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Use of the Triple-Layer Hermetic Bag against the Maize Weevil, *Sitophilus Zeamais* (Mots) in Three Varieties of Maize

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Abstract
Maize ranks with wheat and rice as one of the world's chief grain crops. However, the safety of this important food crop is threatened by pests such as insects, rodents and moulds which results from inappropriate storage methods. Insect pest infestation accounts for about 20-50% of all food crop losses. This study was carried under ambient laboratory conditions of 32± 2°C and 72-88% r.h to determine the effectiveness of the triple-layer hermetic bag in controlling the maize weevil *Sitophilus zeamais* (Mot) on three varieties of maize (Obatampa, Abrodenkye and Kamangkpong). Five (5) kilograms of each variety with three replicates were infested with 50 *S. zeamais* and stored for three (3) months in three different types of bags (hermetic, Polypropylene and Jute). Destructive sampling was done monthly to determine the moisture content, viability of each variety and weight loss after storage. Percentage damage of grain due to *S. zeamais* was assessed on the different types of storage bags. The results show that the high yielding Obatampa was more susceptible to *S. zeamais* than the two local varieties; Abrodenkye and Kamangkpong. Damage, weight loss and germination rates were significantly ($p < 0.001$) higher in the polypropylene and jute bags than the hermetic bags. These were also dependent on the length of storage. The triple-layer hermetic bags were effective against *S. zeamais* and could be used for storage of maize.

Keywords: Maize weevil, *Sitophilus zeamais*; Triple-layer hermetic bag; Polypropylene; Jute.

1. Introduction

1.1 Maize production and importance of storage in Ghana

Maize is the most important cereal in Ghana and is the staple food for about 90% of the population.
Average annual production increased from 141,000 metric tonnes in 1983 to 533,000 metric tonnes in 1993 (PPMED, 1993) and currently stands at 1,871,700 metric tonnes (ISSER, 2011).
As maize can be stored for longer periods than root crops, it is a very important crop during the lean season. Post-harvest grain storage in Ghana and other developing countries of the world is a major constraint. Maize price is one of the most important factors that influence its storage in Ghana. Maize deficit areas also experience these price hikes. Such areas usually experience price increase of over 200% to 300% from the main harvest to lean season (SRID, MOFA, 2006). Stored maize is attacked by 20 different species of insect pests including the maize weevil, *Sitophilus zeamais* (Mots.) (Coleoptera: Curculionidae) and the larger grain borer (LGB), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). Recently, it has been reported that 9% postharvest losses are due to insect and mite infestation worldwide; suggesting a need to make strenuous effort to control them (Vachanth et al., 2010). In Ghana, about 20% of annual maize and cowpea production are lost to *S. zeamais* (Owusu-Akyaw, 1991).

The maize weevil, *S. zeamais* (Figure 1) occurs throughout warm, humid regions around the world, especially in locations where maize is grown. It commonly attacks maize before and after harvest, and is also associated with rice. Insect pest damage to stored grain results in major economic losses to farmers throughout the world (Obeng-Ofori et al, 1997). These losses are diverse and intense, and it is estimated that approximately one-third of the world's food crop is damaged or destroyed by insects during growth, harvest and storage.

Besides contamination with the insect bodies and frass, the food substrate can be exposed to quinines that are released from the thoracic and abdominal defense glands (Kabir et al., 2011).
Currently, insect control in stored food products relies heavily on the use of gaseous fumigants and residual contact insecticides (White, 1995; Obeng-Ofori, 2007; 2011). The widespread use of synthetic chemicals has led to some serious problems, including development of resistant insect strains and health hazards to grain handlers (Zettler and Cuprus, 1990; White, 1995; Obeng-Ofori et al., 1998). Annual grain losses of up to 50% in cereals and 100% in pulses have been reported (Obeng-Ofori, 2011), although average losses stand at roughly 20% (Obeng-Ofori, 2011). This calls for better storage systems to protect grains and other food crops, hence the hermetic storage technology.

Hermetic simply means airtight. The origin of hermetic is lost in antiquity. Modern hermetic storage which was pioneered by Calderon and Navarro (1980) consists of a sealed storage system containing a modified atmosphere. This technique is based on the principle of generating an oxygen-depleted, carbon dioxide-enriched interstitial atmosphere caused by the respiration of the living organisms in the ecological system of a sealed storage structure (Donahaye and Navarro, 2001; Obeng-Ofori, 2011). The low permeability envelope maintains a constant moisture environment. Food stored hermetically remains fresh and tasty; seeds maintain their vigour and their ability to germinate.
The current triple layer hermetic bag (Figure 2) technology was developed by the Purdue University to improve upon the storage of cowpea which has proven very effective. It consists of two sealed plastic (polyethylene) bags placed inside a third bag which is made of woven nylon or polypropylene for strength.

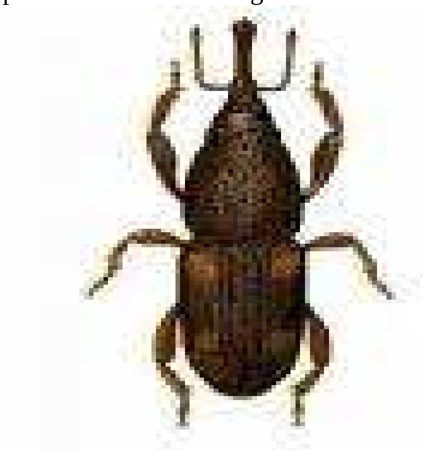

Figure 1: *S. zeamais*

Figure 2: 50kg Triple-layer Bag
(Source: Villers *et al.,* 2006)

This research investigates the effectiveness of the triple layer hermetic bag and two other conventional storage bags in controlling the maize weevil, *Sitophilus zeamais*.

2. Materials and Methods

2.1 Study site

The study was conducted in the laboratory of the African Regional Postgraduate Program in Insect Science (ARPPIS), University of Ghana, Legon in the Greater Accra Region of Ghana from October, 2011 to March, 2012.

2.2 Source of maize varieties and insects for laboratory studies

Maize with an average moisture content of 14.2 was purchased from farmers during the harvesting period (August-September, 2011) in Wa (Northern Ghana) and Techiman (middle belt). Moisture content was determined using a Digital Grainmaster (Protimetre). Three different varieties of maize (Obatampa, Abrodenkye and Kamangkpong) were used. Obatampa is an improved variety where as Abrodenkye and Kamangkpong are local varieties. The main reason for choosing the above varieties for the study is that they are the most commonly cultivated varieties in many parts of the country. They have also been reported to be high yielding, very nutritious and mature earlier than other varieties.

Sitophilus zeamais was collected from infested stock of grains at the Madina market, Accra and reared on whole maize grains at 28 ± 2^{o}C, 65% relative humidity and 12L: 12D photo regime (Osafo, 1998; Bonu-Ire, 2001). The weevils were placed in a plastic bowl covered with a nylon mesh and left under the sun for three hours to kill all mite-infected ones. The survivors were washed in 1% sodium hypochlorite solution. The insects were then washed in water and dried by placing them on filter paper before introducing them into a glass jar containing 500g of sterilized maize. The grains where sterilized in a refrigerator for 24 hours before sterilizing in an oven at 40^{o}C for six hours as recommended by Bonu-Ire (2001). After two weeks of oviposition, the parent stock was removed using an aspirator and killed by freezing. By this, insects of the same cohort were always available for the research.

2.3 Characteristics of bags used

The hermetic three layer bags were supplied by the Forum for Agricultural Research in Africa, (FARA) through Bioplastics (a local manufacturer of plastic and rubber products in Ghana). Each triple layer bag consists of two plastic bags (made of polyethylene) put inside a third bag made of woven polypropylene to give additional protection and strength. The bags were 100µm thick and measure 86cm x 157cm in width and length respectively. Ordinary bags made of polypropylene (fertilizer sack) and jute sacks were used for the control. These were bought from Madina market for the experiment.

2.4 Effectiveness of triple-bagging in controlling S. zeamais

Five (5kg) kilograms of each maize variety was put into each bag and infested with 50 unsexed *S. zeamais* (3 to 7 days old). These were replicated three times and stored for three months. Each bag was tightly sealed and was kept unopened for 3 months. In all there were 81 experimental units. Destructive sampling was done every 30 days for three months to determine the weight loss, percentage damage and the germination potential of the grain in the various bags. Damage at the end of every month was determined by taking a random sample of 100 grains using the cone and quarter method. Bored grains were separated from whole grains and their numbers expressed as a percentage using the formula by Adams and Schulten (1978). At each sampling period, the grains were sieved out from the various bags and mixed thoroughly. The Thousand Grain Mass method as described by Boxal (1986) was then used to assess weight losses.

2.5 Germination potential and vigour

The determination of the germination capacity (or the viability) was carried out by a method recommended by the International Seed Testing Association (ISTA, 2001). The viability test was done before and after storage in the field using a random sample of 100 grains of each variety and replicated four times. Emerged seedlings were counted after 7 days and expressed as a percentage.

3. Results and Discussion

3.1 Moisture content changes and Germination potential

Data collected were subjected to Analysis of Variance using GenStat, 9th edition. Grain germination data showed significant differences ($p < 0.001$) within grain varieties, storage periods and treatments as shown in figure 3.There is a high significant difference ($p<0.001$) between hermetic storage and the conventional bags in terms of viability. This makes hermetic triple-bagging more effective in preserving seed viability than the other bags, hence confirming the results of Donahaye *et al*, (2001).

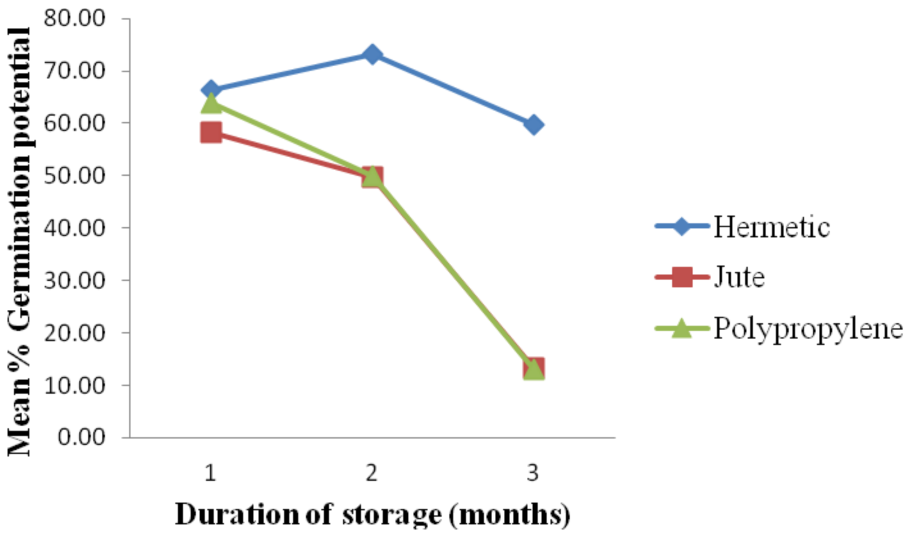

Figure 3: A graph showing the viability of grains infested with *S. zeamais* and stored in different bags over a 3 month period.

At the start of the experiment, the water content of the grain varieties was 13–14.2% (wet basis), which gradually rose with time to reach an equilibrium with the r.h. maintained in the enclosures assisted by the direct re-hydration of the grains from the atmosphere.

The increase in grain moisture content was also influenced by transpiration caused by insects, especially during the last month of storage when the density exceeded 1000 insects per kg in the controls (Polypropylene and jute sacks). This phenomenon was previously observed by Dharmaputra *et al.* (1994) and Fourar-Belaifa ***et al.* (2010)** with a very high *S. zeamais* population density on corn.

A significant increase of moisture content was observed in the infested Obatampa and Abrodenkye. With these two varieties, after 90 days storage, the very high adult insect populations (1000–1300 insects per kg) caused a rise in moisture content of 2%–5% and an increase in temperature inside the grain samples.

Germination capacity was found to be dependent on the storage duration. Whatever the conditions of storage, germination capacity decreased with storage time, as previously established for malting barley (Ellis and Roberts, 1980a; Woods *et al.*, 1994 Jacobsen *et al.*, 2005). The presence of infestation also negatively influenced germination as observed by many authors (Howe, 1973; Fleurat-Lessard and Poisson, 1984, Imura and Sinha, 1984; Fleurat-Lessard, 2002). This acceleration in germination decay could be accentuated in situations where a progressive increase of moisture content leads to the formation of a hot-spot (e.g. in the infested Obatampa variety after a three-month storage period under high r.h.).

3.2 Effectiveness of triple-bagging in controlling S. zeamais

Insect population dynamics, damage and weight loss was used to determine the effectiveness of the various bags in controlling *S. zeamais*. Damage data showed a very high significant difference ($p<0.001$) between the hermetic bag and the two conventional bags as shown in figure 4. The graph shows an upsurge in damage by *S. zeamais* in the jute and polypropylene bags where as in all the hermetic storage treatments, damage levels decreased as the storage period prolonged. Data from the weight loss analysis shows a very high significant difference ($p<0.001$) between the hermetic bag and the conventional bags as shown in figure 5. This is because the respiratory activities of the weevils and the grain itself leads to the depletion of O_2 and a buildup of CO_2 in the sealed triple-bags resulting in asphyxiation and eventual mortalities of the weevils thereby reducing or truncating damage. This confirms the results of Calderon and Navarro (1980) and Donahaye et al. (2001).

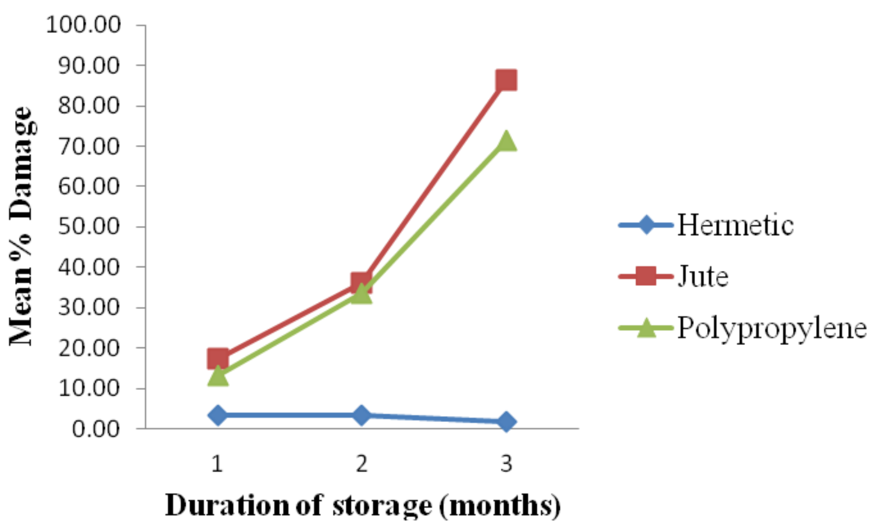

Figure 4: A graph showing the damage caused by *S. zeamais* in different bags over a 3 month period.

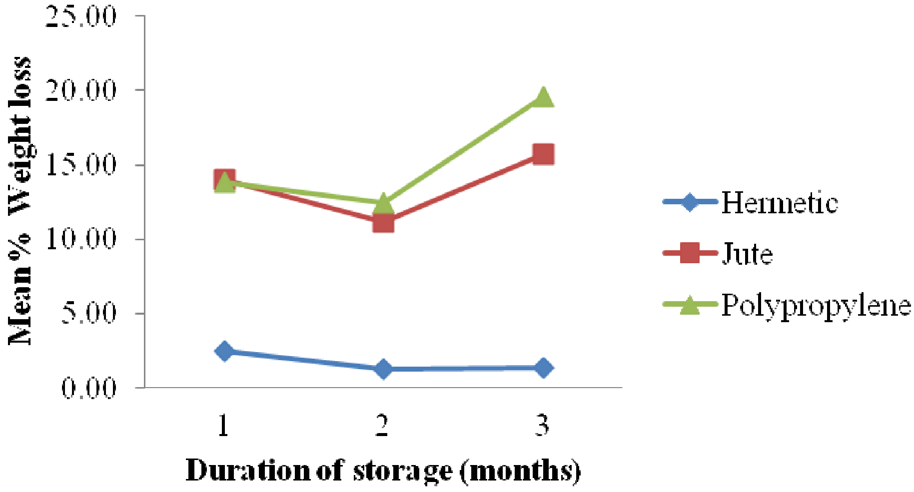

Figure 5: A graph showing the weight loss in percentage caused by *S. zeamais* in different bags over a 3 month period.

Very few insects were detected either by sieving or as hidden stages in the hermetic bags as compared to the controls. The rate of increase of *S. zeamais* populations was mainly dependent on both the bag and storage time for adults and hidden stages. Neither the temperature of storage nor the grain moisture content limited the development of the weevils in the controls. According to Hagstrum and Milliken (1988), the order of relative influence of factors on the development of nine species of beetles including *S. zeamais* is represented by temperature as the principal factor, followed by the water content, then by the food source. In our trial, these three factors were set at near optimum. The results show that the triple-layer hermetic bag is effective against *S. zeamais* and can be used for effective storage of grains.

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