THE USE OF HERMETIC BAGS FOR ON FARM STORAGE OF GRAINS AND PULSES AGAINST INSECT PESTS

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A brief overview of postharvest losses

Post-harvest losses of grains and pulses are extensive and a major threat to food security in East, central and southern Africa. According to AGRA (2013) the major factors that influence losses are: attacks on grain by insects (Fig. 1), mycotoxin contamination, rodents and birds. The most affected crops include maize, dried cassava, rice, sorghum, millet and pulses (AGRA, 2013). This problem is particularly acute in the East African region, where on-farm storage solutions are either not widely available or are poorly adapted to local needs, leading to post harvest losses of up to 30% (Hodges, 2012; AGRA, 2013; Suleiman & Rosentrater, 2015). Consumers of infested and contaminated grains are also exposed to aflatoxin (Suleiman & Rosentrater, 2015) posing a serious health risk (Mutiga *et al*., 2015; Andrade & Caldas, 2015).

Figure 1. Maize damaged and infested by insects.

Current storage practices

Current storage practices (e.g. woven polypropylene or jute bags, maize cribs) are not at all effective against the problem posed by insects and rodents for diverse reasons (AGRA, 2013; Kaminski & Christiansen, 2014). Existing hermetic solutions have notable shortcomings, either in terms of expense (plastic drums, metal silos, cocoons) or effectiveness (existing hermatic bags). These solutions are presented in Table 1.

Hermetic storage of grain uses sealable and airtight containers such as cocoons, metal silos and plastic drums to prevent grain-insect pest contact and to suffocate insects already in the container (Murdock & Baoua, 2014; Ane *et al*., 2011). For most farmers, however, these technologies are somewhat expensive with an acquisition price usually starting at US$ 3 (Jones *et al*., 2014; Bern *et al*., 2013) and not suited to their local conditions.

With the ineffectiveness and/or unaffordability of current storage practices, especially when it comes to stubborn pests such as the larger grain borer (LGB *Prostephanus truncatus*) which remains the most serious pest of maize in many parts of Africa (Nansen & Meikle, 2002), there is clearly a need for better solutions.

Seriousness of the LGB problem

In a quick test to assess the seriousness of the LGB problem, 20 kg of pesticide and insect free maize was kept in a polypropylene bag (PP). 150 LGB adults were introduced in the bag and the test was replicated 3 times. The bags were then kept at room temperature for 3 months. At the end of the period, an average of 2000 LGB adults were collected outside the grain kernels which were still visibly infested (inside the grain) with other LGB adults. In addition to damage observed on the grain kernels, an average 0.85 kg of maize turned into flour which was collected from the bags.

Testing hermetic storage bags against the Larger Grain Borer

Hermetic storage bags kill insect pests introduced with harvested grain through suffocation and dehydration within

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Table 1. Current existing solutions and the reasons for their inefficiency

Solutions	Traditional granary	PP & jute bag	Pesticide dusts	Plastic drums	Metal silos	Cocoon	Existing hermetic bags
Shortcomings	Pests (insects in particular) can enter and damage the produce.	These bags do not prevent damage from either insects or rodents.	Effective but risky: Poor handling and misuse by farmers leading to intoxication risks. Residues over the accepted MRLs are possible.	Can be effective but their cost is prohibitive. Can be holed by the larger grain borer.	Work well aginst the majority of pests but are not affordable.	Not affordable to smallholder farmers.	Effective against the weevil but can get holed by the larger grain borer making them lose hermetic property.

Sources: http://www.fao.org/docrep/w1544e/w1544e04.htm and www.aphlis.net/
https://www.shareweb.ch/site/Agriculture-and-Food-Security/focusareas/Documents/phm_egsp_2008_2011.pdf
http://www.erails.net/images/sudan/moawya-abdalla/dept-pesticides-tox-/files/African%20pesticide%20use%20may%20still%20be%20small.pdf
Bern *et al.* (2013) and Nansen & Meikle (2002)

Figure 2. Perforation of plastic bag by the larger grain borer.

a few days of bag closure (Murdock & Baoua, 2014). Nevertheless, one insect pest, the larger grain borer (LGB) has the ability to bore through most storage bags (Nansen & Meikle, 2002 and Fig. 2) thus breaking the hermetic seal, rendering the bag ineffective and allowing insects to survive and breed. LGB can even tunnel and penetrate through hard materials such as thick plastic and wood (Nansen & Meikle, 2002). The present study aimed at assessing the efficacy of currently available hermetic storage bags against LGB and test the efficacy of a newly developed one which contains a repellent insecticide.

Materials

The trials were conducted at the Africa Technical Research Centre (ATRC), in Arusha, northern Tanzania under the following conditions: Temperature (26–32°C) and 60–70% RH. All the hermetic bags available on the market at the time of the experiment were compared to the new type of hermetic storage bag, AgroZ® Bag Plus, containing alphacypermethrin as repellent insecticide. Table 2 presents the different hermetic bags tested. All trials were conducted using pesticide free maize purchased from farmers shortly after harvest. Shumba (fenitrothion 1% + deltamethrin 0.13%), a pesticide dust commonly used in Tanzania was also tested. The LGB adults used in the experiments were all obtained from ATRC agricultural pests rearing facility. The founder population was initially collected from the field in 2012.

Methods

Laboratory trial: An in-house designed protocol branded tiny bag experiment was first used to assess the ability of the different plastic materials to prevent perforation by LGB adults and other insects already in the bags. In this first experiment, small bags of 3 x 4 cm (Fig. 3) were made from the bag samples using a heat sealer. In each tiny bag, one (1) healthy LGB adult was introduced prior to heat-sealing of the bags. The experiment was replicated 30 times for each treatment and LGB mortality was recorded daily as well as the number of holes in the plastic material tested. The experiment was conducted for 48 hours.

Semi-field trial: In a second experiment, each bag was filled with 87 kg of maize already infested with the maize weevils (*Sitophilus zeamais*). Similarly 87 kg of maize kept in a PP bag was mixed with Shumba following the manufacturer's instructions. For each treatment 4 replicates were considered and 150 LGB adults were introduced in each replicate. All the bags were then kept at room temperature. After 7 months, the bags were opened and their content sieved, using a wire mesh, in order to collect all the insects which were outside the grain kernels and the dust generated by insect damage. The bags used for the experiment were also inspected for holes caused by the insects.

Results-discussions

Tiny bag experiment: after 48 hours, 80%, 30%, 23% and 7% of the tiny bags from respectively the one liner of PICS

Table 2. List of postharvest bags tested.

Type of bag	Bags	Specifications	Designed by
Hermetic	PICS Bag	Pesticide free, made of two separate 80 microns high density polypropylene liner bags pre-inserted one inside the other and both inserted inside a polypropylene bag.	Purdue University
	SuperGrain Bag	Pesticide free, 80 microns, multilayer polymeric bag. It is composed of one liner which is supposed to be inserted by farmers inside a polypropylene bag.	GrainPro
	AgroZ Bag	Pesticide free, 90 microns, multilayer polymeric bag. It is composed of one liner already pre-inserted inside a polypropylene bag.	AtoZ Textile Mills Ltd.
	AgroZ Bag Plus*	An improved version of AgroZ Bag, designed to control LGB and other chewing insects and prevent perforation caused by such insects. It contains alpha-cypermethrin, a repellent insecticide sandwiched between two impervious layers preventing any migration of the active ingredient to contaminate the grain.	
Polypropylene	PP bag	A normal polypropylene bag available in the market and used by farmers to store their produce.	

*Also designed by AtoZ Textile Mills Ltd.

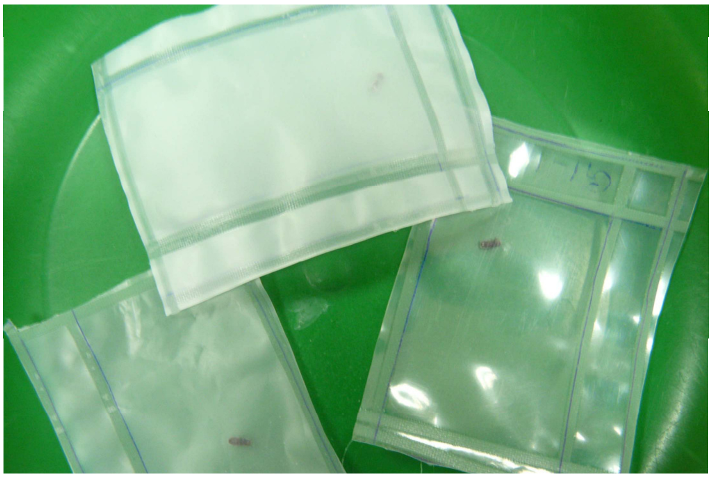

Figure 3. A view of the tiny bag experiment.

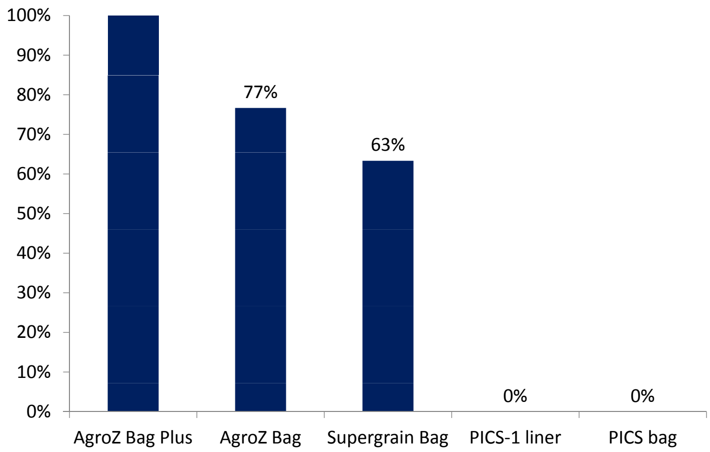

Figure 5. Mortality of LGB adults in tiny bags after 48 hours.

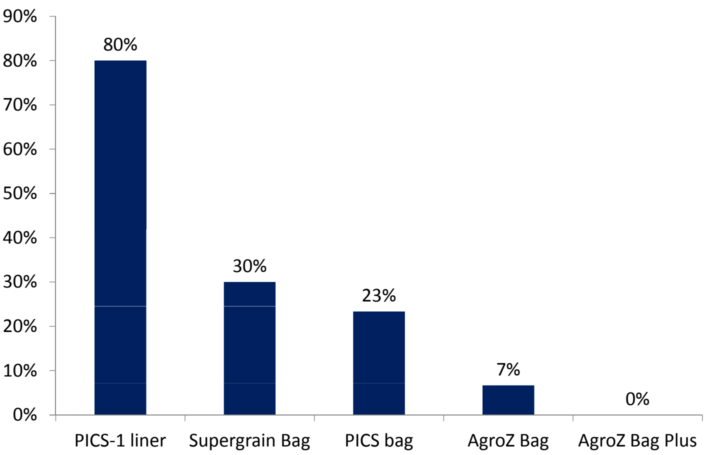

Figure 4. % of tiny bags holed after 48 hours.

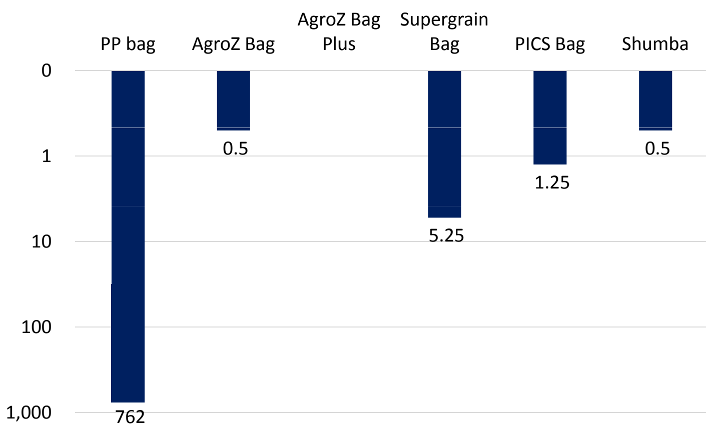

Figure 6. Living LGB adults collected in the different treatments.

bag, two liners of PICS bag, the Supergrain bag and AgroZ Bag were perforated by LGB adults. In contrast none of the tiny bags made with AgroZ Bag plus were perforated by LGB adults (Fig. 4). This suggests that the repellent insecticide (alphacypermethrin) was able to prevent any perforation by LGB adults. Similarly, the greater thickness of AgroZ bag was probably helpful in reducing the number of perforations on this bag. In contrast, 100% of LGB adults were found dead

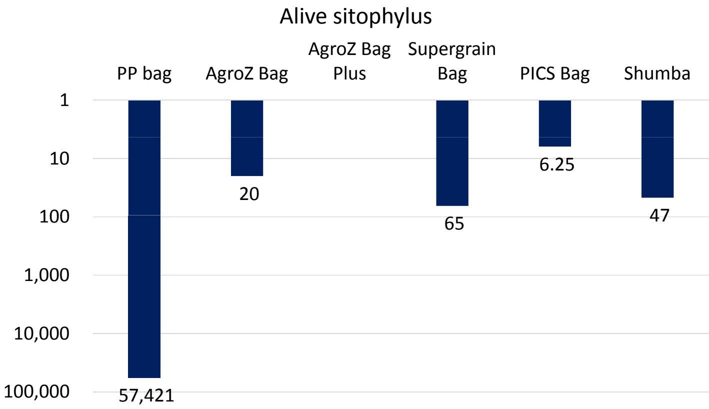

Figure 7. Living weevils adults collected in the treatments.

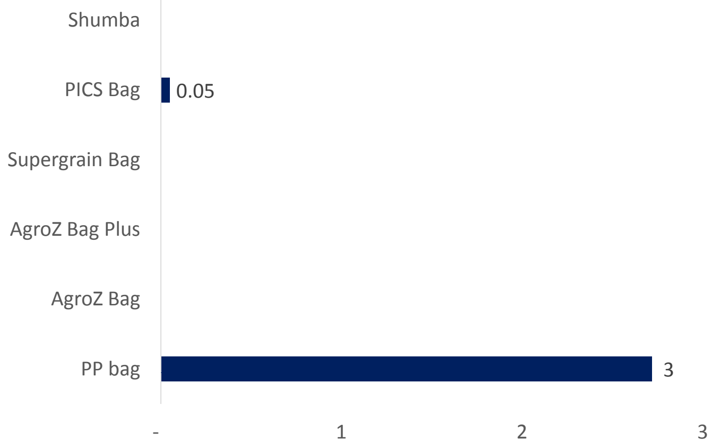

Figure 9. Average weight of dust collected from the treatment in kg.

in AgroZ Bag Plus tiny bags while only 77% and 63% were respectively found dead in AgroZ Bag and in the Supergrain bag samples (Fig. 5). PICS bags with one or two liners were not able to kill any of the LGB adults introduced (Fig. 5). It appears again that the presence of alphacypermethrin in AgroZ Bag Plus could explain the higher efficacy achieved by this bag. The difference in polymers between PICS bag samples made of High Density Polyethylene (HDPE) and AgroZ Bag, AgroZ Bag Plus and Supergrain Bag seems to explain the difference in efficacy. HDPE seems to be less hermetic to oxygen and gas in general than the polymers used in the construction of the other bags.

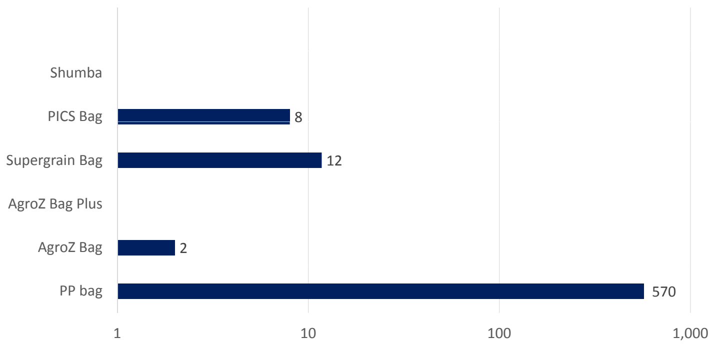

Figure 10. Average number of holes found in the different bags tested.

Figure 8. Living Tribolium spp adults collected in the treatments.

Semi-field trial: in the semi-field trial, the bags were all opened after 7 months. 762 Living LGB adults were found inside the control bag (PP bag) while less than 6 living adults were found on average in the Supergrain Bag and even fewer than two in the other hermetic bags (AgroZ Bag, AgroZ Bag Plus and PICS bag) (Fig. 6). Similarly fewer than one living LGB adult was collected in the maize treated with Shumba (Fig. 6). Similar results were observed with the maize weevils as over 57,000 living adults were collected in the PP bag and fewer than 70 living adults were collected in the hermetic bags and in the maize treated with Shumba (Fig. 7). In AgroZ Bag Plus no living weevils were collected (Fig. 7). More than 3500 living *Tribolium spp* adults were also collected from the PP control bag (Fig. 8). No *Tribolium* adults were found inside the other treatments.

Looking at the damage due to insects, About 3 kg of dust was collected from the PP bag containing pesticide free maize, while all hermetic bags and the maize treated with Shumba were well preserved with no dust generated by insect activities (Fig. 9). In contrast to these results, in terms of efficacy, the majority of the hermetic bags were perforated by the LGB adults with PICS and Supergrain Bag exhibiting 8 and 12 holes on average respectively, while AgroZ Bag had 2 holes on average (Fig. 10). No holes were found in the AgroZ Bag Plus samples tested (Fig. 10). This again suggests that the pesticide repellent prevented LGB adults from perforating the bags, consistent with the results obtained using tiny bags.

Conclusion: All these results point to the fact that hermetic storage bags are as good as pesticide treatment such as Shumba in protecting maize from damage due to insect pests such as LGB and maize weevils. Hermetic storage bags such AgroZ® Bag and AgroZ® Bag Plus, Supergrain Bag and PICS bags are safer ways to preserve maize and other produces than current fumigants and pesticides such as Shumba. All hermetic bags tested were able to minimize or eliminate postharvest losses associated with LGB and other grain weevils. AgroZ® Bag Plus distinguished itself from the other hermetic bags as it was the only one at the end of the experiments which could be reused by farmers as it was not holed by LGB adults. The presence of living weevils in the other hermetic bags seems to be due to the holes observed in these bags in contrast to AgroZ® Bag Plus. The presence of *Tribolium spp* (Flour beetle) observed only in the control PP bag is well explained by the amount of dust (maize flour) collected from this treatment.

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