PROJECT PROPOSAL

AGRICULTURAL ENGINEERING

Field assessment of the efficacy and persistence of a locally-occurring raw diatomaceous earth in protecting maize and cowpeas on small-scale farms under semi-arid conditions

by

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1. INTRODUCTION

1.1 Background

Small scale farmers in Zimbabwe incur losses to stored grain as result of insect damage. Losses in excess of 30 and 50% have been reported in some of the world's developing countries where this food is most needed (Hall, 1970). In Zimbabwe small scale farmers may loose up 15% of their stored grain due to insect pest during one storage season of 8-10 months (Giga *et al,* 1991). With losses occurring at such rates the food security of the country will be under a threat. Storage insect pest causes both grain weight and quality losses.

According to Mvumi *et al* (1995), at least 75% of small-scale farmers use synthetic insecticides to protect their grain from attack by insect pest. However these synthetic insecticides can result in food contamination, putting consumers at a health risk. They also present a health risk to workers during application.

Diatomaceous earth does have great potential to offer an alternative method of grain protection. DEs are inert dust by origin and consist of the fossils of phytoplanktons (diatoms) which are mainly composed of amorphous hydrated silicates (Quarles and Winn, 1996). When insects come into contact with the DE particles, the waxy fat and lipids are absorbed from their cuticles, resulting in water loss dehydration and death (Ebeling, 1971). DEs are of extremely low toxicity to mammals (Subramanyam *et al* 1994) and are commonly used in cattle, poultry and dog feeds to combat internal parasites (Allen, 1972).

Locally, DE deposits have been identified along the Zambezi Valley and these can be locally accessed by farmers. However according to Stathers *et al* (2002) the main problem limiting their use as a grain protectant is the lack of information on their efficacy under small holder farming conditions. Thus there is need to asses the efficacy of the locally-occurring DE in comparison to commercial DEs, synthetic insecticides and other traditional methods of grain protection.

The effectiveness and persistence of the locally-occurring raw DE will be assessed on maize (*Zea mays*) and cowpeas (*Vigna unguiculata*) for up to 40 weeks during the 2004/2005 grain storage season. Maize is the staple crop and cowpeas are an important source of proteins in rural areas. Farmers find it difficult to store cowpeas since they are highly susceptible to insect storage pest. Determination of the most appropriate application rates and the residual protection offered by these DEs is also important.

1.2 Justification

The most widely used method for protecting grain against insect pests during storage is the application of synthetic insecticides (Stathers *et al*, 2002). However, these insecticides are frequently unavailable, out of date or too expensive and their misuse can be a health hazard. Synthetic insecticides are toxic they can also contaminate the food and pollute the environment. Thus the need for a safer method of insect pests control is justifiable. This would offer farmers a variety of insect pest control methods, including traditional methods.

Food security of the country can also be enhanced through the use of an alternative method for insect pest control. DEs are inert dust by origin, they cannot easily breakdown, and hence their persistence is high. DEs are easy to apply and admix with the grain, since they since they are of low toxicity to human beings (Subramanyam *et al*, 1994).

DEs do not require special protective clothing during application though there is need to cover mouth and nose during application to prevent inhalation of fine dust They are environmentally friendly, they do not cause the depletion of the ozone layer. They can easily fit into the existing grain protection system because they can be applied in both bag and storage structures.

The effective ingredients of synthetic insecticides are imported and this requires foreign currency which could be used for other purposes if an alternative method can be developed. So development of a local DE would reduce these expenses and enhance the country’s foreign currency base. Adoption of this post harvest technology would mean increased investments into the mining industry which will in turn create more employment and improve the country's economy. Exporting of the local DE to the neighbouring countries would also increase the country's foreign currency earnings.

1.3 Objectives

The broad objective is to assess the efficacy and persistence of a locally-occurring raw diatomaceous earth.

Specific objectives are:
1. To evaluate the efficacy and persistence of locally-occurring raw DE under on farm conditions
2. To determine the most appropriate application rate of a locally-occurring raw DE.

1.4 Hypothesis

A locally occurring raw DE is as effective and persistent as the synthetic insecticides or other commercial DEs.

2. LITERATURE REVIEW

2.1. Mode of action of diatomaceous earths

A considerable amount of research has been done on the use of inert dusts as insecticides, and their mode of action. Diatomaceous earths are inert dusts by origin and as a natural product they are chemically stable.

According to Chiu (1939b), inert dusts promoted water loss and their killing power is dependent considerably on the relative humidity of the insects' environment. This implies that, dusts kill by desiccation. However the way in which dusts promoted water loss remained obscure. Mellanby (1932) showed that in case of starving mealworms *(tenebrio molitor)* the weight lost as carbon dioxide in respiration was almost exactly equal to weight gained by the metabolic oxidation of food reserves to carbon dioxide and water loss and that therefore the weight change of insect treated with inert dust represented its water loss. There is no sufficient evidence that the weight loss was due to water loss. Furthermore water loss might be a secondary symptom arising from some unfavourable effects of dust on the organism such as for example some form of irritation.

Germer (1936) found that at 100% relative humidity, starving weevils dusted with an inert dust called Naaki, survived longer than control insects without dusts but under different conditions. The findings are however not reliable because it is impossible to carry out experiment with insects on grain in saturated air, since grain absorbs water and insects can never be in an environment of 100% until the grain has completely gone mould. It was then concluded that, the mode of action of dusts on insects is confined almost entirely to increasing rate of evaporation of water from them, and any other harmful effects, that may arise from ingestion of dusts, are negligible.

Mode of action of the inert dust is generally accepted as desiccation .Two observations support this conclusion. According to Fields and Muir (1995), inert dusts are more insecticidal when grain moisture content or relative humidity is lower and also insects treated with inert dusts have higher rates of water loss. However tests with two weevil species of *Sitophilus oryzae* and *Sitophilus granarius* did not reveal the same result (Carlson and Ball,1962).This implies that the desiccation theory may not be applicable to these two species or does not fully explain the mode of action on the two insect species. Further theories suggest that DE absorbs wax fats and oil (lipids) from the epicuticle (skin) of insects and other invertebrate pests (Ebeling, 1972).Once the waxy oil coating is removed the insect cannot retain water and dies due to hydration.

2.2 Factors influencing DE efficacy.

Behaviour of insects plays an important role in the efficacy of DEs, for instance insects that move extensive through grain, such as *Cryptolestes ferrugineus* may be more damaged than sedentary insects such as *Rhyzopertha dominica* (Fields, 2001). Higher concentration of DE is needed to protect corn than wheat (Ebeling, 1971; Aldryhim 1993; Quarles 1992ab). This implies that the type of grain is an important factor affecting DE efficacy, because before DE can give protection it must adhere first. Thus DE adheres more readily to wheat as compared to corn, increasing effectiveness at low concentration on wheat than corn increasing effectiveness at low concentration on wheat. Despite commendable work on the effect of grain type on the efficacy of DEs, much of these researches have been centred on commercial crops. Hence there is also need to test on DE efficacy and effectiveness on traditional crops.

According to LaHue (1970), Quarles (1992a), the measured effectiveness of silica gel against the lesser grain borer on wheat was found to be about 27 times that of DE Permaguard. The effectiveness was attributed to silica gel's higher capacity of oil absorption. This implies that the type of silica can affect adherence and DE efficacy. There can be a 20 fold difference in insecticidal activity between geological sources (Korunic, 1998). This implies that choosing the appropriate sources can increase efficacy of DE.It is therefore important to determine the type of silica in the DE deposits which have been identified locally along Zambezi Valley near Chirundu.

According to Stathers *et al* (2004), DE products were more effective at 50% relative humidity than at 60% in the laboratory. This implies that lower relative humidity promotes more water loss and hence increased efficacy. However a field test could have produced results which are more applicable to the actual storage environment. Furthermore Quarles (1996) indicated that DEs are more effective at higher temperatures as water loss is enhanced. This implies that higher storage temperatures are needed for effectiveness of DEs and there could be need for further studies on ways of increasing storage temperatures so as to increase DE efficacy. In relation to the factors affecting the DE efficacy Quarles (1996) showed that DEs are less effective on moist grain (> 14.55 moisture content) because insects have a constant source of water to replace the lost water. This implies that higher grain moisture reduces effectiveness of DEs.

Thus there is need for more field studies to asses the suitability of a locally-occurring raw DE to the local climate.

2.3. Health implications of DE

DEs are of extremely low toxicity to mammals (e.g. DE rat oral $LD_{50} >$ 5000mg/kg (Subramanyam *et al*,1994) and are generally regarded as safe by the USA Environmental Protection Agency (Anon, 1981). Despite giving the extend to which DEs are of low toxicity to mammals, the source does not show how the chemical composition or nature of DEs affect its toxicity since DEs are of different chemical composition.

The compositions of amorphous silica in the DEs affect its toxicity to mammals. Up to 2% GRAS (Generally Regarded As Safe) diatomaceous earth is allowed as food additive and up to 2% of amorphous fumed silica or silica gel is added as an anti-caking agent to many processed foods (Quarles., 1992ab; FDA., 1995ab; Villota and Hawkes., 1986). Although the source mentions the inclusion of amorphous silica as food additives, it does not indicate the importance of the substance to mammalian bodies.

Furthermore Fields (2001) showed amorphous silica to be carcinogenic if inhaled. However the use of dust masks or use of low amorphous silica DEs can protect against health risk. Despite giving alternative solutions to reduce the health risk of DEs the source is however not clear as to weather the use of low amorphous silica DE might have an effect on the efficacy. It is therefore of importance to determine the silica composition of the locally-occurring raw DE as this might have an effect on both the efficacy and health hazards associated with its use.

2.4. Efficacy assessment

2.4.1 Laboratory trials

Commendable efforts have been made in assessing the effects of grain moisture on the effectiveness of the DEs. According to Stathers *et al* (2004), relative humidity affects the rate of water loss by the insect and therefore influences the effectiveness of these DEs. In support of this Stathers *et al* (2004) further indicated that DE products were more effective at 50% relative humidity than 60% in the laboratory. A field study could have produced results which are more applicable to the actual storage environment. Furthermore the study was focused on the relative humidity which is only a single parameter of the storage environment. The effects of other factors need to be evaluated as well. Thus there is need to carry out more field studies in assessing the persistence and efficacy of inert dusts.

In the laboratory tests (Subramanyam *et al* ,1994) showed that all adults of *Cryptolestes ferrugineus* and *Cryptolestes pissilus* exposed to shelled maize treated with a DE called Insecto at 0.5g/kg of grain were killed within 2 days .However the laboratory results cannot be compared with the work conducted in United States on the long-term effectiveness of older diatomaceous earth formulations, mainly because Insecto was applied at 0.5g/kg of grain, whereas older diatomaceous earth formulations were evaluated using very high rates(usually at 3.5g/kg;range.1.75-7.0 g/kg).The tests also focused on a smaller insect spectrum..

Giga and Chinwada (1994) evaluated the efficacy of Dryacide compared to pimiriphos-methly and methacrifos in the laboratory. The results showed that the toxic effects of pirimiphos-methyl and methacrifos on bean bruchids decreased slightly with age of treatments. This suggested that Dryacide could be used as an alternative to dilute dusts. The findings were only focused on one insect pest and it could be different with other insect pests.

Despite the reliability of laboratory methods in evaluation of DEs, more field tests are of critical importance as these simulate the actual grain storage conditions under which the DEs will be applied. Furthermore it gives farmers an opportunity to do the day to day management of the trials.

2.4.2 Field tests

In United States, DE dusts have been evaluated for suppressing insects in stored shelled maize(Redlinger and Womach, 1996), wheat (Strong and

Sbur, 1963; White *et al*,1996; LaHue,1965,1967,1978), and rice (McGaughey, 1972).The diatomaceous earths tested were Kenite, Perma-Guard (LaHue 1965; Redinger and Womack, 1996 ;White *et al*, 1966) and Dicalite IG3 (Strong and Sbur, 1963). The results were that the effectiveness of these dusts on various insect species was variable, and high rates of (2-4g of dust/kg of grain) were necessary to obtain satisfactory (greater than or equal to 95% mortality) insect control. However the high application rates affected the flowable properties of the grain, test weight was reduced, grain quality was lowered and excessive amounts of dusts were produced during handling. As a result the dusts were initially not widely used or accepted by the grain industry for insect pest control. It is also of importance to assess the effects of the local DE on the grain flowable properties as they might have an effect on the grain qualities. The effectiveness of these dusts varied possibly because they were applied at different rates. Furthermore the tests were carried under different storage environment and also differences in the chemical composition of the dusts.

Subramanyam *et al* (1994) noted reduction of the effectiveness of a DE called Insecto at 0.5g/kg of grain on *Rhyzopertha dominica* and *Sitophilus orzyae.* This was attributed to uneven coverage of Insecto on grain kernels. The results implies that even distribution of dusts is important for the effectiveness of the DEs. The research was centered on a wide range of insect species, which does not truly reflects the actual storage conditions.

Prior to treatment, it is important to have some idea of the spectrum of insect pests most likely to be present during the storage season, to ensure that DEs are applied at an adequate application rate to protect the commodity (Stathers *et al*, 2004). This implies that insect require different application rates of the DEs for effective control. It is therefore essential to determine the most appropriate application rates which can be effective for a wider range of insect species under typical on-farm conditions. Thus there is need to assess the effectiveness and long term persistence of locally occurring raw DEs, in comparison to other commonly used methods as this might have important implications for the storage conditions of prior to application.

Much research has been done in trying to assess the effectiveness and persistence of DEs in Zimbabwe (Giga and Chinwada,1994;Stathers *et al*, 2002). Research on DEs began in the late 1990s and has been centred on evaluating imported DEs, Dryacide and Protect-It that Stathers *et al (*2002) found to be effective and persistent grain protectants. However, most of the work done focused on commercially developed DEs. For example trials have confirmed that the DEs Protect- It and Dryacide could successfully reduce populations of some major Zimbabwean storage pest, under constant climatic conditions (Giga and Chinwada,1994; Stathers *et al*, 2002). However these trials does not simulate the actual storage conditions, since in practice climatic conditions cannot be constant. Thus there is need to assess and determine the effectiveness of a locally-occurring raw DE under local climatic conditions.

Commendable work has been done in the field assessment of persistence and effectiveness of DEs. Stathers *et al* (2002b) showed that DEs called Protect-It and Dryacide were effective in protecting maize, cowpeas and sorghum during a 40 week storage period in three ecological zones of Zimbabwe. The recommended application rates were 0.1% Protect-It and 0.2% Dryacide. The results are more valuable because data on environmental storage conditions, duration of storage, application rates and grain types was captured. Furthermore the tests were carried out in two consecutive seasons however not for cowpeas. However the tests were centered on commercial DEs, thus there is need to evaluate the efficacy of a locally-raw occurring DE

3. METHODOLOGY

The study will be carried in Buhera District which falls under Natural Region (111).

3.1Trial Site, Timing and environmental conditions

Field trials will be carried out in Buhera district, under on farm-conditions in Ward 4. Researchers will set up the trials which will be managed by farmers on a day to day basis. Trials will be conducted over a 40 week period during 2004/2005 grain storage season starting from July 2004 to April 2005. This will be done to obtain data throughout the whole of the storage season. Rainfall, temperature and relative humidity data will be obtained from the meteorological station and these will be used to explain variations among the results.

3.2 Storage facilities

Treated maize grain will be loaded into 50kg polypropylene bags and these will be sourced from the local market. As for cowpeas, specially made 10kg polypropylene bags are to be used. The loaded bags will then be stored in different household within the Ward. Bags will be stored on raised platform, so as to prevent spoiling of grain through moisture movement from the floor.

3.3 Treatments preparation

Raw DE will be obtained as rock chalks , mined from Chemutsi in Zambezi Valley near Chirundi through the Dorowa Minerals Ltd, which is a private company. The rocks will then be pulverized using a pestle and mortar and then sieved using a 150 micrometer sieve to obtain a fine dust (Chemutsi grain protectant). Protect-It is a commercially registered DE and will be imported from a commercial company in Canada. Shumba Super Dust is a synthetic insecticide composed of 1% fenitrothion and deltamethrin 0.13% as its active ingredients and will be obtained from the local commercial market. Finger millet chaff is to be obtained from threshing of finger millet and maize core ashes from burning maize core cobs. These are some of the traditional methods used in Zimbabwe's rural areas by smallholder farmers.

3.4 Experimental design

A randomized complete block design with four replicates will be used the trial. The households will be treated as separate blocks. Allocation of treatments to bags will randomize within blocks to eliminate bias and to ensure that there will be an independent observation.

3.5 Grain treatments

Maize and cowpeas grains will be obtained from different farmers, and all will be mixed thoroughly at one place so as to cater for variety differences.

3.51 Maize treatments

Maize will be treated by thorough admixing with the grain protectant on polythene sheets using clean shovels. Treated grain will then be then loaded into 50kgs (actual mass of the grain). Four replicates per treatment will be made, with each treatment being represented. The bags will be sewed and taken for storage.

Treatments were as follows:

Grain protectant	Application rates
Protect-It	0.1%w/w
Chemutsi	0.15%w/w
Chemutsi	0.2%w/w
Chemutsi	0.25%w/w
Shumba Super Dust	0.4%w/w
Finger Millet Rapoko	1:1 v/v

3.52 Cowpeas treatments

Cowpeas will be treated by thorough admixing with the grain protectant on polythene sheets using clean shovels. These will be loaded into 10kgs (actual mass of the grain). Four replicates per treatment will be made with each treatment being represented. The bags will be sewed and taken for storage.

Treatments will be as follows:

Grain protectant	Application Rates
Protect-It	0.1%w/w
Chemutsi	0.1%w/w
Chemutsi	0.15%w/w
Chemutsi	0.2%w/w/
Maize core ashes	5%w/w

3.6 Grain sampling

Samples of approximately l.5kg of maize and 500g cowpeas will be collected these will be measured using a field scale. This will ensure enough grain for analysis. Sampling will be done at loading in order to assess the pretreatment condition of the grain. Sampling will be carried out after every 10 weeks during the storage season. Bag sampling probes will be used to obtain the samples of grain. Several thrusts will be made to obtain the required sample mass. A probe will be reserved for sampling one particular treatment, whilst one spear will be used for Chemutsi DE treatment of different rates. Samples will be collected into labeled plastic bags and then tightly sealed to prevent further moisture variation. Several thrusts will be made to obtain required sample mass. Collected samples will be emptied into labeled plastic bags and then tightly sealed to reduce further moisture absorption.

3.7 Sample analysis

3.71 Moisture content determination

200 grammes of maize and 150 grammes of cowpeas grain will be removed from each sample for moisture content determination. 3 sub-samples will then be used to determine moisture content. Weight of the wet sub-samples will be determined using a laboratory scale. These will be placed into an oven at 113 ^{0}C. After 4 hours the dry weight of each sub-sample will be determined. Moisture content will be calculated using a conventional wet basis approach as shown in the formula below

Moisture content %(mc) = (Wwet-Wdry/Wwet)*100

Where: W*wet*=weight of wet sub-sample., W*dry*=weight of dry sub-sample

3.72 Insect counting

Further analysis will be done by determining the insect pest populations and species. Firstly trash will be separated from insects using a nest of sieves. Manual counting will be done to determine sample populations of dead and live insects with the help of forceps and a tally counter. Counting will be carried out within five days after sampling. All sieved samples will then be weighed and placed into a freezer, to prevent to prevent further insect development before damage assessment.

3.7.3 Grain damage assessment

Samples from the freezer will be mixed thoroughly by shaking so as to eliminate bias. A riffle divider will be used to obtain a reduced working sample. 3 reduced working samples from each sample will be analyzed for the extent of grain damage. Damaged and undamaged grain will be counted and their masses will be determined. Damaged maize grain will be classified by the number of holes and three classes will be used namely 1, 2 and greater than or equal to 3.

4 DATA ANALYSIS

MS Excel will be used for data entry and summarizing the required variables. Data will be analysed using the Genstat5 executable statistical package. An Analysis of Variance (ANOVA) will be carried out to determine if there are any significant differences between the treatment means.

5 EXPECTED RESULTS

Local DE will be found effective and can be registered by a local Agro-chemical company

6. LIST OF RESOURCES AND MATERIALS

Storage facilities	Plastic sample bags, Polypropylene bags for maize and cowpeas
Grain protectants	Shumba Super Dust, Chemutsi, Protect-It, Mize core ashes, Finger millet chaff
Admixing	Shovels , Polythene sheets,
Sampling	Bag sampling probes,(ideally one for each treatment), Rubber bands , Oven ,Mass balance, Nest of sieves, Field scale, Forceps and tally counter, Trays, Riffles and Divider,

	freezer
Grain quantities	1400kg(Maize), 240kg(Cowpeas)
Labour	8 farmers to host the trials , 2 additional workers for sample analysis

7. TIME PLAN

Activity	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mac	Apr	May
1.trial set up											
2.Sampling											
3.Sample analysis											
4.Data entry and processing											
5.Data analysis											
6.Writting up											

7.Binding of dissertation and final submission											

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