ETHNOBOTANICALS IN GHANA: REVIVING AND MODERNISING AGE-OLD FARMER PRACTICE

Steve Belmain and Phil Stevenson from the Natural Resources Institute in the UK describe how farmers' indigenous knowledge has improved grain storage practice through botanical pesticides and how it can be optimised through understanding the modes of action of the active components

Introduction

Throughout the developing world, poor rural communities have used their knowledge and insight about their environment to improve their livelihoods. Research funded by the Crop Post-Harvest Programme of the UK Department for International Development is using existing farmer knowledge about botanical pesticides to develop cost-effective and sustainable storage pest control strategies for small-scale farmers. Research has provided an understanding of plant chemistry and modes of action for plant species already used by many farmers in Ghana for stored product pest control. This has shown that these pesticidal plants can be used reliably and safely to treat grain and legumes when stored in small quantities at the farm level. Because of their indigenous use in Ghana, legal registration of these botanical products is not required for their promotion in Ghana.

Background

Small-scale farmers throughout sub-Saharan Africa continue to have problems protecting their harvested crops from insect infestation during storage. Traditional grain storage structures vary considerably (Figure 1) and are unable to prevent insect infestation. Storage losses are typically patchy and can be a big threat to food security and household incomes particularly when losses are severe. Because of the risks associated with grain storage, farmers try to minimise their losses by selling their grain soon after harvest. Unfortunately, since most farmers sell their grain at this time, market prices are low as the market is flooded with recently harvested grain. Farmers could achieve a much higher price if they were to sell their grain later in the season, but they must control insect infestation of the grain over this time period.

Subsistence farmers often lack the financial resources to buy good quality commercial insecticides to protect their stored food, and their inappropriate use of conventional pesticides can result in risks to human and environmental health and promote insecticide resistance. Traditional storage methods using indigenous plants with insecticidal properties could, if improved, offer a safer, low-cost and more dependable method of storage protection while reducing the increasing reliance upon conventional pesticides. Farmers need this information to support their decision making with respect to the reliability of control they can expect when using a particular plant material to reduce insect infestation.

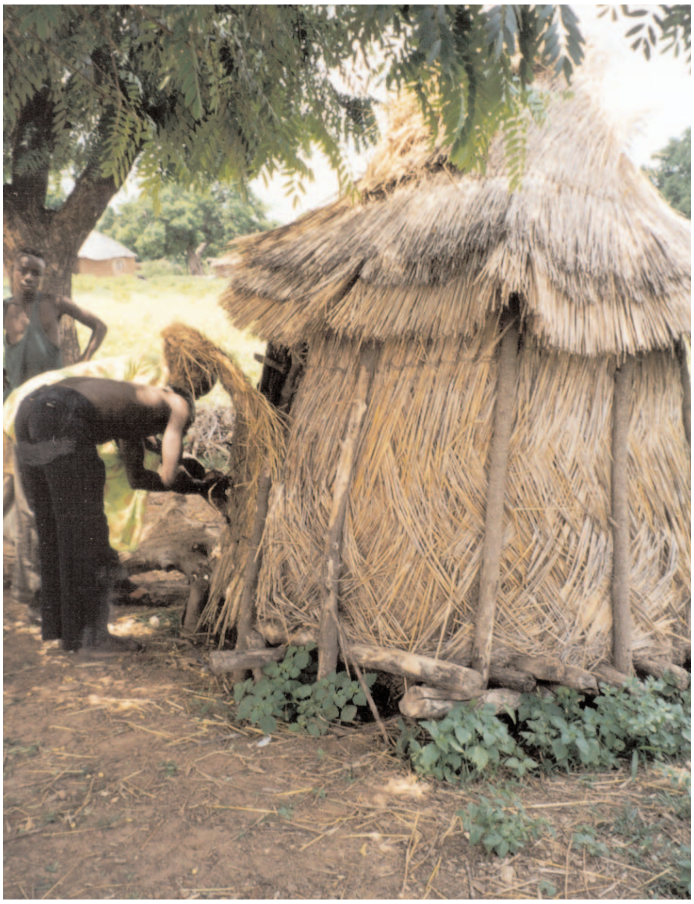

Figure 1 **Structures for storing harvested grain and legumes vary considerably depending on availability of materials. Most storage structures have a thatched roof and walls made from woven grass and/or sticks which may or may not be covered with mud.**

Farmer participatory appraisals

The first step of the research involved conducting rural assessments in the savannah regions of Ghana (Figure 2) by the Ghanaian Ministry of Food and Agriculture which identified sixteen plant species commonly used by farmers for stored product protection (Table 1, p 237). The identity of the pesticidal plants was confirmed against the type specimens at the Royal Botanic Gardens, Kew, UK. This was extremely important because sometimes several local language names could refer to the same plant species, or a single local name could refer to several plants with similar characters or from closely related genera.

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Figure 2 **The map of Ghana indicates the northern area (outlined in green) which was surveyed for indigenous post-harvest practices using plant materials with insecticidal properties. In all, more than 500 farmers were surveyed from 45 villages spread around the Northern, Upper East and Upper West Regions.**

Figure 3 **Many farmers extract pesticidal plants in hot water. The extract is then poured over the commodity or the commodity is dipped into the extract, and the commodity is then dried in the sun before storage. Laboratory and field trials found that this method was largely effective due to the hot water and the sun drying which killed off any existing infestation in the commodity. Although research has indicated that many of the active constituents found in the plants are water soluble, the concentration applied by quickly dipping the commodity into the extract is very low. However, this may be sufficiently repellent to prevent re-infestation of the grain**

The way farmers were reported to use the plants varied considerably. Some farmers would make a hot water extract of the plant which they would pour over their commodity or use as a grain dip (Figure 3). Some farmers used the plant material as whole flowers or leaves, whereas others would grind the material into a powder (Figure 4). The amount of material used to treat the commodity also varied, and some farmers would admix the botanicals while others would layer it with their commodity. The plant parts used for any given species varied the least, and, generally, all farmers consistently used the same plant parts (*e.g.* leaves, roots, flowers) for a particular plant species. The main differences found in application methodology illustrated how innovative and experimental farmers could be, but it also highlighted that communication between farmers may be a problem as no single method was markedly more popular than another. It was, therefore, necessary to determine the most effective application method to control storage pests. Research, discussed below, was designed to investigate the efficacy of control through laboratory and field-based trials among the different plant species and among different application methods.

From the beginning of the project, efficacy was recognised as only one of the factors that farmers would consider when choosing a method of pest control. So during the appraisal surveys, farmers were asked to assess the control strategies they use according to how they influence their choice of pest control options. Plant species and commercial synthetics were assessed by farmers for their cost, effectiveness, availability, toxicity, ease of use, acceptability and versatility. These criteria were ranked, and the results indicated that cost was far more important than efficacy. Furthermore, some plant materials were preferred over others, depending upon their availability or ease of use. In all, more than 500 farmers were surveyed from different villages across northern Ghana, and all the farmers rated the use of plant materials favourably in comparison to commercial synthetics. Most farmers highlighted the prohibitive costs of using commercial synthetics but expressed equal concern towards the toxicity of synthetic pesticides. Safety

Figure 4 **The most common method for using pesticidal plants for stored product protection is pounding the plant to a powder and admixing this with the commodity. This is laborious work, but research indicates it is the most effective method of applying botanicals for stored product protection.**

Figure 5 **Neem leaves, *Azadirachta indica*, being stripped from the stem and shade dried. The dried leaves will then be pounded and admixed at between 2–5% with commodity, the higher the concentration the more effective and long-lasting the protection offered.**

issues arise because farmers in many developing countries can not always be sure that the pesticides they buy are the correct pesticide for the job or whether they have been adulterated. Although it could be argued that 'natural' botanical pesticides may also be toxic to humans, they are at least of known quantity, and farmers feel more comfortable when using them for the same reasons that most consumers would consider a 'natural' product to be safe.

In discussion with farmers and rural communities, our survey showed that 74% of villages in the three northern regions visited used botanicals as storage protectants. However, the use of plant materials was concentrated in the Upper East Region where the number of farmers using botanicals was 95%. These distinctions in prevalence of usage tend to be attributable to ethnic and cultural differences in indigenous knowledge (Cobbinah *et al*., 1999). Promoting botanical use through institutions such as the Ghanaian Ministry of Food and Agriculture may provide a way to reach a wider audience by spreading knowledge across cultural barriers.

Confirming efficacy

Some plants used for post-harvest storage protection in Ghana had already been studied for various pesticidal and medicinal uses. For example, chilli peppers and orange peel are well-known botanicals for post-harvest protection (Onu and Sulyman, 1997; Lale, 1992). The neem tree, *Azadirachta indica*, is probably the most well-known botanical and is used widely throughout Asia and Africa for a variety of medicinal and agricultural uses (Puri, 1999; Narwal and Tauro, 1997) (Figure 5). However, literature reviews indicated that some of the plants identified in our survey were virtually unknown. So their efficacy needed confirmation through standardised laboratory and field studies. These initial trials were conducted following the methods by which farmers in Ghana already used the plants for stored product protection. Methods were further developed by admixing powdered plant materials at different concentrations with the test commodity and subsequently infesting with the major insect pests of stored cereal grains and legumes. Both laboratory and farmer participatory research trials showed that some plants were found to be largely ineffective at reducing infestation, and these were subsequently dropped from our research activities.

Our trials showed that the efficacy of different plant species was not correlated with the prevalence of use by farmers. In other words, the abundance of the plants growing in the natural environment and other marker criteria were important factors in how widely a plant was used by farmers. For example, trials showed that the plant material most effective in controlling storage insects was *Securidaca longepedunculata*, but this was not the most widely used plant by farmers. Evidence collected through discussions with farmers and from habitat abundance surveys conducted by the Ghanaian Forestry Research Institute indicated that plants such as *S. longepedunculata* were increasingly rare in the environment due to over-collection, unsustainable harvesting methods, uncontrolled bush fires and poor plant propagation characteristics. Similarly, some of the more widely used plants for stored product protection were not always highly effective but were easily collected from abundant natural habitats.

Farmer participatory research

Over the past five years, farmer participatory trials have been conducted over the storage season. About 200 farmers from the Northern and Upper East Regions have been involved each year testing the efficacy of the botanicals under farmer storage conditions using their own harvested commodities. These trials have also been a way of gathering feedback from farmers on which plants they think are working best and gauging how other factors influence pest control (Figure 6).

Depending on when and how farmers harvest their grain, insect infestation can occur before it is put into storage. Initial levels of pest infestation can, therefore, vary considerably among farmers, and this has a large impact upon how well botanical treatments work. Botanicals are a complex mix of compounds that may be acting in different ways on the target pest which can impact upon the choices a farmer makes. For example, if initial insect infestations are high, a farmer should perhaps choose a plant which causes significant adult mortality. However, with relatively clean grain a farmer may opt for a plant material which is largely repellent to insects. Because recommendations made to

Figure 6 **Optimising how plant materials are used for stored product protection involves LEFT) giving farmers a choice on which plants they will use during research trials they will manage in their own store using their own commodity. RIGHT) The plant materials being offered as choices to this farmer are (clockwise from top left) *Cassia sophera*, *Securidaca longepedunculata*, *Ocimum americanum*, *Lippia multiflora*, *Synedrella nodiflora* and *Azadirachta indica*.**

farmers need to be simple and trustworthy, a series of experiments were conducted which aimed to understand more specifically how the plant materials worked in the storage environment. Natural variability of secondary metabolites found within plants could affect the reliability of control experienced by farmers. For example, anecdotal information indicated that some plants work only in particular regions while not in others. We, therefore, needed to establish whether this was because different species were growing in different regions or that the active ingredients were not present in plants collected from different areas. Through analyses conducted by the Royal Botanic Gardens, Kew and the Natural Resources Institute, all the botanicals showed significant phytochemical changes, both quantitatively and qualitatively, according to harvest location, season and, not surprisingly, plant part. However, phytochemical variability did not appear to effect overall bioactivity with regard to stored product pest control. As the bioactive constituents are not well-known for each plant species, it may be inappropriate to make correlations between phytochemical variability and bioactivity. Through this research, the mode of anti-insect activity of the plant materials has been shown to be important. For some of the species, such as *Cymbopogon schoenanthus*, the plant is highly repellent but not particularly toxic to insects, and despite its lack of toxicity, it is still effective in protecting farm stored grain as demonstrated in farmer participatory trials (Levinson and Levinson, 1999). Repellent plants may indeed be preferable because their human toxicity could be argued to be lower than an outright insecticidal plant.

Safety

It should not be assumed that just because the botanical pesticides are naturally derived that they are safe to use and consume by humans, and some form of safety assessment needs to be considered. In order to assess their mammalian toxicity, some of the more promising plant species were tested for toxic effects against vertebrates (Belmain *et al.*, 2001). Research conducted by the UK Medical Research Council showed that rodents expressed no symptoms of toxicity when plant materials were incorporated into their diets over a six-week period with the exception of *Securidaca longepedunculata* and *Chamaecrista nigricens*, which gave some indication they could be harmful if ingested at high concentrations over prolonged periods of time. Many of the plants used for stored product protection have alternative uses as medicines or food spices, indicating that any serious vertebrate toxicity would have been established through the development of the ethnobotanical

Table 1 The sixteen plant species below are commonly used by farmers in the north of Ghana for stored product protection. Species marked with an '*' remain the focus of further research on pesticidal plants which have been selected through laboratory and field research that showed them to offer good insect pest control.

Latin name	Method of use cited by farmers	Mitigating factors	Prospects for increased promotion
*Azadirachta indica**	Most farmers use leaves, using either fresh or dried whole leaves, leaf powder, a paste or water extract, admixed or layered. Many other uses as medicines, crop pesticides, soap	Chemistry and bioactivity of leaf material highly variable depending on collection time and place Although seed oil is recognised to be more effective, few farmers use seeds because it's laborious and smelly to process	Excellent, widely available, large body of research showing good quality control, powdered leaves better than water extract of leaves
*Capsicum annuum**	Whole or powdered chillies admixed or layered	Unacceptable levels of grain tainting for some purposes	Excellent. Good quality control, commonly grown as a spice
*Cassia sophera**	Powdered leaves and seeds. Also used as green manure and as a supplement to animal fodder and ethnoveterinary uses	Chemistry and bioactivity highly variable depending on collection time and place	Excellent. Widely prevalent with good quality of control
*Chamaecrista nigricens**	Powdered leaves, admixed or placed at top and base. Veterinary and medicinal uses. Sometimes sold in markets	Reduced availability as plant suffers from over-collection	Good. Propagation reduced due to savannah fires and high usage. Environmental protection and/or cultivation required
*Citrus sinensis**	Orange peel dried, powdered and admixed	Expensive in north of Ghana as oranges are imported from the south	Good. Cost-effective only in areas where citrus is grown. More effective against legume pests than grain pests
Combretum spp.	Powdered leaves. Also used as green manure and as a supplement to animal fodder.	About 20 species of the genus found growing within the same habitat with similar anatomical characteristics	Poor. Low efficacy, dropped from further trials. Taxonomic confusion may be responsible for variable effects experienced by farmers
*Cymbopogon schoenanthus**	Whole or powdered flower heads or entire plant. Sometimes sold in markets. Used as a mosquito repellent	Reduced availability as plant suffers from over-collection	Good. High demand increases scarcity, but is relatively easy to propagate
Khaya senegalensis	Powdered bark admixed	Bark harvesting often leads to tree death	Poor. Although excellent control, difficulty in policing patch bark harvesting, and conservation priorities prevent its promotion
*Lippia multiflora**	whole leaves and/or flowers, admixed or layered		Good. Restricted habitat range, efficacy lost within three months
Mitragyna inermis	Whole or powdered leaves admixed or layered		Poor. Low efficacy, dropped from further trials
*Ocimum americanum**	Whole or powdered mature plants, admixed or layered. Ceremonial and medicinal uses		Good. Widely prevalent but efficacy lost within three months
Pleiocapa mutica	Powdered leaves. Also used as a supplement to animal fodder.		Poor. Low efficacy, dropped from further trials
Pterocarpus erinaceus	Powdered leaves or roots admixed, water extract of leaves or roots. Leaves often used as a supplement to animal fodder.		Poor. Low efficacy, dropped from further trials
*Securidaca longepedunculata**	Water from soaked roots, admixed powdered root bark. Many other uses, including water purification, ceremonial, medicinal, washing clothes. Sometimes sold in markets.	Reduced availability as plant suffers from over-collection	Good. Quality of control excellent but harvesting of roots results in high plant mortality and reduced natural propagation. Ongoing research to cultivate the plant may improve prospects.
*Synedrella nodiflora**	Water from boiled leaves and flower heads, poured or immersed 20-30 sec., powdered leaves and flower heads. Often burned inside houses as a mosquito repellent		Excellent. Widely prevalent
*Vitellaria paradoxa**	Seed oil or oil extraction residue admixed	Oil predominantly used for cooking. Oil extraction is laborious but often done to provide cooking oil.	Good. Only for legume pests, best control by using residue plus a small quantity of oil

knowledge. The risk of consuming larger quantities of botanicals through storage protection would be reduced through winnowing, washing, processing and cooking. We recommend further research investigating potential botanical residue levels on treated food after processing and cooking before the institutional promotion of botanicals for stored product protection begins.

Future Prospects

Evidence collected from small-scale farmers indicates that they prefer pesticidal plant materials over other forms of pest control during storage. However, individual farmer knowledge about different plants and how best to use them varies considerably. Research to date has been able to narrow down the list of plants, focussing upon those that work best and optimising their application methods for on-farm storage use. It is hoped that this new knowledge can be widely disseminated to farming communities through partnerships with NGOs and farmer extension programmes operated by the Ghanaian Ministry of Food and Agriculture. One issue which remains unresolved is the accessibility and availability of the plant materials. This does affect farmer choices. Most of the plants are collected from the wild and some species are suffering from over-collection and environmental degradation. In order for these plants to be used sustainably, we hope to investigate their propagation and cultivation potential as well as their conservation in the wild. Some of the species such as *Azadirachta indica* and *Synedrella nodiflora* could be considered weeds, and their invasive properties and prolific regeneration imply that neither plant is likely to become threatened. However, many of the species are potentially vulnerable with regard to their regeneration potential, showing sporadic and patchy growth due to widespread and uncontrolled annual fires. Promotion of botanicals will ultimately assist biodiversity conservation of the savannah by increasing its perceived value.

Research at the Natural Resources Institute and the Royal Botanic Gardens, Kew continues to isolate and identify the active constituents from some of the less well-known plant species. This information can principally be used to help assess the safety of the botanicals as well as their optimal application methods. By knowing more about the phytochemistry of the plants we may be also able to identify other plant species which share the active constituents, thereby reducing collection pressures on traditionally collected species. The identification of novel compounds or modes of action found in the botanicals could lead to the development of new commercial products for the wider benefit of humanity and the country of origin.

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