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Field efficacy of hermetic and other maize grain storage options under smallholder farmer management

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ABSTRACT

Household grain storage continues to be of paramount importance in improving food security in sub-Saharan Africa (SSA) where maize post-harvest losses of 10–20% are reported. On-farm trials to compare alternative solutions for reducing household maize storage losses were conducted in the 2014/15 and 2015/16 storage seasons in two contrasting agro-ecological zones in the Hwedza district of Zimbabwe. A wide range of treatments including a commercial synthetic pesticide composed of fenitrothion 1% and deltamethrin 0.13%, unregistered but commonly used botanical pesticides (*Aloe* ash, *Colophospermum mopane* leaves, *Eleusine coracana* (rapoko) chaff, and *Ocimum gratissimum*), hermetic storage facilities (metal silos, GrainPro Super Grain Bags (SGB) IVR™, Purdue Improved Crop Storage (PICS) bags), and storage bags with deltamethrin incorporated into their fabric, were evaluated. The results demonstrated the superiority of hermetic storage facilities (PICS bags, SGBs, and metal silos) in suppressing insect pest build-up, insect grain damage and weight loss in stored maize grain. A newly introduced synthetic pesticide on the Zimbabwean market which has pirimiphos-methyl 1.6% and thiamethoxam 0.36% was also evaluated in the 2015/16 season and was found to be highly effective. The following grain storage technologies: hermetic metal silos, SGB bags, PICS bags, and the pesticide pirimiphos-methyl 1.6% and thiamethoxam 0.36% are therefore recommended for smallholder farmer use to reduce stored grain losses due to insect pests.

1. Introduction

Maize is a staple food in much of sub-Saharan Africa (SSA) where it is grown mainly by resource poor farmers (Phiri and Otieno, 2008). Most SSA countries experience tropical climatic conditions with distinct uni or bimodal rainfall seasons, and a hot dry season (Gordon, 2009; Besada and Sewankambo, 2009). Consequently, in many areas, a rain-fed crop is harvested once per year; and the grain dried and stored for gradual household consumption until the next harvest arrives or kept for sale later in the season (Mvumi and Stathers, 2003).

In unimodal rainfall areas, smallholder farmers will typically store their maize grain for periods of up to eight or twelve months (Mvumi and Stathers, 2003). During this storage period, grain is vulnerable to attack by insect pests resulting in considerable losses. Average maize postharvest losses of 18.6% have been estimated across SSA (APHLIS, 2014), and the World Bank's Missing Food study reports grain postharvest losses of 10–20% in the same region; with an annual value of US$ 4 billion (World Bank et al., 2011). Insect pests of economic importance in stored maize in SSA include the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera; Curculionidae) (Stathers et al., 2002a,b; Midega et al., 2016); the red-rust flour beetle, *Tribolium castaneum* Herbst (Coleoptera; Tenebrionidae) (Stathers et al., 2002a,b; Mvumi and Stathers, 2003); the Angoumois grain moth, *Sitotroga cerealella* Olivier (Lepidoptera; Gelechiidae) (Stathers et al., 2002a,b; Mvumi and Stathers, 2003; Midega et al., 2016) and the larger grain borer (LGB), *Prostephanus truncatus* Horn. (Coleoptera: Bostrichidae) (Nyagwaya et al., 2010; Abass et al., 2014). The introduction and establishment of the LGB in the late 1970s increased the magnitude of grain storage losses in Africa (Boxall, 2002; Mutambuki and Ngatia, 2012). Storage insect pest problems are likely to be

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exacerbated by global warming as most of these pests multiply faster under higher temperatures (Gornall et al., 2010; Stathers et al., 2013).

While many farmers in SSA rely on synthetic pesticides to control grain storage insect pests, many others who cannot afford or access synthetic pesticides use methods such as “botanical leaf powders” (Mvumi and Stathers, 2003). Botanical pesticides are products derived directly from plants that have pesticidal properties (Ortiz-Hernandez et al., 2013) and are used to protect crops and livestock, crop products, the environment and humans from synthetic pesticide toxicity which has become a global problem (Rozman et al., 2007). Recent studies suggest botanical pesticides have gained enormous research attention as in many cases, smallholder farmers consider them the only economic option for grain storage (Stevenson et al., 2014). Moreover, concerns over pesticide residues in food (Damalas and Eleftherohorinos, 2011) are also driving the need for safer alternative storage technologies. The overzealous use of synthetic pesticides has resulted in unforeseen dangers, leading to increased regulation and focus on alternative pest management methods (Isman, 2006).

In this study, a range of alternative grain storage technologies including unregistered botanical pesticides, synthetic pesticides, air-tight (hermetic) storage as well as polypropylene bags with the synthetic pesticide incorporated in their fabric; were evaluated for efficacy against maize storage insect pest damage. Hermetic storage technologies provide farmers with chemical-free grain protection options (Villers et al., 2010; Mutungi et al., 2014). The hermetic storage facilities tested were GrainPro Super Grain Bags (SGB) IVR™, Purdue Improved Crop Storage (PICS) bags, and metal silos. The PICS bag has two inner liners each made of 80 μm thick polyethylene (Baributsa et al., 2012), and these liners are placed one inside the other in a woven polypropylene bag (Murdock et al., 2012). By contrast, SGBs just have a single polyethylene liner inside a woven polypropylene bag (De Groote et al., 2013). Once the hermetic bags are loaded with well-dried grain and tied shut, the biological activity of the grain and respiration of any insects present, results in depletion of oxygen and build-up of carbon dioxide concentration inside the bag to levels high enough to cause asphyxiation or desiccation of the insects (Murdock et al., 2012; Hodges and Stathers, 2012; Moreno-Martinez et al., 2000). The ZeroFly® technology makes use of woven polypropylene bags with deltamethrin incorporated into the polypropylene fabric and insects are killed when they come into contact with the bag (Baban and Bingham, 2014; Costa, 2014).

Few field studies have comprehensively tested such a range of storage technologies under smallholder farmer circumstances to determine their efficacy and appropriateness, especially where *P. truncatus* occurs. To promote the integration of the new technologies with indigenous knowledge, co-learning and co-innovation; a Learning Centre approach, as described by Mashavave et al. (2011) was used in evaluating the storage options. It is anticipated that the knowledge and hands-on experience of farmers, extensionists and other stakeholders gained through participating together in the trials will facilitate quicker, longer-term and more wide-spread adoption of the most effective grain storage technologies. The current paper reports on the bio-physical findings of the trials, while the results of the farmer and stakeholder interactions are reported separately, elsewhere. The specific objective of the current study was to evaluate the potential of the hermetic storage containers and deltamethrin-incorporated polypropylene bags in controlling maize storage insect pests in smallholder farming systems compared to farmers' normal practices and commercial synthetic pesticides.

2. Materials and methods

2.1. Site description

Field trials were conducted in the Hwedza district (18°41′ S; 31°42′ E) of Zimbabwe in two consecutive grain storage seasons (2014/15 and 2015/16). The trials were hosted by smallholder farmers in two wards (the administrative unit between district and

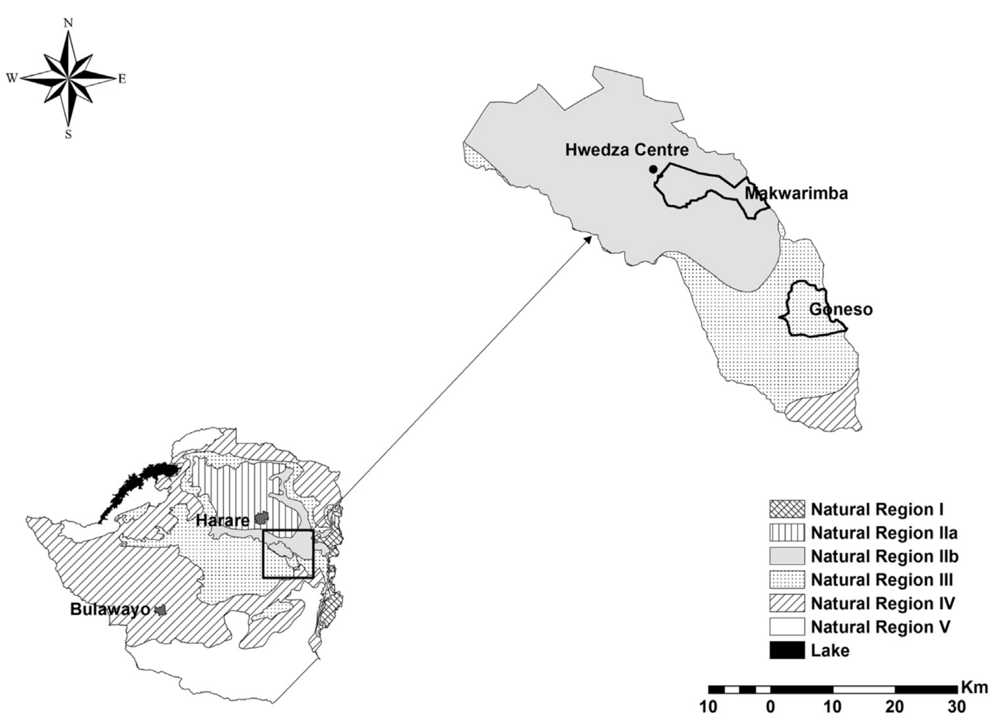

Fig. 1. Map of Zimbabwe showing study sites in Hwedza district, Makwarimba ward (Natural Region IIb) and Goneso (Natural Region III).