**Introduction to**

Diatomaceous earths (DE)

- are obtained from the fossils of phytoplanktons (diatoms)
- are composed mainly of amorphous hydrated silicates
- when diatoms settle to the bottoms of lakes and seas, diatomaceous earth deposits are formed

**DE - mode of action**

Exert their effects on insects through physical means

- Act as dessicating agents - DEs absorb wax from the cuticle leading to water loss and dehydration of insects, DE’s may also abrade the cuticle.
- Repellent - dusts in general are repellent to insects

**Which insects are most susceptible to DE’s?**

- Insects with a large surface area to volume ratio (often smaller insects)
- Insects with body hair e.g. *Oryzaephilus mercator*
- Insects with a thin cuticle
- Insects protected by a low-melting grease e.g. cockroaches, rather than those with a hardened waxy cuticle
- Those that feed on dry grain as opposed to those that constantly obtain water by sucking on vegetation

**Diatomaceous earths (DE)**

- Birds and mammals take “dust baths” to free themselves of mites and other parasites
- The Chinese used DE for pest control 4000 years ago
- The Aztecs of ancient Mexico are said to have mixed maize with lime to preserve their grain

**Inert dusts - History**

- DE can be used to treat cracks and wall crevices to repel insects
- DE’s are also used against some field pests
- Cattle, poultry and dog owners add 1-2% DE to animal feed

**Use of DEs in other aspects of pest management**
DE is used in many commercial products including:

- food additives
- baby powders
- oil removers from concrete floors
- deodorizing compounds
- swimming pool filter systems
- filters in the brewery industry
- detergents

Inert dusts, particularly diatomaceous earths, were known to offer safer alternatives to synthetic chemicals, but information on their efficacy under tropical small-scale farming conditions was limited.

Current DE grain protectant uses
DE products are registered for use as grain protectants in Australia, Brazil, Canada, Croatia, China, Germany, Indonesia, Japan, Philippines, Saudi Arabia, United Arab Emirates and USA.

Uses:
- Grain treatment using a dust applicator
- Structural treatment of grain silos with DE slurry spray application
- Top dressing with DE layer combined with fumigation or aeration

Safety and diatomaceous earths
Toxicity - very low mammalian toxicity
- rat oral LD50 >5000 mg/kg
- GRAS (USA Environmental Protection Authority)
- FDA has exempted DE from requirements of fixed residue levels when added to stored grain

Inhalation can cause respiratory problems, hazard level is affected by:
- Amount of dust
- Particle size
- Crystalline silica contamination
**Zimbabwe Field Trials: 1998-2000**

- Storage insects pests are a priority problem in the smallholder farming sector of Zimbabwe.
- In PRA Surveys conducted in 1996 & 1997 farmers showed concerns on efficacy of synthetic insecticides.
- Their safety was questioned.
- Research identified DEs as safe and effective but needed to be tested under tropical conditions.
- 3 crop types (maize, sorghum & cowpeas) & 3 agro-ecological zones (IIa, III & V) to capture whole spectrum of insect species.

**Results - Zimbabwe**

- Field trials that using maize, sorghum and cowpeas, DEs could effectively protect these commodities for >8 months storage in the three agro-ecological zones.
- *Rhyzopertha dominica* was more tolerant to DEs on sorghum.
This work has now been published:


Protect-It is currently in the process of being registered for use as a grain protectant in Zimbabwe by EcoMark Ltd.
Farmers in Tanzania also perceive storage pest damage to be a serious constraint to household food security and sales income opportunities.

- The storage protectant market is dominated by organophosphate-based insecticides
- However there are serious problems regarding availability, adulteration, quality, cost and application methods
- As a result many farmers are hesitant to use them and have switched to local methods including use of ash, animal dung, plant materials with little or no success
- Farmers are repeatedly asking service providers for better alternatives and a wider choice of products

From 2002 to date, research trials have been set up in:
- Mlati village, Kongwa district, Dodoma Region
- Mwamakaranga village, W. Shinyanga district, Shinyanga Region
- Mwitu village, Kishapu district, Shinyanga Region
- Arri village, Babati district, Manyara Region
- Singe village, Babati district, Manyara region

The commodities studied included: maize, sorghum and beans

The grain protectants being tested include:
- traditional protectants (ash, plant materials)
- commercial synthetic pesticides, e.g. Actellic Super dust, Stocal Super dust, Shumba Super dust
- DEs - Protect-It, Dryacide and Tanzanian DE from Kagera
- combinations of diatomaceous earths & synthetic chemical pesticides

In July 2002, work to evaluate whether diatomaceous earths and other protectants were safe, effective and affordable treatments for rural householders was initiated by the Plant Health Services Division of the Tanzanian Ministry of Agriculture and Food Security in collaboration with the Natural Resource Institute (UK) and the University of Zimbabwe.

In the graph, the mean percentage of damaged grains is shown for different treatments and application rates over various dates: 
- Protect-It (100g/100kg)
- Protect-It (250g/100kg)
- Protect-It (100g/100kg) + Permethrin (2mg/kg)
- Dryacide (250g/100kg)
- Actellic Super dust (100g/100kg)
- Traditional protectant, cowdung ash (1.5kg/100kg)
- Untreated control

Jaribio la hifadhi ya mahindi cha Mlati (2002/03) (Maize grain protection trials, Mlati village, Kongwa district)
The DEs, Protect-It and Dryacide come from North America, but DE deposits also exist in East and Southern Africa. DE samples from Tanzania, Zimbabwe, Zambia, and South Africa were tested in laboratory trials. The results were promising and samples from Kagera region in Tanzania, and Chemutsi river and Beitbridge in Zimbabwe were included in field trials.
Mean number of insects in maize grain stored at Mlali village, Kongwa district using different protectants during 2003/2004

Mean number of LIVE insects in maize grain stored at Mlali village using different protectants during 2003/2004

Jaribio la hifadhi ya mahindi kijiji cha Arri (2004/05) (Maize grain protection trials, Arri village, Babati district)

Mean % number of damaged grains (± SEM)

Storage period (weeks) and treatments

Treatments and application rates
What about farmers perceptions of the DEs?

Farmers assessed the quality of grain stored for 10 months using the different treatments. We assumed that farmers in different wealth groups might have different perceptions of the grain.

Indicators used by the key informants to differentiate between the different wealth groups in Mlali iyegu village, Kongea district, Dodoma Region, Tanzania.

Assessment of maize grain samples after 40 weeks storage with different grain protectants by a group of 14 men from lower wealth households in Mlali village, Tanzania following the 2003/2004 storage season.

At the end of the exercise the total score for each of the treatments was calculated, and the identity of the codes revealed and the efficacy of the treatments discussed.

Farmer Managed Trials

In the 2nd and 3rd years farmers set up their own trials with the DE Protect-It at their homes, the project team have visited them regularly to learn about how their trials were doing.

Important criteria for evaluating stored maize grain:
- No insect boring
- No unwanted chemicals hazardous to humans
- No rotting
- No insect boring
- No chaff

Using each of the criteria they had mentioned as important, they assessed code labelled samples of each of the different treatments and gave it a score (using a simple three point scale).
Farmer managed trials using an imported diatomaceous earth (DE) and field efficacy and persistence of local DEs as grain protectants in Zimbabwe

**Introduction**
- Imported enhanced DEs found effective in small-scale on-farm storage systems for periods of 8-10 mths @ 0.1%w/w in Zimbabwe
- These DEs also needed to be tested under farmer management conditions to explore farmer-diversity
- Hypothesised that local DEs could more economic than imported ones in the long term
- Local deposits of DEs identified in Beitbridge & Zambezi Valley but efficacy unknown
- Initial laboratory trials indicated that the Zambezi Valley DEs had potential

**Treatments - Zimbabwe**

**Harare 2003/04 (Maize)**
- Actellic Super Dust
- Protect-It 0.1%w/w
- Local DE1 (Chemutsi) @0.1; 0.2; 0.25%w/w
- Untreated control

**Harare 2004/05 (Maize)**
- Local DE1 (Chemutsi) @0.15; 0.2; 0.25%w/w
- Local DE2 (Beitbridge) @ 0.2% w/w

**Farmer Managed Trials: 2003-2004**
- Trials set-up in Buhera district by a total of 30 farmers after initial demonstrations
- Compared Protect-It @ 0.1% (w/w) with farmer practices on maize over 36wks of storage
- Farmers used ground goat droppings, finger millet chaff fresh Eucalyptus leaves, fresh Garcinia leaves, and maize cob ashes.
- Majority used Shumba Super Dust which was commonly available in the local shops

**Treatments - Zimbabwe**

**Buhera-2004/2005 Cowpeas**
- Protect-It (100g/100kg) 0.1%w/w
- Chemutsi (150g/100kg) 0.15% w/w
- Chemutsi (200g/100kg) 0.20% w/w
- Maize core ashes (500g/100kg) 0.5% w/w
- Untreated control

**Buhera-2004/2005 Maize**
- Protect-It (100g/100kg) 0.1%w/w
- Chemutsi (100g/100kg) 0.15% w/w
- Chemutsi (150g/100kg) 0.15% w/w
- Chemutsi (200g/100kg) 0.2% w/w
- Shumba Super dust
- Finger millet chaff (50% v/v)
- Untreated control
**Treatments - Zimbabwe**

*Bungo-2004/05 Sorghum*

- Protect-It (150g/100kg) 0.1% w/w
- Protect-It 100g/100kg + Permethrin 2mg/kg
- Local DE1 (Chemutsi) (200g/100kg) 0.2% w/w
- Local DE1 (Chemutsi) (250g/100kg) 0.25% w/w
- Local DE2 (Beitbridge) (200g/100kg) 0.2% w/w
- Shumba Super Dust (100g/90kg)
- Untreated control

**RESULTS - RESEARCHER MANAGED TRIALS**

The Chemutsi DE was effective at ≥0.2%w/w and was as efficacious as Protect-It 0.1% and Actellic Super Dust 0.05%.

- Some farmers re-treated or re-winnowed & ‘sunned’ own grain => insect infestation
- DE better or similar to synthetic insecticides
- Traditional protectants not effective for long
- At a farmer workshop, Protect-It was ranked highly
- Traditional protectants were lowly ranked

**RESULTS - FARMER MANAGED TRIALS**

- Mean % number of insect damaged grains (± SEM)
- Mean total no. of insect pests/kg (± SEM)
- Maize insect damage, IAE, Harare, 2003/04
- Insect numbers in Farmer Managed Trials, Buhera district, 2003/04

**Storage facilities**

- Maize insect damage in Farmer Managed Trials, Buhera district, 2003/04
- Insect numbers in Farmer Managed Trials, Buhera district, 2003/04
Opportunities/Challenges

What needs to be done next, to help DEs reach the market so that farmers can access these safe and effective grain protectants?

- Registration of imported DEs – complex and extremely slow
- What will be the cost of imported DEs vs synthetic chemicals?
- Safety of local DEs – analysis for crystalline content in progress
- Local exploitation of DEs – Environmental issues have to meet Gvt regulatory requirements
- DE combinations with other protectants for bostrichid control?

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