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Field studies with insecticide treated packaging for the control of stored product insects

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Abstract

Food Security is an issue that will impact everyone by 2050 it is projected there will be a global crisis unless action is taken. The ZeroFly® Storage Bag is a new combination of key technologies developed to reduce post-harvest losses. It contains an insecticide, Deltamethrin that is incorporated within the polypropylene yarns woven into a storage bag. The level of insecticide residue found on grains stored for up to two years in ZeroFly® Storage Bag are below CODEX & EPA maximum residue levels. This technology can be combined with natural rodent repellent compounds and the multilayer hermetic liners, meaning these bags can adhere to and improve on currently accepted practices and requires limited behavior change for the user. Studies show that the ZeroFly® Storage Bag can effectively control key stored product insects. The presentation will explore the current scale-up efforts and strategies of distribution planned throughout Africa and Asia, this would also include an assessment of the broader impact of ensuring the most appropriate combinations of technologies reach the most vulnerable groups.

On-Farm Comparison of Different Postharvest Storage Technologies for effectiveness in pest management in a Maize Farming System of Tanzania Central Corridor

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Abstract

Seven methods for storing maize were compared with traditional practice of storing maize in polypropylene bags. Twenty farmers managed the experiment under their prevailing conditions for 30 weeks. Stored grain was assessed for damage every six weeks. The dominant storage insect pests identified were the Maize weevil (*Sitophilus zeamais*) and the Red flour beetle (*Tribolium castaneum*). There was no significant difference ($F = 87.09$; $P < 0.0001$) in insect control and grain damage between hermetic storage and fumigation with insecticides. However, the insecticide treated polypropylene yarn (ZeroFly®) did not control insect infestation of grain for the experimental period under farmers' management. Grain damage was significantly lower in hermetic storage and fumigated grain than ZeroFly® and polypropylene bags without fumigation. No significant difference in grain damage was found between airtight treatment alone and when combined with the use of insecticides. During storage, *S. zeamais* was predominant and could be of more economic importance than *T. castaneum* as far as maize damage is concerned. Even though ZeroFly®, and polypropylene bags without grain treatment did not control storage pests, farmers still prefered this cheap technology. Hermetic storage techniques can be recommended to farmers without the use of insecticides provided they are inexpensive, and the proper application of technologies is ensured.

Key words: Maize Farmers; Hermetic storage; Grain damage; Food loss; Insect damage

1. Introduction

Maize is one of the crops most severely affected by Post harvest Losses (FAO, 1998; Abass et al., 2014). Major losses of stored maize are caused by insect pests especially the larger grain borer (LGB), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), the Red flour beetle (*Tribolium castaneum*), and the Maize weevil (*Sitophilus zeamais* Motschulsky) (Coleoptera: Curculionidae) (Golob and Hanks, 1990). If the grain is dried to an appropriate moisture level of 12–13% storage insects can be controlled effectively with fumigants such as Phostoxin (Hodges, 1986). In Tanzania, farmers are allowed to use Phostoxin if supervised by authorized extension agents, but the effectiveness of such arrangements at the community level is yet to be ascertained. Farmers widely use a mixture of Pirimiphos-methyl (Actellic) and Permethrin, commercially sold as Actellic Super (local name: *Shumba*) but farmers are often unable to verify the genuineness of some local brands.

More recently hermetically sealed containers are being promoted in Africa to control storage insect pests, based on the oxygen depletion mechanism that rapidly occurs in the containers, causing an increase in CO_2 concentration and death of the pests (Yakubu et al., 2011; Murdock et al., 2012; Baoua et al., 2013; de Groote et al., 2013; Moussa et al., 2014, Chigoverah and Mvumi, 2016; Likhayo et al., 2016; Midega et al., 2016). Metal silos, plastic barrels and flexible hermetic storage systems, such as Purdue Improved Crop Storage (PICS) bags, super grain bags (SGB), Zerofly bags, cocoons, and others, are being tested to control storage insect pests in different African countries (Quezada et al., 2006; Phiri and Otieno, 2008; Baoua et al., 2013, 2014; Jones et al., 2014). However, the potential adaptability of the technologies and their acceptance by farmers as alternatives to the use of insecticides is required. This study was conducted in Tanzania to determine the relative effectiveness of different hermetic storage materials under actual on-farm conditions and farmers' management practices and elucidate sociocultural evidence on their acceptability.

2. Materials and Methods

2.1 Description of the experimental sites

Twenty farmers in four villages located in three agro-ecologies (Southern Guinea Savannah, Northern Guinea Savannah, and Semi-arid Sudan Savannah) within two regions of Tanzania (Dodoma and Manyara) were involved in the experiment. The relative humidity (H_{in}), and temperature (T_{in}) inside the storage facilities were monitored using electronic data loggers *(Dickson TK550 model).*

2.2 Experimental set up

Shelled maize with natural insect infestation was stored in eight different storage treatments as follows.

Metal silo hermetic: Hermetic storage of untreated maize using a metal silo filled to 90% of the 500 kg capacity.

Metal silo phostoxin: Hermetic storage using a metal silo filled to 90% of the 500 kg capacity with a Phostoxin-treated grain (active ingredient is aluminum phosphide, 57% w/w).

Plastic barrel hermetic: Hermetic storage of untreated grain using a plastic barrel (a flat-topped 50-liter high-density polyethylene container) filled to 90% of its capacity.

Plastic barrel Photoxin: Hermetic storage of Phostoxin-treated grain using a plastic barrel filled to 90% of its capacity.

PICS: Hermetic storage of 100 kg of untreated grain using two 100-kg Purdue Improved Crop Storage (PICS bags, described by de Groote et al., 2013) purchased from Pee-Pee Tanzania Ltd, Tanga, Tanzania.

ZeroFly®: Storage of 50 kg of untreated grain using a ZeroFly® storage bag (non-hermetic; polypropylene bag with deltamethrin insecticide incorporated at the rate of 3 g/kg ± 25%) purchased from Vestergaard, Lagos, Nigeria, and shipped by airfreight to Tanzania. Four 50-kg bags were used.

PP Shumba: Storage of 100 kg of grain treated with Actellic Super® (Pirimiphos-methyl 16 g/kg plus Permethrin 3 g/kg) in polypropylene (PP) bags (non-hermetic). This is the common farmers' practice known as *Shumba* in Tanzania. Two 100-kg bags were used.

PP without treatment: Storage of untreated grain in polypropylene (PP) bags (non-hermetic) commonly used to transport and store grain. Two 100-kg bags were used (control).

2.3 Grain sampling and field assessments

Sampling: A representative sample (1 kg) from each treatment was collected at 6-week interval, transferred into a labeled paper bag, sealed, and then transported to the laboratory for further analysis. All samples were stored at ambient conditions until processed.

Grain moisture (GM) and Bulk Density (BD): Samples were tested for percentage grain moisture (GM), and bulk density (BD; g/cm^3) using a hand-held grain moisture tester (Dickey-John GAC ® Plus, Illinois, USA).

2.5 Laboratory assessment

Insect counts: The type and population of insects were visually evaluated in the laboratory following the method described by Ng'ang'a et al. (2016).

Grain assessment: In the laboratory, samples were visually examined for broken and damaged grain (DG) using the 1000 grains count. The percentage DG was calculated following the formula described by Boxall (1986). Weight loss (WL) was calculated as shown by Njoroge et al. (2014).

2.6 Farmers' perceptions of the storage technologies

At the end of the experiment, the participating farmers (20 respondents: 6 female, 14 male; 70% aged between 40 and 60 years) were asked to rate the storage technologies according to their perceptions about effectiveness to prevent grain loss and how the farmers liked the storage technologies.

2.7 Data analysis

Data were entered into an Excel spreadsheet and analyzed using SAS® version 9.4 (SAS Institute, Cary, NC). To determine means and frequencies to explain the data pattern. A stepwise multiple comparisons GLM procedure was used to determine the pattern of differences in the samples. Significant differences in storage parameters were concluded when the coefficient of the interaction term was significant at $P < 0.05$, $P < 0.01$, or $P < 0.001$ as the statistical significance levels. Additionally, standard errors were calculated and used as means separation tests.

3. Results and Discussion

3.1 Relative humidity and temperature conditions during the experiment

Average relative humidity (H_{in}) inside four selected treatments representing insecticide treated and untreated maize inside all polypropylene bags (including ZeroFly), PICS bags, all metal silos, and all plastic barrels during the entire period of storage was 60.35±0.97, 66.24±1.14, 68.50±0.27, and 66.7±1.24 respectively. Similarly, average temperature (T_{in}) condition inside the containers was 29.65±0.51, 25.02±0.23, 25.57±0.03, and 25.07±0.20 for all PP bags without treatment (including ZeroFly), PICS, all metal silos, and all plastic barrels, respectively.

Maize stored in hermetic storage containers had a higher GM content than in non-hermetic bags (ZeroFly®, PP *Shumba,* and PP bags without treatment; Fig. 1).

The moisture content of grain stored in non-hermetic conditions (ZeroFly®, PP bags) reduced until week 18 of storage and increased slightly afterward. The moisture content of grain in hermetic conditions increased slightly during storage. These values were significantly higher than the moisture content of the maize stored in the non-hermetic facilities (especially the PP bags).

3.3. Bulk Density (BD) of stored grain

The BD of stored grain decreased from the start of storage until storage Week 6 in all the storage conditions (Fig. 2). The BD of the grain in ZeroFly® and PP bags decreased during storage.

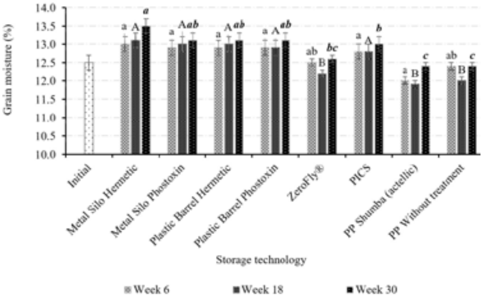

Fig 1: Percent (Mean±SE) grain moisture in the storage technologies over 30 weeks of storage. Foot note: Significant difference between means at Week 6 denoted by different lower-case letters (F=5.04, P<0.0001), significant difference at Week 18 denoted by different upper case letters (F=11.46, P<0.0001), significant difference at Week 30 denoted by different bold lower case letters in ***italics*** (F=7.69, P<0.0001).

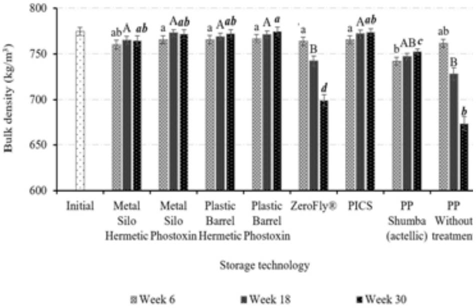

Fig. 2: Grain bulk density ((mean ± SE) in the storage technologies over 30 weeks.
Significant difference at Week 6 denoted by different lower case letters (F=3.16, P=0.0038), significant difference at Week 18 denoted by different upper case letters (F=11.23, P<0.0001), significant difference at Week 30 denoted by different bold lower case letters in ***italics*** (F=49.85, P<0.0001).

3.4 Insect population

Two major maize spoilage insects were identified: *S. zeamais* and *T. castaneum*. We did not find *P. truncatus* throughout the storage period. The population of live adult *S. zeamais* in the grain increased rapidly in ZeroFly® and PP bags (Fig. 3) but reduced in all the airtight containers. The insect was completely absent in PP *Shumba* (Actellic).

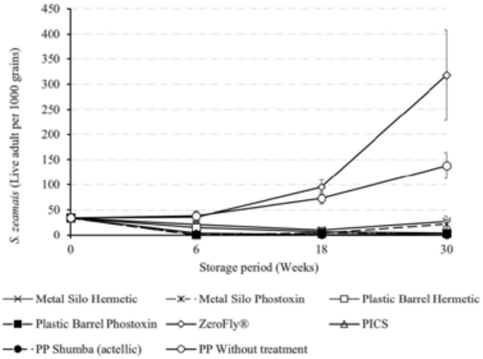

Fig 3: Number (mean ± SE) of live *S. zeamais* adult polupation in the storage technologies over 30 weeks.

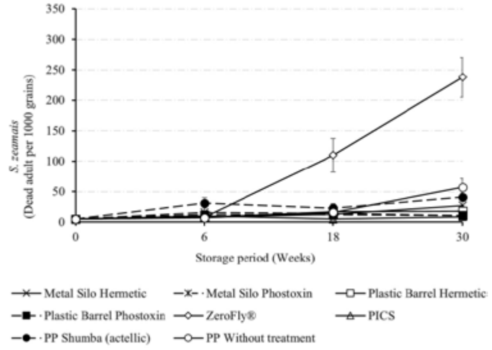

Fig. 4: Number (mean ± SE) of dead *S. zeamais* adult population in the storage technologies over 30 weeks.

At the end of storage the number of dead *S. zeamais* adults was highest in ZeroFly®, and in PP bags (Fig. 4). PICS had the lowest number of dead *S. zeamais* adults, significantly fewer than in other treatments (F = 28.01; *P* < 0.0001). Adult *T. castaneum* was not detected at the time of storage but later detected during storage (Fig. 5&6). At week 30 of storage, the population of live *T. castaneum* adults was low in all airtight containers and insecticide-treated grain while it was significantly higher in ZeroFly® and PP bags(F = 33.98; *P* < 0.0001). Dead adult of *T. castaneum* was found in ZeroFly® and PP bags, maximum of one was found in hermetic storage containers and also in grain treated with insecticides.

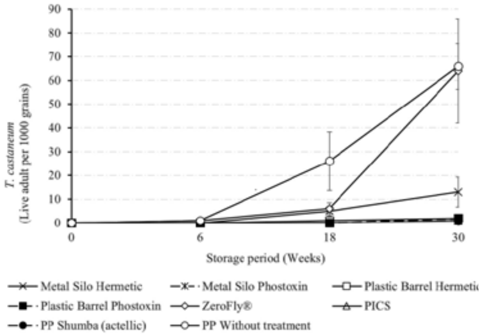

Fig. 5: Number (mean ± SE) of live *Tribolium Castaneum* adult population in the storage technologies over 30 weeks.

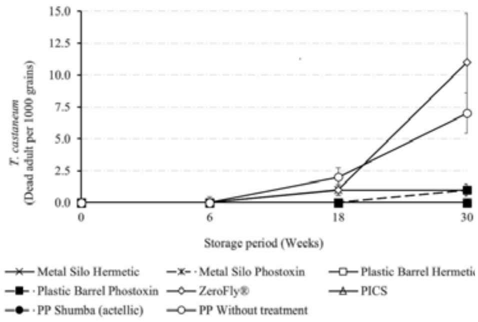

Fig. 6: Number (mean ± SE) of dead *Tribolium Castaneum* adult population in the storage technologies over 30 weeks.

3.5 Grain damage (DG)

Fig. 7 reveals very crucial patterns of insect behavior concerning the destruction of grain and the consequent food loss during storage if farmers would adopt the various storage technologies tested. The results reveal the implication of poor shelling methods that break the grain before storage and how this could accentuate insect damage. Significant difference at Week 6 denoted by different lower case letters (F=3.17, P=0.0037), significant difference at Week 18 denoted by different upper case letters (F=25.06, P<0.0001), significant difference at Week 30 denoted by different bold lower case letters in ***italics*** (F=89.09, P<0.0001).

During storage, there was an initial decrease in DG at week 18 after which DG values increased.

The increases were highest in PP bags (PP without treatment) and in ZeroFly® bags at week 30 of storage, and were significantly higher (F = 87.09; *P* < 0.0001) than the DG percentage in all the other storage treatments. No significant differences were observed among the remaining treatments irrespective of the use of insecticide whether combined with hermetic storage or not.

3.6 Weight Loss (WL)

The consequence of the increase in DG and other factors was that average WL in PP bags (PP without treatment) and ZeroFly® bags continuously increased but did not change significantly in any of the remaining storage treatments (Fig. 8). At week 30 of storage, WL was significantly higher (F = 10.31; *P*<0.0001) in untreated grain stored in ZeroFly® (8.1 ± 0.6%) and PP bags (11.6 ± 1.7%) than in PP bags with insecticide treatment (PP *Shumba*; 4.4± 0.2%). There was hardly any WL in PP *Shumba* and the hermetic treatments.

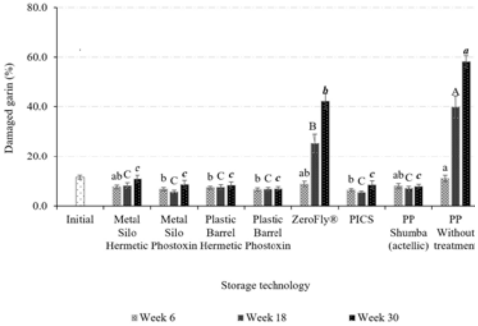

Fig. 7: Percent (±SE) of damaged grains in the storage technologies over 30 weeks

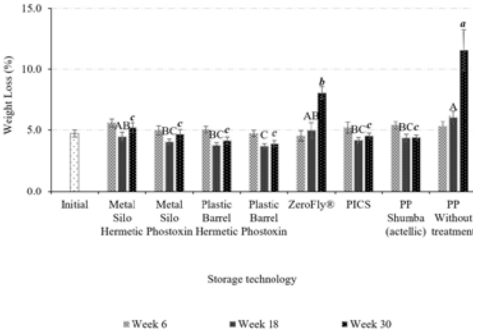

Fig. 8: Percent (±SE) grain weight loss during 30 weeks of storage No significant difference between means of weight loss (%) at Week 6 (F=0.99, P=0.4379), significant difference at Week 18 denoted by different upper case letters (F=3.74, P<0.0005), significant difference at Week 30 denoted by different bold lower case letters in ***italics*** (F=10.31, P<0.0001).

3.7 Agents of grain loss

Considering a batch that was damaged at base condition (before storage), the most critical causes were calculated to be grain breakages (32.2%), fungi infection (31.8%), and damage by insects (24.1%). After storage, the most economically important damage agents were insects: 25.4% for plastic barrel Phostoxin, 90.8% for ZeroFly®, and 91.4% for PP bags without treatment. Fungal coloration appears to constitute an important agent of grain defects in the hermetic containers. The increase in moisture in hermetic storage could promote fungi growth. Since a large insect population would cause more damage, therefore, preventing an increase in insect population is a critical factor for reducing DG and WL. In addition, *S. zeamais* seems to be more economically important in the Central Corridor of Tanzania than *T. castaneum* concerning damage to stored maize grain and food losses.

3.8 Farmers' perception

Farmers rated the hermetic storage technologies without insecticide application (metal silo hermetic, plastic barrel hermetic and PICS) as the most effective ways to control storage pests. However, contrary to trial results, PP *Shumba* was not rated as effective. Farmers also liked the same hermetic technologies best. Metal silos were preferred to plastic barrels.

Even though PP bags without treatment did not control storage pests, farmers still liked them as this was a cheap technology. PP *Shumba*, and above all ZeroFly® bags were liked the least. Farmers indicated that the PP *Shumba* treatment was not liked because it altered the taste of the grain. Field observations revealed that farmers who store their maize with insecticide avoid using such grain as much as possible for household consumption but prefer to sell it.

4.0 Conclusion

This study showed that hermetic storage techniques could be used to store grain for 30 weeks without a significant effect on the quality and germination of the grain. Storage of maize treated with Actellic Super in PP bags, a traditional practice in Tanzania, was effective in controlling insect damage. However, for public health reasons, the application of insecticides to staple food should be avoided especially in locations where trained personnel to supervise the use of insecticides are absent. Hence hermetic storage without the application of insecticides is preferred, but the storage materials need to be made affordable to the smallholders. Sound handling and management of the technologies by farmers must also be ensured, i.e., proper placement and hermetic sealing of lids should be ascertained; insect infestation from the field should be as low as possible; grain must be properly dried before storage, and re-infestation during the intermittent opening of airtight containers should be prevented as much as possible.

Acknowledgement

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Quality and mycotoxin contamination of maize stored in air-tight containers in rural farm stores: data from two semi-arid zones in Kenya and Tanzania

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Abstract

Hermetic containers have been promoted in recent years for chemical-free grain storage among smallholder farmers. In the context of grain quality, the influence of maize storage and pre-storage practices (harvesting time, dehusking, drying, and shelling method) on performance of air-tight bags was investigated in the semi-arid regions of south eastern Kenya and northern Tanzania. Completely randomised trials were conducted in farmer-own stores; shelled maize was filled in air-tight bags or woven polypropylene (PP) bags and stored for 30-35 weeks. Insect damage, physical grain quality, mould infection were evaluated at 6-7 weeks intervals, and mycotoxin contamination was examined at onset, mid, and end of storage. Maize stored in hermetic bags was generally free from insect infestation, while PP bags permitted profuse build-up of insect populations causing grain damage of up to 82%. Total aflatoxin contamination of maize stored at moisture content below 14% increased significantly in the PP bags (5 - 8 folds) but not in the air-tight ones. Harvesting, drying and shelling practices significantly influenced the quality of maize stored in hermetic bags, resulting in sorting losses of 6-23 kg/100 kg after 6-8 months of storage. Since sorting is an important operation for improvement of food value and market quality, such losses would significantly lower the benefits of air-tight storage. Pre-storage practices of sorting, cleaning and moisture verification by farmers have impact on overall performance of air-tight storage.

On-Farm Maize Insect Pest and Mycotoxin Levels in Ghana

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Abstract

Maize post-harvest losses are perennial in Ghana but reliable comparative information on on-farm losses of maize produced in the Middle and Northern Belts of Ghana is lacking. Two studies were conducted from September 2015 to February 2016 to identify factors contributing to on-farm losses of maize in these two Belts. In the Northern Belt, the study was conducted in six communities including Adubiyili, Diari, Pong-Tamale, Savelugu, Toroyili and Zamnayili; and in the Middle Belt, in Ejura, Sekyedumase and Amantin communities. Moisture content, percent weight loss, percent insect damaged kernels (IDK) on numerical basis ($\%IDK_{nb}$) and percent IDK by weight basis ($\%IDK_{wb}$), insect pest abundance, and mycotoxin levels were estimated. Moisture content values of maize at pre-harvest and heaping stages in all nine communities were below 15%. *Sitophilus zeamais*, *Sitotroga cerealella*, *Cathartus quadricollis*, and *Carpophilus dimidiatus* were found to attack maize on-farm in communities in the Middle Belt, but no adult insect pests were collected on pre-harvested maize in the Northern Belt. The $\%IDK_{nb}$ values on-farm in all nine communities were < 2% per 250 g. Mean aflatoxin levels below 15 ppb were obtained from pre-harvested maize in both regions but levels above 15 ppb were obtained from heaped maize on-farm. Fumonisin levels of maize were below 4 ppm on pre-harvested and in heaped maize in both regions. Results show that heaping maize on-farm increases aflatoxin levels beyond the acceptable threshold level and should not be practiced.