how well the plants control insects we are also gathering data on potential toxicity to humans.

Table 1: Some of the Ghanaian plants currently used for grain stock protection in Ghana

Family	Species	Method of use
Leguminosae	*Cassia sophera*	Admix powdered leaves
Leguminosae	*Chamaecrista nigricans*	Admix powdered leaves
Labiatae	*Ocimum americanum*	Admix whole or powdered plants
Labiatae	*Synedrella nodiflora*	Admix powdered leaves or treat with water extract of leaves or whole plant
Rubiaceae	*Mitragyna inermis*	Admix seeds or powdered leaves
Polygalaceae	*Securidaca longepedunculata*	Admix powered roots or treat with water extract of roots
Meliaceae	*Azadirachta indica*	Admix powdered leaves or oil extract from seeds
Gramineae	*Cymbopogon schoenanthus*	Admix flower heads or entire plant

Two of the pesticidal plants under study, *Securidaca longepedunculata* and *Cymbopogon schoenanthus*, appear to be under threat in the wild due to high level of environmental degradation in the Sudan Savannah and their numerous uses as medicines and pesticides. Both of these species are subject to unsustainable methods of harvesting as whole plants are uprooted. Two other species, *Azadirachta indica* and *Synedrella nodiflora*, are widely available throughout the savannah zones and neither is likely to be endangered owing to their invasive nature and prolific powers of regeneration. Many of the species are vulnerable as they have slow regeneration, showing sporadic and patchy growth due to widespread and uncontrolled annual fires.

Figure 4: A specimen of *Chamaecrista nigricans* from northern Ghana

iii) Solar disinfestation

Grain legumes, such as cowpeas, are sold soon after harvest in many semi-arid areas of Africa, either because producers need cash to meet debts or because they cannot prevent losses due to storage insects. Bruchid beetles (mainly *Callosobruchus maculatus*), are the major insect pests of stored legumes and also attack mature pods in the field before harvest. Damage and weight loss in stored seeds is caused by larvae that develop within the grain, consuming the seed. Selling early in the storage season results in a loss of income because prices rise as grain legumes become increasingly scarce. However, deterioration in grain quality is not just a problem faced by farmers. Traders at all levels within the system also suffer storage losses due to insect pests and this is also a concern for food aid agencies. Surveys in northern Ghana, revealed that the most important issue for farmers in on-farm storage of cowpea and bambara is not the actual weight losses but the damage incurred as damaged beans command a much reduced market price.

The surveys also identified a variety of traditional methods of control used by farmers against bruchids. A selection of these traditional methods and of modern alternative methods was tested in 'on-station' trials. The most promising methods were then tested in farmers' stores. These trials revealed that hermetic storage in plastic buckets is very effective. Unfortunately, it was also the most expensive form of protection tested and is therefore unlikely to be adopted by farmers. Solar disinfestation proved to be very valuable, it uses the green house effect created by a sheet of transparent plastic laid on top of a thin layer of seeds (Fig. 5). This increases the temperature sufficiently to kill the bruchids within the seeds. Treatment with kim-kim (*Synedrella nodiflora*) extract, admixture with shea nut butter or ash also showed promise. However, although kim-kim is a treatment traditionally used on bambara, participating farmers indicated that this discolours cowpea grain, which deters consumers and reduces the market value. The potentially useful methods were adapted to maximise efficacy and to suit small-scale farmers.


Figure 5: Farmers demonstrating solar disinfestation in northern Ghana, cowpea spread in a thin layer (LHS) and then covered with a polythene sheet (RHS)

Farmers in two villages in northern Ghana were asked to choose and test for themselves the three best methods: solar disinfestation repeated every month, solar disinfestation at harvest, followed by admixture of shea nut butter or of ash. To date the results are promising (Fig. 6)

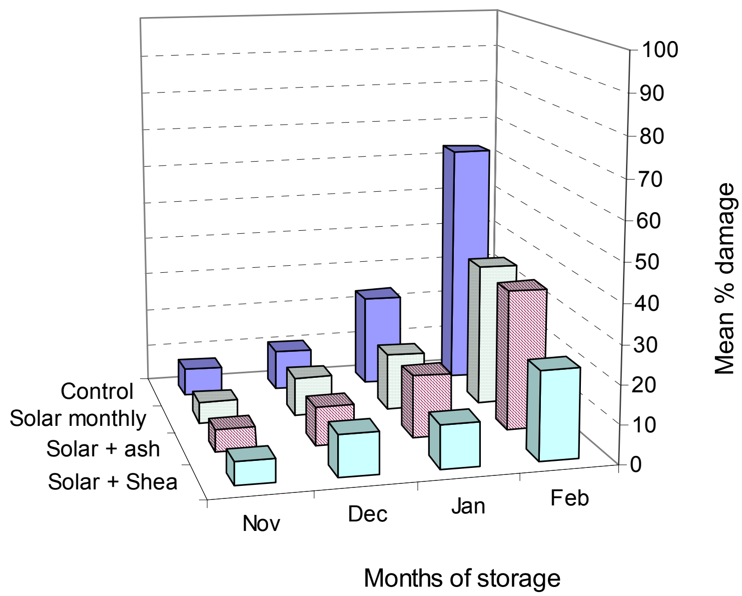

Figure 6: Mean % grain damage recorded in cowpea stored by farmers using various stock protection measures in northern Ghana (on-going trial)

iv) Targetted application of pesticide

One means of reducing small-scale farmers' usage of storage pesticides would be to promote the more selective application of treatments. To achieve this we have investigated the use of pesticides targetted at the bottom layers of grain masses or sometimes both the top and bottom layers. In the case of bottom layer treatments, we believe that any control achieved would be due to the behaviour of the initial colonisers of grain. Beetles like the weevils *Sitophilus* spp and the Larger Grain Borer (*P. truncatus*) have a strong tendency to migrate downwards when first arriving in a grain mass, and will consequently come into contact with the treated bottom layer. All treated areas receive the manufacturers' recommended dosage of pesticide.

In Ghana, we tested the efficacy of pesticide treatments restricted to only the bottom 20% of maize cob stores. Maize cobs were sprinkled in layers with Actellic Super (pirimiphos methyl and permethrin mixture) as a dilute dust or an emulsion. With half the replicates, a plastic sheet was provided as a partial barrier to the migration of insects into the stores. Such treatment was successful (Fig. 7) with the plastic sheet providing a little extra protection.

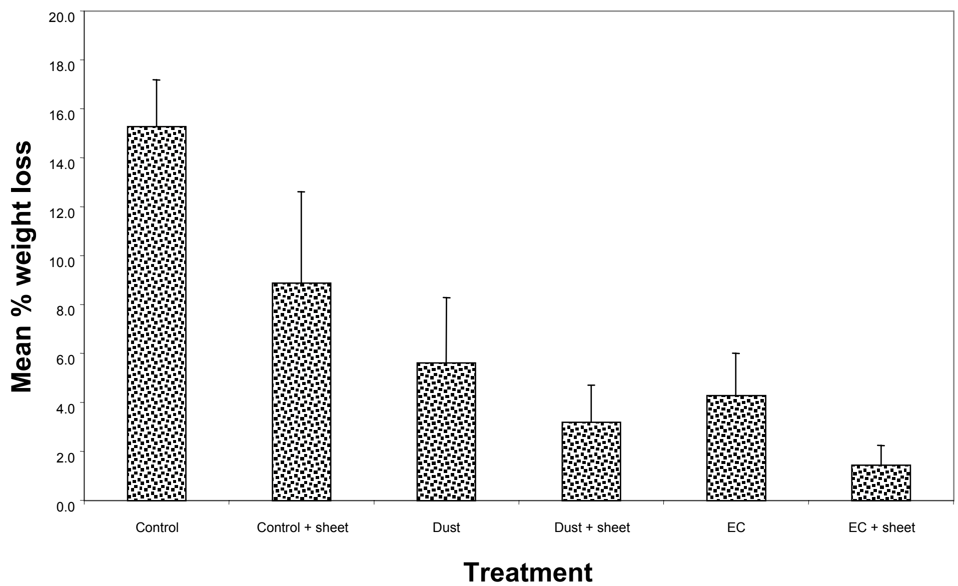

Figure 7: Mean weight losses (±sem) from maize cobs stored in maize cob barns for six months and given various protective treatments which included dilute dust (dust) or emulsifiable concentrate (EC) formulations of Actellic Super with or without a plastic sheet (sheet) over the barns (n = 3).

In Zimbabwe, we tested the protection of small bulks of shelled grain. The bottom 20% of the grain bulk was treated and in some cases so also was the top 10% layer. This gave reductions of 70% or 80% of the normal full treatment (Fig. 8). Two pesticides were included in the trial, a dilute dust formulation of Actellic Super and a diatomaceous earth preparation (Protect-it). The latter had already been shown to be a possible alternative to synthetic pesticides for the protection of grain in Zimbabwe (see p. 3).

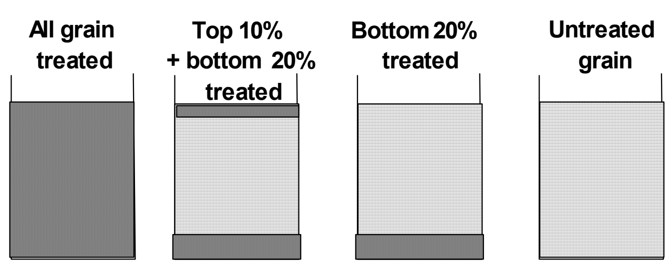

Figure 8 - Treatments tested in farm stores using Zimbabwe maize grain

After eight months storage weight losses were significantly higher in the control than in grain receiving any of the treatments (Fig. 9). There was a trend for losses to rise as the treatments became more targetted but even when the treatment was applied to only the bottom 20% of grain losses were only 0.7% more than the complete treatment. When pesticide applications were targetted at top and bottom, treatments of Actellic Super or Protect-it both gave good protection (Fig. 9).

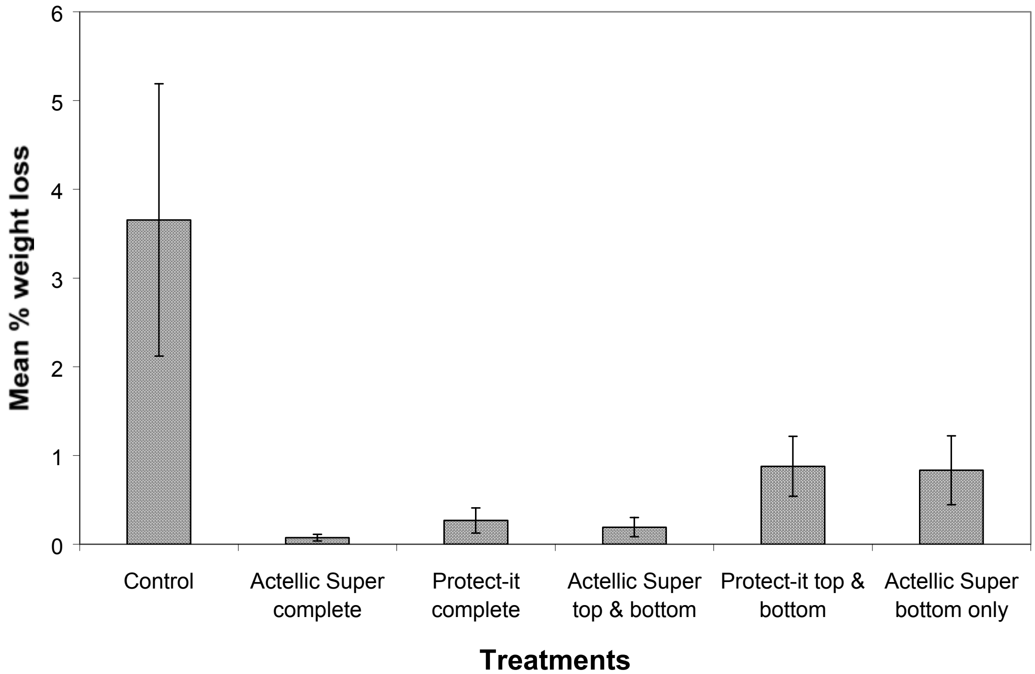

Figure 9: Mean % weight loss (±sem) due to insect attack in farm stored maize grain in Zimbabwe given various pesticide treatments and stored for eight months (n = 4)

If farmers were to adopt a targetted pesticide treatment then the options are a top and bottom, or bottom-only, application. If they sell or consume the top layers of grain soon after storage then the bottom only option would seem most appropriate although a top treatment could be added in due course. For long periods of undisturbed storage the top and bottom option should offer the best results. The next phase in our studies will be to work together with farmers to examine whether or not they can benefit from targetted insecticide application and whether other stakeholders such as insecticide companies will support the proposed method. The technique is currently being investigated by small-scale farmers in the Volta Region of Ghana and are being assessed by smallholder farming communities in Mashonaland (West Province).

How these project can be made to have impact on the livelihoods of small-scale farmers

The projects described here are all funded by the Crop Post Harvest Programme of the UK's Department for International Development and all have the goal of reducing poverty by the promotion of sustainable livelihoods. They focus on limiting the amount of synthetic pesticide applied to farm stored commodities with the intention of making the protection of crops in farm stores more effective, more affordable and more sustainable.

Before and during the implementation of these projects the practices and needs of farmers have been assessed using appropriate survey methods. Where necessary 'on-station' trials have been used to 'prove' technologies. Once methods have shown good promise they have been offered to farmers in participatory research trials. In this way both farmers and extension services have been able to make their own evaluation of new methods compared with standard practice and have been encouraged to take ownership of them.

All the projects will have come to an end by the close of 2002 and by that time it is intended that there will be a range of options developed that can be used by small-scale farmers. It is not intended that these methods should be seen in isolation but they should be extended as a package of options from which farmers and their advisors can pick and choose according to circumstances and preferences. The development of such packages should form the next phase to these projects and will offer integrated pest management for small-scale farmers. An important aspect of such an approach will be the development of decision making methods. One of these is already under development to help the extension services know in which years severe infestations by *P. truncatus* can be expected. The development of packages of pest management options supported by decision making methods is a crucial step in ensuring that this research makes an impact on the livelihoods of poor farmers.

Acknowledgement – The work described was undertaken with our collaborators in Ghana (Post Harvest Management Division, Ministry of Food and Agriculture) and Zimbabwe (Plant Protection Research Institute; Institute of Agricultural Engineering. This report is an output from research projects funded by the United Kingdom Department for International Development (DFID) for the benefit of developing counties. The views expressed are not necessarily those of DFID. R7486, R7373, R7442, Crop Post Harvest Research Programme

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