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Effectiveness of Maize Cob Powder in Controlling Weevils in Stored Maize Grain

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Abstract: The broad objective of this study is to assess the effectiveness of maize cob powder in controlling maize weevils in stored maize grain. A completely randomized block design, in which twelve small bags of maize containing 0.5 kg of maize grain (SC5313 dent variety), were used. Three concentration levels of maize cob powder 5g, 45g and 75g per 0.5 kg were compared with the control experiment containing conventional chemical Actellic super at 5g. Findings showed that conventional chemical control was more effective than traditional method at 5g and 45g levels of maize cob powder. However, greater effectiveness of cob powder was observed at 75g level. In the absence of conventional methods of control, which are unavailable due to local supply bottlenecks, the study recommends use of maize cob powder to control weevils.

BACKGROUND

The importance of the maize sub sector within the Southern African Development Community (SADC) region is well researched and documented. Maize is an integral component of the staple diet of the citizenry of this region and is also considered to be an essential source of cash for farmers.[1] It is also used in the manufacture of a wide spectrum of industrial products ranging from animal feeds to food products. Thus, the maize sub sector has important backward and forward linkages with industry.

In recent years, the region has witnessed dramatic changes in rainfall patterns ushered in by global warming that culminated in more frequent droughts.[2] The effect of intermittent droughts has manifested itself in declining maize output, further exacerbating the livelihoods of farmers and the general populace. The effects of poverty largely stem from the failure of agriculture to sustain the lives of the rural poor. It is therefore not a surprise that the majority of the families in SADC live on less than $1 per day.[3]

Declining food production exposes farmers to chronic and transitory food shocks. This creates the need for farmers to come up with mechanisms for conserving their scarce food resource base. Maize, which is normally stored in granaries, is usually treated with a different array of chemicals for preservation against pests such as weevils. Indeed, weevils *(stophilus zeamais)* are often identified as one of the major problems causing loss of stored grain in Africa.[4] It is estimated that weevil attack accounts for approximately 5-10% of maize grain loss in Southern Africa.[5]

In Zimbabwe, two main chemicals -- Shumba and Actellic Chirindamatura Dust ---- are used to conventionally treat stored maize grain.[6] However, the inimical macro-economy has resulted in high prices for these products and the need for identifying other methods of preserving maize grain. One port

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of call for rural farmers is using localized methods of preservation found within indigenous knowledge systems.

Indigenous knowledge is unique to a given culture or society.[7] It creates the basis for local level decision-making in agriculture, health care, food preparation and preservation, education, and natural resource management. Indigenous knowledge is an important ingredient for development but is grossly under-utilized.[8]

A cocktail of methods, extracted from local knowledge, have been used to preserve maize grain for generations in Zimbabwe. However, one of the most eminent "indigenous approaches" of maize preservation is using maize cob powder. After shelling maize, the remnants are burnt and the resultant powder is sprinkled on maize grain and this confers longevity to maize grain.

This method can be questioned from two angles. Firstly, to what extent does this method improve the shelf life of stored grain? Secondly, does the resultant soot from burnt cob powder discolor the maize grain or render it unfit for human consumption? Thus, the crux of the matter in this study is to broadly look at the value of local knowledge in preserving stored maize grain.

Problem Statement

Conventional approaches to development in Africa have often required the transfer of technology from developed to developing countries. This obliterates the importance of local knowledge and experiences in solving local problems peculiar to rural communities. Although, weevils account severe losses in stored maize grain in Southern Africa, the sustainability of conventional chemicals used to preserve grain is questionable given the high level of poverty present in the rural communities in Africa. Local prescriptions emanating from indigenous knowledge base, such as the use of maize cob powder are grossly under-researched. Thus, there is a paucity of information which illustrates the value of indigenous knowledge in the preservation of agricultural and food products. This study therefore provides a scientific inquiry to practices passed on for many generations in Zimbabwe.

Research Questions

1. To what extent is maize cob powder effective in controlling stored maize grain?
2. Do the maize ashes have an effect on the quality of the stored grain?

Objectives

The broad objective of this study is to ascertain the value of indigenous knowledge through determining the effectiveness of traditional methods of preserving maize grain.

The specific objectives of the study are:

1. To assess the effectiveness of maize cob powder in controlling weevils in stored maize grain.
2. To ascertain the effects of maize cob powder on quality of stored grain.

Justification of study

The inauspicious macro-economic environment in the country implies that farmers cannot effectively access conventional technologies for preserving maize grain. Although indigenous knowledge is one of the options for farmers, little is known about whether the various methods used locally are effective. Therefore this study is important in generating information for sharing experiences with local rural communities constrained by scarce resources.

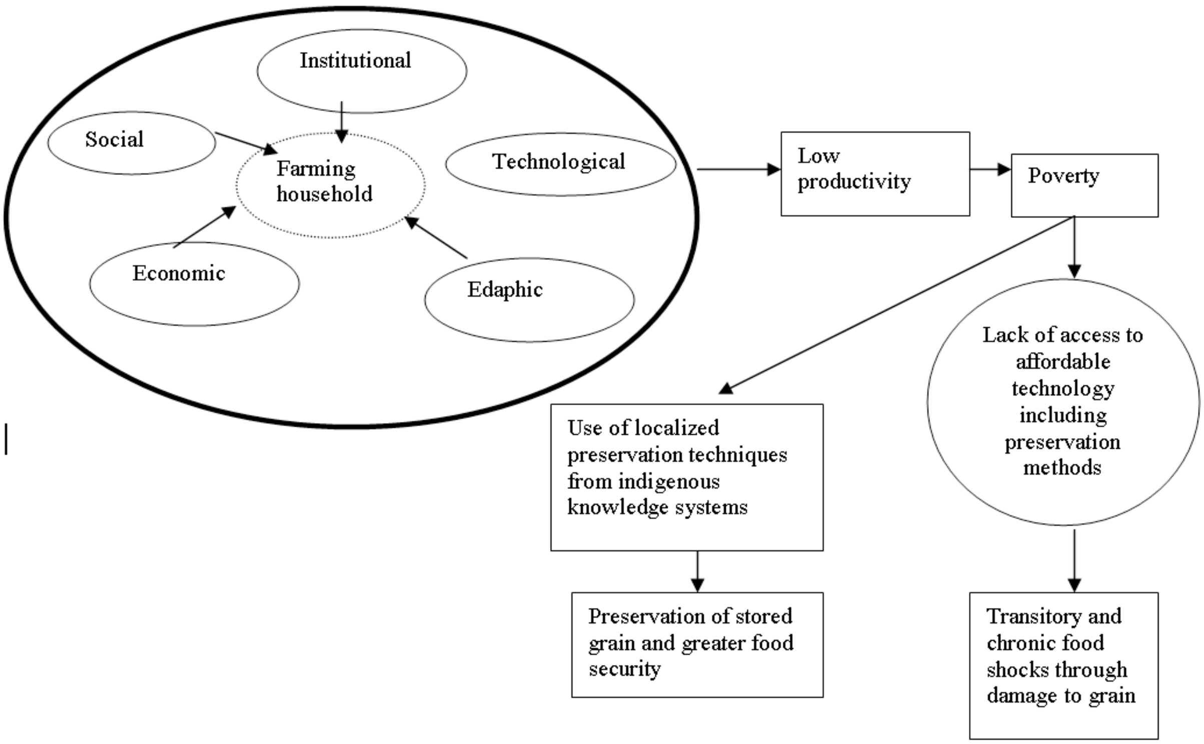
LITERATURE REVIEW

CONCEPTUAL FRAMEWORK

Fig 2.1 depicts the complex environment within which the smallholder farmer operates. Outcomes for the farming household are shaped by social, economic, institutional, and technological factors. Economic factors determine farmers' participation in markets and this can have a direct bearing on farm productivity through acquisition of production inputs. The institutional environment mainly consists of information sources such as extension workers for enhancing access to credits and agricultural information. Edaphic conditions are shaped by the prevailing climatic conditions and affect productivity by determining rainfall patterns and soil fertility, among other issues. The social environment consists of the networks through which the local community shares information. Indigenous knowledge is also part of the social system but is normally overridden by formal sources of information such as extension agents.

Overall, the farmer is operating in a constrained optimization scenario and this often leads to low productivity. Low productivity translates into poverty since agriculture fails to sustain farmers through sale of produce. This condemns the farmer to subsistence production, that is producing only for family

Fig 2.1 Relevance of indigenous knowledge to farmers' livelihoods



needs. However, this food stock, mainly maize, is exposed to pests and other hazards such as weevils. This can potentially result in further food bottlenecks for the farmer. Since the household is not effectively participating in the cash economy, it cannot access expensive technologies for preserving this food stock. Assuming rationality, the farming household then resorts to using cheaper methods of preserving food reserves such as using maize cob powder. This ensures that the household is able to overcome transitory food shocks. Therefore indigenous knowledge can compliment already existing conventional methods of food preservation.

Effects of maize cob powder on maize kennels

According to the 1995 Elwell study, ashes from plants (wood, cobs, and stalks) used in combination with agricultural lime has the effect of preventing insects from moving from seed to seed. Seeds soaked in cob ashes are protected against fungal and bacterial diseases as well as protection from weevil attack. Cob ash contains certain natural salts and these create inimical conditions for growth and habitation of weevils. This characteristic gives the ash some insecticidal property. Other studies have also shown that salt mixed with maize grain confers protection to grain for sustained periods of time.[9]

Results from a series of experiments in some African countries such as Zambia and Mozambique have shown that maize protected using traditional methods of preservation (e.g. cob) ash was not significantly different in quality from maize grain protected by conventional chemicals.[10] However, there are gaps in the scientific literature on using cob ash in traditional African systems.

Conventional approaches to protecting grain against weevil attack

A number of insecticides, usually in the form of fumigant dust are used to control weevils. These include methyl bromide, phosphine and carbon disulphine, and Malathion dust. Other approaches for protection against weevils include use of airtight storage systems to suffocate weevils and weevil proof containers.

Over the years, concerns have been raised over the use of chemicals on human health and ecosystem balance.[11] Argues that over-use and abuse of agro-chemicals imposes serious costs on a nation's economy while eroding the ecological foundations and thriving agro-ecosystems. Evidence from different African countries illustrates that improper use of chemicals is causing loss of life and negative repercussions on human health.[12]

Traditional remedies used for post harvest crop preservation in Zimbabwe: Historical Overview

State-sponsored attempts to introduce new technological innovations among smallholder farmers in colonial Zimbabwe were begun in 1926. The Rhodesian government enacted a two tier agricultural extension policy that served the interests of smallholder and large scale farmers through the Department of Agricultural Development (DEVAG) and Department of Conservation and Extension (CONEX) respectively.[13] The extension approaches used were prescriptive and tended to deligitimize the use of methods derived from indigenous knowledge by farmers. Indigenous methods of crop preservation were used by local farmers during the 19th century and early part of the 20th century. However, the nature of crop preservation has been dynamic from the pre-colonial period to present day Zimbabwe. A key feature of most approaches is that they are derived from locally available natural materials such as trees, shrubs, and sometimes parts of crops. Since there were little or no cash demands in the acquisition of traditional methods of preservation, it meant that they were readily available and thereby consistent with the small farmers' social, economic, and institutional setting. An inventory of the known methods of crop preservation used by smallholder farmers during the pre-colonial period is presented in this section. Some of the preservation materials are native to Zimbabwe (lipia and marigold species) whilst others are exotic (eucalyptus species). The exotics could have been brought by early Portuguese traders during the pre-colonial period since they started spreading from the Southern part of the country which borders with Mozambique along routes used by the Portuguese.

Eucalyptus species (Gum Trees)

The basis for using gum trees as a method of crop preservation is predicated on the strong aromatic smell that characterizes the leaves of the trees. In Zimbabwe, gum tree leaves have been used to preserve crops such as beans, Irish potatoes, maize, millet and sorghum.[14] The oil exuded by the gum leaves repels bean bruchids whilst the aroma emanating from the leaves repels maize weevils. In all cases the gum leaves are spread before and after the crop is stored such that there are two layers of leaves in the granaries. The quantity of leaves used for any given crop depends on expectations of the likely occurrence of pests as well as the farmers' experience with the method. Use of gum tree leaves has been restricted to areas where the tree grows well in Zimbabwe, particularly in natural regions 1 -- 3 which receive at least 500 mm per annum and relatively warm temperatures that range from 18 degrees Celsius.

Lipia Javanica

This is a common perennial shrub in Zimbabwe with a characteristic aromatic smell. Historically, the leaves have been known to repel pests and it has also been used as a spray against aphids. In grain crops such as maize, it has been used to repel a broad range of pests, including weevils.

Marigold leaves

Marigold is one of the most problematic weeds in Zimbabwean crop agriculture. In spite of this, the weed is used by some farmers to kill nematodes and suppress other oil borne infections. In grain crops, it is used by placing alternate layers of grain with the marigold leaves. This method is more rarely used in most parts of the country since its effectiveness hinges on the availability of the plant within the farmer's environs.

Salt

Salt (in dehydrated form) or in solution has a dehydrating effect on soft-bodied insects such as caterpillars, snails and slugs. Salt is not used in the preservation of grain crops since most of the pests attacking these types of crops have a hard outer shell.

Tobacco

Tobacco contains the strong aromatic poison nicotine that is toxic to a wide spectrum of pests and microorganisms. In Zimbabwe, farmers use it as a method of crop preservation, especially against the grain weevil, only at low levels in cases of lack of access to conventional chemicals such as Target® or Coopers Shumba. Tobacco can also be dusted on to vegetables as a remedy against spider mites, aphids, and various caterpillars. Farmers argue that it is less harmful in this form. However, the main drawback of this method is that food plants treated with tobacco must not be eaten for at least three days.

Wood ash

Wood ash use for the preservation of grain crops in Zimbabwe dates back at least to the late 19th century. During this period, agricultural production by farmers was largely subsistence oriented. Furthermore, no manufactured chemicals were known by the farmers themselves or traded by the early Portuguese traders who came into the country during this time. Wood ash was by-product of fires prepared for cooking purposes by households. It was used mainly for two purposes. Firstly, it was applied in fields as a form of fertilization and as a deterrent to slugs, snails and cutworms. Secondly, it also found its use in grain storage where it was often mixed with other ingredients obtained from other plants.

Characteristics of smallholder agriculture in Zimbabwe

In Southern Africa, smallholder agricultural production is relatively homogenous with the majority of farmers practicing crop agriculture on tropical soils poor in organic matter with low inherent soil fertility)mainly lacking nitrogen, phosphorus, and sulphur). As a result of general economic malaise characterizing this region, productivity has been declining thus compromising the food security situation of rural households.[15]

In Zimbabwe, agriculture has traditionally been the prime mover of economic development. Prior to the recent land reallocations, large-scale farmers occupied about 11.2 million hectares whilst small farmers occupied 16.3 million hectares with an average of 16.3 hectares per farmer.[16] Crops such as maize, millet, groundnuts, and sorghum dominated the cropping pattern. Cash crops are primarily tobacco, cotton, and soybeans. Crop productivity among smallholder farmers increased nominally by 400 percent between 1980 and 1990 from Z$148.28 million (US$ 148.28 million) in 1980 to Z$ 603 million (US$ 120 million) in 1990. This trend was attributed to the use of inputs such as fertilizers, chemicals, and hybrid seeds. For instance, seed sales rose from 4, 500 tonnes in 1980/81 to 16,000 tonnes in 1989/1990 and fertilizer sales increased from 24,000 tonnes in 1975 to 130,000 tonnes in 1986 and to around 200, 000 tonnes in 2003.[17] Presently, approximately 96% of farmers use improved seed despite evidence that open pollinated varieties such as Salisbury White and Hickory King are surging back because of current high seed costs. Productivity in the 1990s generally declined because of droughts of 1991/92 and the 1993/94 seasons. The structure of agriculture changed from the year 2000, ushering in more resource stressed smallholder farmers. Although agricultural exports are still important, these have been declining due to a range of problems such as rising cost of inputs and recurring droughts from 2001 to 2004. For instance, the fertilizer price to maize ratios from 1980 indicate that the price of fertilizer has been raising faster than the price of maize, thus lowering the gross margin obtainable from major crops. Therefore crop production systems relying on external inputs are not sustainable for most smallholder producers both because of the immediate escalating procurement costs and longer term effects on the environment.

Social context

Zimbabwe has been facing an inimical economic environment over the past five years (2000-2005). As a result, the gross domestic product (GDP) has been declining by an average 8% per annum.[18] The rate of inflation has risen from 32 to 1042 percent in the years -- 1998 2006.[19] Foreign direct investment declined from US $ 440 million in 1998 to US $ 3.6 million in 2005 resulting in foreign currency bottlenecks.[20]

These challenges have trickled down to the farm level, particularly reducing the profitability of agricultural activities and purchasing power. The population living below the poverty datum line (US $ 1 dollar per day) was 36% between 1989-1994 and rose to above 80% in 2003.[21]

Use of inputs by smallholder farmers

Most smallholder farmers in the country still use hybrid seeds which account for 90-95% of all maize seed planted by farmers in any given season. The rising cost of maize seed has, however, resulted in an increase in the number of farmers (20%) using retained seeds, mainly in the northern provinces of the country. In addition, the increasing cost of fertilizers has resulted in changes in the crop production systems. Farmers located in southern and eastern provinces of the country are relying on cattle manure as opposed to conventional chemical fertilizers.[22] Farmers have also been facing post harvest problems because of difficulties in accessing markets. Thus, there is gravitation towards sustainable, low input production systems by Zimbabwean farmers in the country.

Opportunities for using traditional production methods by farmers in Zimbabwe

The unstable environment over the last five years has negatively affected the nominal prices of fertilizers and chemicals. Free government input supply schemes meant to bridge this gap have been falling in nominal value and are not effective in enhancing access to inputs by farmers. The use of inorganic fertilizers and chemicals has therefore been declining among smallholder farmers. In Chivi District of Masvingo Province, for example, use of inorganic fertilizers and agro-chemicals decreased by 78% and 71% respectively.[23] Reliance on expensive hybrid seeds by farmers negatively affected traditional systems of storage and the re-use of seeds in subsequent production seasons. The need for farmers to explore options of crop production and preservation is inevitable given the current supply bottlenecks and also because capital markets are increasingly becoming closed to farmers through prohibitive interest rates nearing 300%.[24] There is gathering evidence, which indicates that farmers in the country, particularly in the southern and eastern districts, are resorting to traditional methods of production and crop preservation. The main advantage of these methods is that the materials used are locally available and within the farmers' reach. They are also relatively easy to use and can be environmentally sustainable. Despite claims by farmers that most of the methods based on traditional knowledge are 'effective' there is little supporting scientific evidence within Southern Africa.

RESEARCH METHODOLOGY

Study Site

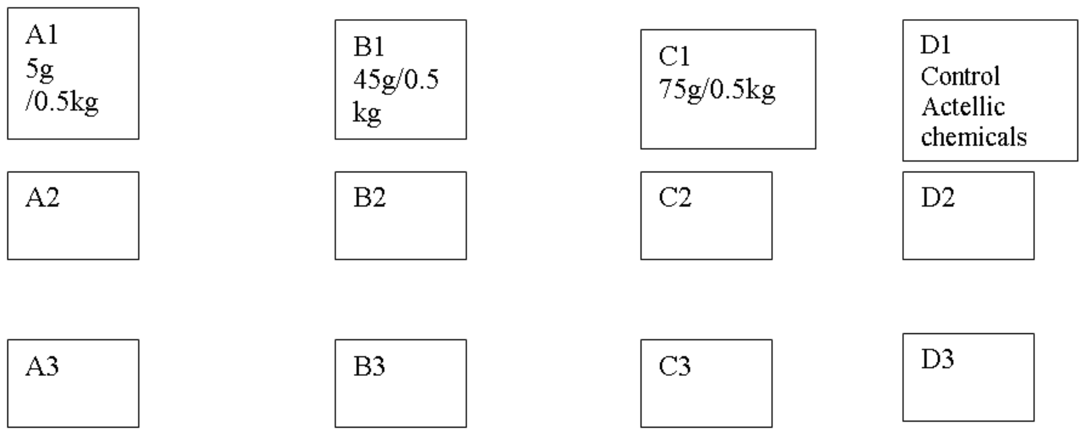
The experiment was conducted at Belvedere Technical Teachers College (BTTC) farm located in Mashonaland East Province of Zimbabwe. The study site conditions are typical of agro-ecological region II, one of the prime agricultural zones of the country. This region covers 7,343,059 ha and this represents approximately 18.68% of the total land size in Zimbabwe. Rainfall received in a normal season ranges from 700-1050mm and is restricted to the summer season. Temperatures ranging from 20-27 degrees Celsius are experienced.[25] Farming in this region is mixed and eminent crops include maize, cotton, tobacco, and soybeans whilst significant beef, dairy and pig production also take place.

Research Design

The methodological framework used a completely randomized block design with four treatments replicated three times. Treatments were 5g, 45g, 75g of ash per bag and 5g of Actellic Chirindamatura dust (manufacturer's recommended level). In this approach, 12 small jute bags of maize containing 0.5 kg of maize grain (SC5313 dent variety) were used. The SC513 was chosen since it is a commonly grown variety among smallholder farmers in semi arid areas. Harvested maize was checked for the existence of weevils before the experiment and also that it was free from inorganic chemicals. The nine bags were then sub-divided into three groups. The first three bags were labeled A1, A2, and A3, the second group B1, B2, and B3 whilst the third group was labeled C1, C2 and C3. The three bags in each set were considered replications for the experiment. To the first set of bags, 5g of ash were mixed with maize grain in A1, A2 and A3. For the second set of bags, B1, B2 and B3, 45g of ash were added. On the third set of bags, 75g of ash was added to the C1, C2 and C3. Extra three maize bags D1, D2 and D3 were used as the control group of maize. The bags were then put under the same conditions: which would mimic typical conditions of African granary, i.e. dry with ambient temperatures of about 24 degrees Celsius. Equal numbers (10) of weevils (Stophilus zeamais) were then put in each of the maize grain bags, ensuring that the weevils did not migrate from one-grain bag to another. The researchers then checked weekly for any changes in the containers over a period of 2 months.

Layout of the experiment

Fig 3.1 Layout of experiment



Hessian bags were used for the experiment and were arranged in the manner depicted in Fig 3.1. The room was clean and ventilation was guaranteed to ensure that the weevils had sufficient air supply. In addition, the grain bags also allowed for air movement without allowing them to migrate out of the bags. Blocks indicate replications for each level of ash concentration.

Parameters collected from each sample unit

Two parameters were of interest in this research and these included:

- Number of live and dead weevils collected weekly at different concentration levels
- Change in the color of grain

Data Analysis

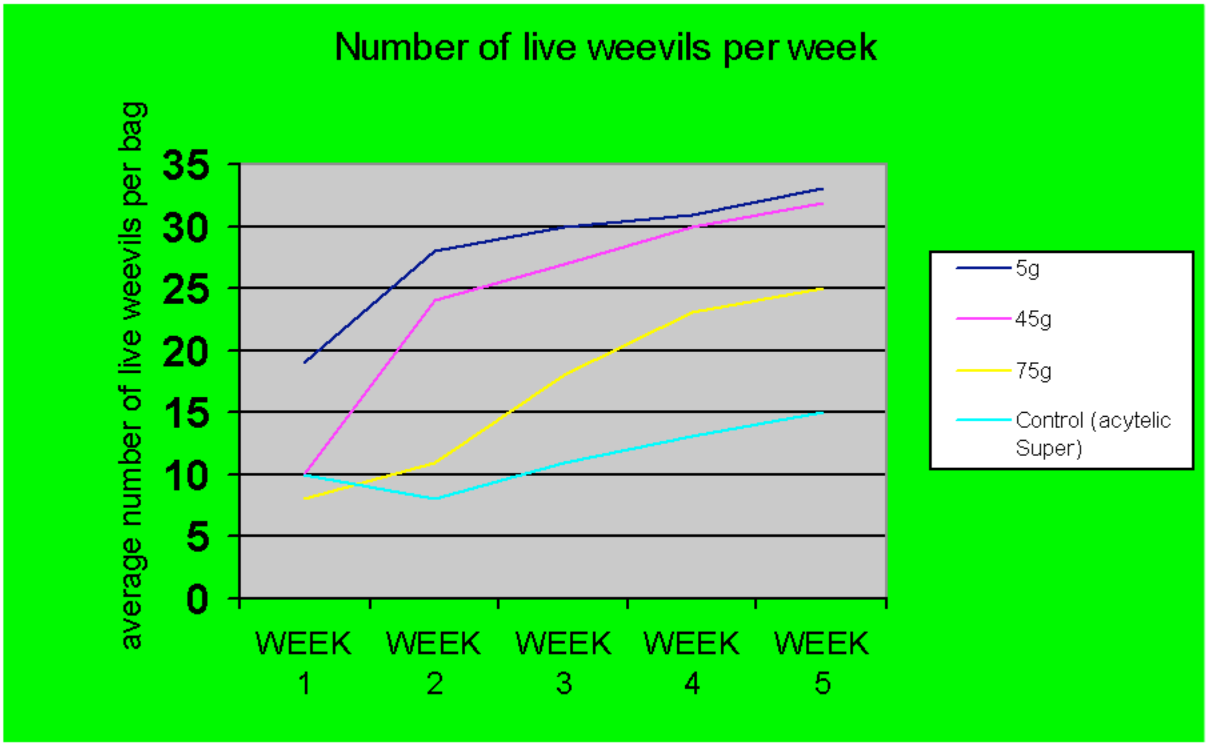
An analysis of variance table was set to investigate whether there were statistical differences in the numbers of live and dead weevils as well as the quality of maize grain used. A one-way ANOVA table was set up to investigate whether there were differences in the grand means of weevils over time.

RESULTS AND DISCUSSIONS

Variations of live weevils at different levels of ash powder concentration

Fig 4.1 indicates the changes in the number of weevils from each bag over five weeks. The basic shapes of the functions are almost similar with the number of weevils in each bag increasing over the 5-week period. The higher the concentration of ash in the bag, the lower the incidence of weevils. This may be attributed to the toxic effect of higher levels of cob powder administered to the different bags. It can also be seen that for the control (which used Actellic Chirindamatura Dust), number of weevils were higher in the first than the 75-g ash powder concentration but this changed from week 2, with the control group increasing at a steady rate. The findings of this study are similar with those of Elwell and Booysen who illustrated that an increasing cob powder concentration results in a reduction in the incidence of weevil attack. [26]

Fig 4.1 Graph showing weevil numbers per week with varying ash powder concentrations



Means from each sample
Mean and standard deviations from each block

Results from Table 4.2 show that the control group of bags had the lowest number of weevils throughout the 5-week period followed by the 75g cob powder concentration. The least effective rate of application was the 5g-concentration level.

Ash Concentration	Minimum	Maximum	Mean	Standard deviation
5g	19	31	27	5.5
45g	10	30	23	8.8
75g	8	23	15	6.8
Control (Acetylic Super)	8	13	10.5	2.5

ANOVA RESULTS

The main hypothesis to be tested in this study was to determine whether there is a difference between the average numbers of weevils found per unit time across the different treatments. The results of the ANOVA table are shown below.

ANOVA TABLE

Dependent Variable **Number of Weevils**

Source of variation	***Mean squares***	***F value***	***Significant F***
Concentration Levels	205.500 (MSE1)	4.693	0.022
	43.792 (MSE2)		

The hypothesis being tested by the ANOVA table is that there is no difference in the average number of live weevils per bag over the 5 weeks. Since the significant F value is less than 5%, we reject the hypothesis that the means are equal. Therefore, the effects of the conventional chemical and cob powder are statistically different at the 5% level. One can conclude that there is a difference in effectiveness of maize cob powder and acetylic Super under the given set of conditions. The results from this study are at variance with those found by Elwell, 1995. However, this could be attributed to the different conditions under which their research was carried out.

Changes in the color of grain

At the end of 5 weeks, each of the samples was exposed to winnowing to remove the dust and ash. It was observed that for 5 and 45g ash concentration the dust could be easily removed. At 75g there was an element of discoloration, though this was not deemed significant in terms of quality.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of the study indicate that higher levels of cob powder are associated with lower incidence of weevils in any given sample. In the experiment, two treatment levels (the 5g and 45g) were observed to be increasing functions. These two functions increased at an increasing rate in the first two weeks and increased at a decreasing rate in weeks 3 to 5. This could be attributed to the slow toxicity effect of the cob powder in the first two weeks. The subsequent shape of the functions could be explained by the attainment of a minimum toxic threshold as the weevils are further exposed to the local microenvironment within experimental bags. Lower levels of cob powder permit relatively rapid multiplication of weevils. The shape of the 75g function almost resembles that of the control, in that weevil multiplication is curtailed in the first two weeks before increasing at a decreasing rate albeit at a lower level. It is possible that levels slightly higher than the 75g could almost simulate the shape of the control function.

The results showed that there is a statistical difference in effectiveness between the conventional and traditional approaches of preserving maize. The average numbers of weevils for the experimental period were 11 for the control and 15 for the 75g treatment level. Based on these observations, the conventional chemical control is superior in conferring an environment that is toxic to the multiplication of weevils. The need to explore the effects of levels such as 80 or 85 g of cob powder cannot be over-emphasized. Higher levels of cob powder would, however, also mean greater demand for the farmers to gather cobs and fuel energy, burning the shelled cobs, and creating fine powder through removing undesired objects. This would increase the shadow economic cost of the maize cob powder.

The transaction costs of acquiring conventional chemical techniques for preservation are relatively high for most smallholder farmers who are frequently located in inaccessible production areas. These costs include searching for appropriate information on the available chemicals and markets (such products may be unavailable in formal markets due to input supply bottlenecks in the country), as well as transport costs to and from formal market outlets. These costs can act as deterrent to smallholder use of chemicals for post harvest preservation.

The farmer is faced with a dilemma: he/she wants to ensure food security from one season to the next but also needs to acquire the form of crop preservation technology at a low cost. In the absence of the required chemicals, smallholder farmers can trade efficiency of the preserving technique for convenience and affordability. Traditional techniques confer some measure of protection but this protection may only be guaranteed at high levels of ash concentration of at least 76g/0.5 kg of maize. Amounts such as 76g could be used for levels of up to 5 kg of grain. Using this upper limit, this translates into 0.76 kg per bag and 15.2 kg of ash per tonne of grain.

It is also important to note that the findings of this study were only reflecting a given set of conditions in the Middleveld of Zimbabwe and this could affect the results. It is critical to broaden the scope of the study to include different maize varieties. Although the behavior of weevils was not an explicit parameter in this study, future related study endeavors could also investigate the relationship between weevil behavior and ash.

Recommendations

According to study findings and experiences of some farmers, it is possible to use an application rate of at least 76 g of ash for 5 kg of maize grain. As such, a rate of around 15 kg of ash is recommended per tonne of maize grain. Since measurement challenges are encountered by farmers in quantifying the required levels of ash, a 50kg sack (by volume) full of shelled maize cobs can give 2-3 kg of ash depending on the level of burning. Thus 5*50kg sacks of maize cobs may suffice to treat 1 tonne of maize grain.

The value of indigenous knowledge cannot be doubted as illustrated by the study. Farmers may use cob powder in protecting their harvest against weevils. As a rule of thumb, effectiveness of cob powder is normally observed at high levels of concentration. Farmers will have to strike a balance between low cost and the labor time invested to remove ash when preparing for food consumption.

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