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Evaluation of Plastic and Steel Bins for Protection of Stored Maize against Insect Infestation in Ghana

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Abstract

Maize is a staple food in Ghana where there is ever increasing demand for its use to also support poultry and livestock production. However, post-harvest loss of maize is high in Ghana. This study evaluated the effectiveness of plastic and steel bins as bulk storage structures to reduce maize post-harvest loss in Ejura, Ghana during the period from February 2016 to January 2017. Maize pre-disinfested with a solar biomass hybrid dryer was stored in the following treatments: i. a white 7-ton plastic bin filled with untreated maize, ii. agreen 7-ton plastic bin filled with untreated maize, iii.a 6-ton Kikapu steel bin filled with untreated maize, iv. six 50-kg polypropylene (PP) bags filled with maize treated with Betallic Super (80 g pirimiphos-methyl and 15 g permethrin per liter as an emulsifiable concentrate (EC)), and v. six 50-kg PP bags filled with untreated maize ascontrol. Moisture content, insect pests, insect damaged kernels (IDK), grain weight loss, aflatoxin and fumonisin levels data were collected monthly. *Sitophilus zeamais*, *Triboliumcastaneum, Cathartusquadricollis*, and *Cryptolestesferrugineus* were the dominant insect species collected from maize samples. At the end of 12 months of storage, % IDK in the control was >17% while IDK values in the other treatments were <3%. Mean grain weight losses of <1% were recorded in the bin treatments. Mycotoxin levels in the control were above the allowable threshold of 15 ppb. Our data suggest that use of plastic and steel bins has potential to reduce post-harvest loss of maize during storage.

Key words: Storage bin**,** post-harvest loss, aflatoxin, fumonisin, grain storage.

1. Introduction

Maize is a staple food for about 1.2 billion people in sub-Saharan Africa (SSA) (IITA, 2009). In Ghana, there is ever increasing demand for its use to support poultry and livestock production. However, measurable quantitative, qualitative, and economic losses of maize grain occur along the post-harvest system (Tefera, 2012). And, the Food and Agriculture Organization of the United Nations and World Bank data estimated that post-harvest loss (PHL) of cereals in SSA ranged between 5–40%, and worth approximately $4 billion (Zorya et al., 2011).

Insect pest infestation constitutes the major threat; these infestations can cause losses of approximately 20–50% of stored maize in most African countries (CABI, 2012). Although synthetic insecticides can be effectively used to manage stored-product insect pests, the majority of resource-poor farmers in developing countries do not use these chemicals because of inability to afford them, along with the associated environmental and health concerns among others. Therefore, farmers resort to the use of traditional storage techniques including bag storage, and warehouses (FAO, 1994; Adejumo and Raji, 2007). However, bag storage is the most preferred storage technique in developing countries (Koona et al., 2007; De Groote et al., 2013) even though post-harvest losses in bagged commodities are high.

Therefore, there is a need to explore the use of alternative technologies for the protection of grains. In Ghana, little research has been undertaken in bulk storage of maize in plastic and steel hence this study which evaluated the effectiveness of two 7-metric ton plastic storage bins (white and green color) and a 6-metric ton steel bin to protect maize against infestation by stored grain insect pests as compared to farmers' current practice of using PP bagswith or without pesticide.

2. Materials and Methods

This study was conducted in Ejura, located in the Middle Belt of Ghana. The site selected for the study was near a maize market where insect pressure was expected to be high. The study spanned the period from February, 2016 to January, 2017. Maize pre-disinfested with a solar biomass hybrid dryer was stored in the following storage types as experimental treatments: i. a 7-ton white plastic bin filled with untreated maize, ii. a 7-ton green plastic bin filled with untreated maize, iii.a 6-ton Kikapu steel bin filled with untreated maize, iv. six 50-kg polypropylene (PP) bags filled with maize treated with Betallic Super (80 g pirimiphos-methyl, and 15 g permethrin per liter as an emulsifiable concentrate (EC), and v. six 50-kg PP bags filled with untreated maize (control).

No insect pest-control measures were conducted during the 12-month storage period of the study. The experimental design used was completely randomized design (CRD). However, the bin treatments could not be replicated because of budgetary constraints arising from the cost of plastic and steel storage bins and quantities of maize used. However, there were six replicates for the bag treatments. White maize variety "Obaatanpa" sourced from a single farmer was dried to a moisture contentof 12.5% using a solar biomass hybrid dryer. Initial and monthly maize samples were collected from storage bins and bags. Three out of six bags from the control and Betallic-treated maize were randomly selected and 250-g sample taken from each bag during each sampling month. For the storage bins, 250 g samples were taken from three different sections along a vertical profile (top, middle and bottom sections). In each section of the profile, grains were collected from six random positions. Moisture content (MC) and temperature of maize in each selected bag and each section of the storage bins were determined using a John Deere moisture meter and PHL moisture meter developed by the USDA-ARS. Maize samples were transported to the insect laboratory of the Department of Crop and Soil Sciences of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana in 17-liter Koolatron® 12-V Compact Portable Electric Cooler for mycotoxin analyses. Insect species and numbers and percentage insect damaged kernels (%IDK) were also determined. Mycotoxin (aflatoxin and fumonisin) analyses were performed using a standard Romer Labs test kit (romerlabs.com). Weight loss due to insect damage was assessed using the count and weigh method of Harris and Lindbald (1978) and Boxall (1986) as:

$$\text{Weight loss (\%)} = \frac{[(WuxNd)-(WdxNu)]}{Wux\ (Nd+Nu)} x\ 100$$

Where, W_u= Weight of undamaged grain, N_u= Number of undamaged grain, W_d= Weight of damaged grain, and N_d= Number of damaged grain.

Statistical analysis was not performed on the data because the storage bins were not replicated. Only means and standard error were calculated using SAS version 9.4 (SAS Institute, Cary, NC).

3. Results

The results showed that initial mean moisture content (MC) of maize in bins was 15.9–18.0% compared to the bags (10.1–10.5%); however, MC in the bins declined to 12.6–12.9% in March. Grain MC subsequently fluctuated in all the treatments reaching 14.0–14.3% and 13.8% in the bins and bags, respectively at the end of the experiment. No live insect species was observed during the first 6 months of storageprobably because pre-storage disinfestation was effective against the adults and re-infestation was virtually nil? Temperaturesrecorded were between 26.6 and 39.7 °C whiles relative humidity ranged 22.9-73.1%. The dominant insect species found after the sixth-month period were *Sitophilus zeamais*Motschulsky, *Triboliumcastaneum*Herbst, *Cathartusquadricollis*Guerin-Meneville, and *Cryptolestesferrugineus*Stephens. *Sitophilus zeamais* was the most dominant insect species with a mean total 34.3 ± 6.7 per 250 g in the control; other treatments had < 4 per 250 g) (Table 1). The highest total number of *C. quadricollis* (10.83 ± 3.55 per 250 g) was recorded in the Betallic treatment while the bin treatments had <1.00 per 250 g. With the exception of the white plastic bin which had 1.17 ± 0.41 live *Cryptolestesferrugineus*per 250 g, all other treatments had < 1.00. Percentage insect damage kernels (% IDK) was highest in the control (17.9 ± 5.2) than the other treatments (<3%) (Fig. 1), which is below the 5% threshold set by Ghana Standard Authority (GSA) for commerce (Reference). Mean grain weight losses recorded in the bin treatments were < 0.5% throughout the storage period. However, ~1.6% mean grain weight loss was recorded in the control (Fig. 1). Mean aflatoxin levels of maize in the storage bins were below 15 ppb which is the safe threshold set by GSA (year?). However, in the control, mean aflatoxin level was over 47 ppb at the end of the study (Fig. 2). Similarly, mean levels of fumonisin in the control was 5.3 ppm which is above the safe threshold of 4 ppm; mean levels of fumonisin in the bins and the betallic treatment was < 2 ppm.

Tab. 1. Mean total number (±SE) of *Sitophilus zeamais*(SZ), *Triboliumcastaneum* (TC), and *Cathartusquadricollis* (CQ) per 250 g of maize sampled from five storage types in Ejura, Ghana from September to January.

Storage type	SZ	TC	CQ
Control	34.28 ± 6.75	2.28 ± 0.68	1.28 ± 0.45
Betallic	0.28 ± 0.14	0.11 ± 0.08	10.83 ± 3.55
White plastic bin	0.94 ± 0.26	0 ± 0.0	0.78 ± 0.47
Green plastic bin	1.72 ± 0.38	1.06 ± 0.32	0.22 ± 0.13
Steel bin	1.11 ± 0.34	2.83 ± 0.69	0.06± 0.06

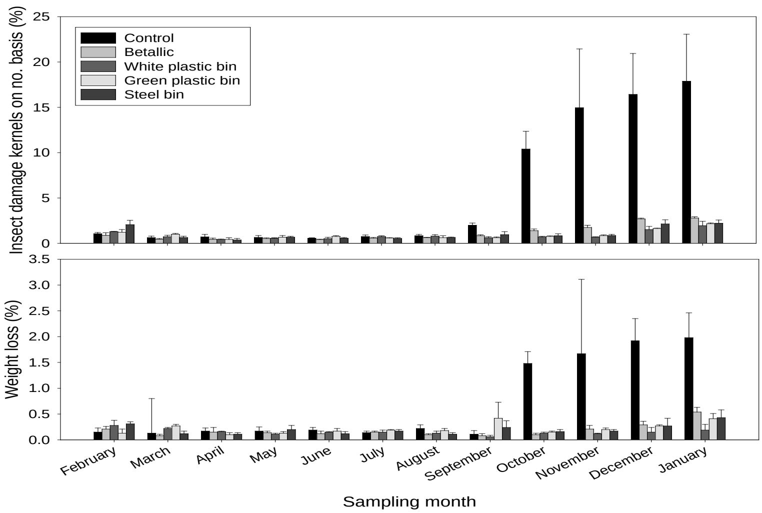

Fig. 1.Percentage insect damage kernels on number basis and percentage weight loss (Mean ± SE) per 250 g of maize obtained from five storage types in Ejura, Ghana.

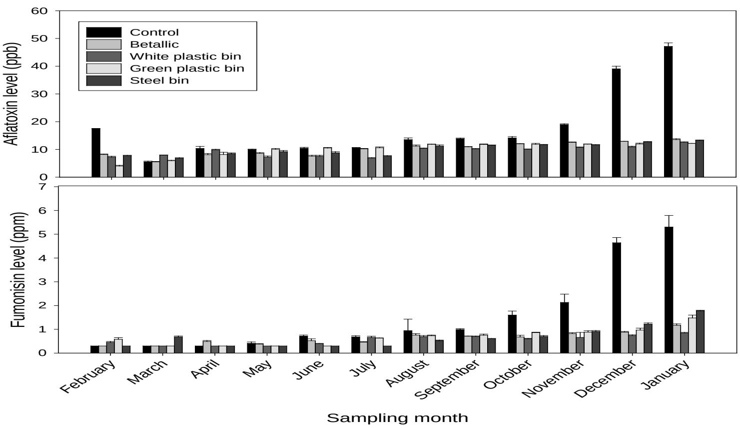

Fig. 2. Aflatoxin (ppb) and fumonisin (ppm) levels (Mean ±SE) in maize sampled from five storage types in Ejura, Ghana.

4. Discussion

The results of this study demonstrate that storage bins can keep the quality of maize for a reasonably longer period of time than the PP bags if they are properly designed and managed. It must be noted that during sampling a lot of insects which otherwise might have entered to infest maize inside the bins were found dead on the lid on the plastic storage bins**.**

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Insect infestation and quality loss of major stored products in Ghana

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Post-harvest losses are economically significant in Ghana for a broad range of commodities, resulting in a substantial negative impact on food security and livelihoods. Maize grains are the main food crops that provide staple diet for the majority of the population. A nation-wide survey was conducted in the three different geographical zones of Ghana (Northern savannah, the semi-deciduous middle belt and the coastal zones) to determine insects infesting major staples and evaluate the damage and losses caused. At each sampling, 1 kilogram of grain was sieved. Insects, frass and grains were collected separately. A random sample of 100 grains was taken from each sample for the determination of moisture content, percentage damage, weight loss and the number of insects per kilogram. The Thousand grain mass method was used to determine dry-weight loss. The levels of grain damaged were significantly different among the samples. Maize from markets in the Central region recorded the highest mean damages (14% and 17%) while the least (0%) was from Tinga in the Northern region. *Sitophilus zeamais* was the predominant insect in all maize stores and farms across the country. Its damage was lower than that caused by *Prostephanus truncatus*. Several parasitoid Hymenoptera, and an anthocorid predator were also collected in this survey. The parasitoids will be identified to species level to help us understand their biology and consequently develop rearing models for mass release to curb the injuriousness caused.