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Do diatomaceous earths have potential as grain protectants for small-holder farmers in sub-Saharan Africa? The case of Tanzania

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Abstract

Participatory on-farm field trials were set up over three storage seasons, from 2002 to 2005, in different agroecological zones of Tanzania to compare the efficacy of the enhanced diatomaceous earths (DEs) Protect-It® and Dryacide® alone or combined with the pyrethroid permethrin. Other treatments included three commercially available synthetic chemical dilute dusts, containing 1.6% pirimiphos-methyl and 0.3% permethrin (Actellic Super and Stocal Super from different manufacturers) and 1% fenitrothion and 0.13% deltamethrin (Shumba Super); traditional protectants; and a locally available DE collected from Kagera in north-west Tanzania. Treatments were applied to maize and sorghum grain and dried beans. Insect pests are the main threat during storage, which in Tanzania includes the devastating larger grain borer, *Prostephanus truncatus*. All the grain protectants, except the traditional ones, kept damage incidence well below that of the untreated controls, and usually below 10% for periods of 40 weeks of storage. Exceptions occurred when grain was badly infested prior to treatment, in which case Actellic Super dust was more effective than the DEs. Very little difference in damage was observed between the DE treatments until 40 weeks of storage. In addition to the commercially available synthetic grain protectants, Protect-It® 0.25% w/w or Protect-It® 0.1% w/w plus permethrin at 2 mg/kg can be recommended to protect dry un-infested, winnowed maize and sorghum grain that is to be stored on-farm in sacks or woven granary baskets for periods of 4 months or more in Tanzania. Beans can be protected with lower application rates of Protect-It® 0.05% w/w or Dryacide® 0.1% w/w. The study also demonstrated that Actellic Super dust obtained from an approved source and applied according to the manufacturer's recommendations is effective in protecting stored maize, sorghum and beans for periods of at least 40 weeks—contrary to many of the suggestions that this product is no longer effective in Tanzania.

Keywords: Diatomaceous earths; Food security; Pest management; Post-harvest; Rural livelihoods; Maize; Sorghum; Beans; *Prostephanus truncatus*; African diatomaceous earths; Combinations

1. Introduction

Farmers throughout sub-Saharan Africa suffer serious losses to their stored produce due to insect damage. For many people, these losses threaten household food security or undermine market returns, driving them to seek options for protecting their grain during storage. In addition to many of the traditional stored-grain protection practices, such as admixing grain with ash or plant materials, farmers can purchase synthetic chemical pesticides if they can afford to do so. In Tanzania and many other countries in sub-Saharan Africa, the main commercially available grain protectant recommended for storage insect pest control is a dilute dust containing

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1.6% pirimiphos-methyl plus 0.3% permethrin (Actellic Super dust (ASD)), although recently several other similar mixtures have entered the market. Unfortunately, since the distribution of these pesticides was privatised in Tanzania in the 1990s there have been widespread reports from farmers of efficacy, adulteration and availability problems. In addition, regulatory action may lead to the loss of some organophosphate-based grain protectants in the US (Arthur, 2002), which may trigger their gradual removal from the global market.

Further research has been in response to farmers' and other agricultural stakeholders' demands for alternative grain protectants. In Zimbabwe, from 1998 to 2000, diatomaceous earths (DEs) were found to be effective grain protectants against insect damage for small-scale on-farm storage systems (Stathers et al., 2002a, c). However, while many storage insects are ubiquitous throughout sub-Saharan Africa, the devastating larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), has not yet been recorded in Zimbabwe. *P. truncatus* is an indigenous storage pest of Meso-America and is assumed to have been introduced to Tanzania with grain imports during food shortages in the 1970s (Golob, 1991), from where it has spread to neighbouring countries, and is now the most serious pest of stored maize in Africa. *P. truncatus* can cause more than twice the weight loss in maize than infestations of indigenous insect pests such as *Sitophilus zeamais* (Motschulsky) (Hodges et al., 1983; Dick, 1988).

DEs consist of the fossils of phytoplanktons (diatoms), which are composed mainly of amorphous hydrated silica (~90% SiO_2) and other minerals (Round et al., 1992; Quarles, 1992). The fossilised diatoms become diatomite, which can be quarried, dried and ground to produce the fine talc-like dust known as DE. While DEs are considered to be non-toxic to mammals (Quarles, 1992), when DE particles come into contact with insects, they absorb wax from their cuticles, causing water loss and inducing desiccation and death (Ebeling, 1971).

While stored product insect species are generally susceptible to DEs, there are significant variations in the degree of susceptibility of different life stages, strains and species (Carlson and Ball, 1962; Desmarchelier and Dines, 1987; Korunic, 1998; Subramanyam et al., 1998; Mewis and Reichmuth, 1999; Fields and Korunic, 2000; Rigaux et al., 2001; Baldassari et al., 2004; Vayias et al., 2006). There is general consensus that the most sensitive stored product species are in the genus *Cryptolestes* and that *Sitophilus* spp. are less susceptible, followed by *Oryzaephilus*, *Rhyzopertha* and *Tribolium* spp., which appear to be most tolerant (Maceljski and Korunic, 1972; Desmarchelier and Dines, 1987; Korunic and Fields, 1995; Fields and Muir, 1996). Much of the DE research, however, has focused on a very limited number of species that are important in large-scale storage, and has tended to ignore insects that cause devastation to small-scale farmers in the developing world, such as *P. truncatus* and the moth *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae).

Many DE dusts are now commercially available and are registered for use as grain protectants in Australia, Brazil, Canada, Croatia, China, Germany, Indonesia, Iran, Japan, Philippines, Saudi Arabia, United Arab Emirates, UK and the USA. However, DEs from different sources vary in their efficacy against insects (Snetsinger, 1988; Katz, 1991; McLaughlin, 1994; Fields and Korunic, 2000) and generalisations about their efficacy should be avoided. This variation among DEs is mainly due to the different physical and morphological characteristics of the diatoms rather than their origin (Korunic, 1998). Furthermore, differences in efficacy also depend on the ability to adhere to different types of grain. La Hue (1972) found that DEs did not adhere as well to maize as to wheat or sorghum. More recent work showed that less than 6% of the applied DE was retained on maize, compared to >87% on rice (Kavallieratos et al., 2005). The presence of broken kernels is also known to reduce DE efficacy, due to the absorption of fatty acids from the broken kernels by the DE (Cotton and Frankenfeld, 1949; McGaughey, 1972; Nielsen, 1998).

DEs have extremely low toxicity to mammals (e.g. the DE Insecto® has a rat oral LD_{50} >5000 mg/kg (Subramanyam et al., 1994)). DEs are 'generally regarded as safe' by the USA Environmental Protection Agency (Anonymous, 1991). The US Food and Drug authority has exempted DEs from requirements of fixed residue levels when added to stored grain (Anonymous, 1961). Recent medical studies even suggest that DEs are capable of reducing blood cholesterol in humans (Wachter et al., 1998). Due to their high porosity, DEs are used in filters to help clarify fruit juices, beers, wine, pharmaceuticals, swimming pool waste and dry cleaning solvents among others (Subramanyam and Roesli, 2000); as a filler in paints, plastics, asphalt, as a coating agent in fertilisers and as a carrier for pesticides (Jefferson and Eads, 1951); as a mild abrasive; and as a particle aggregate in industrial absorbents. Cattle, poultry and dog owners commonly use DEs as a feed mix to combat internal parasites (Allen, 1972). Silica is used as a thickener in ointments and suppositories, as a filler in tablets, as an anti-caking agent in processed foods, in toothpaste, and to prevent clogging in hygroscopic powders (Martindale, 1972; Budavari, 1989; FDA, 1995). These alternative applications could play a crucial role in increasing the interest of private sector companies in DEs as grain protectants.

Negative health effects could come from long-term chronic exposure to quantities of inhaled dust. The critical issues associated with this are the amount of