Impact of a novel tool, ZeroFly® Storage Bags, within multi country field trials; controlling key target post-harvest storage pests on various commodities

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DOI: 10.14455/DOA.res.2014.138

Abstract

Food production losses post-harvest affect the consumer, leave to reduced profitability and threaten global food security. Protection against insect pests can be ineffective, expensive, requires repeat intervention and raises safety and environmental concerns. The ZeroFly® Storage Bag was developed for postharvest storage of commodities including cereal grains, pulses, oilseeds and seeds. Insecticide is incorporated into woven polypropylene fibers providing powerful killing action against stored product insects before they can infest the grain/seed packed in the bag. The active ingredient deltamethrin is released on the surface of the material in a sustained manner for up to two years so that the commodities stored in the sacks are continuously protected against insect infestation. Maximum Residue Limits (MRL's) are below the strictest limits available worldwide including, Codex Alimentarius, US EPA & European Community standards (2 mg/kg of grain) & Indian Standards (0.05 mg/kg of grain) even under high pressure, temperature and wet weather condition for the full 2 year storage period. All toxicology data has come out very positively; Oral Toxicity on Rats: Globally Harmonized System (GHS) as category 5: Safe, Acute dermal irritation/corrosion potential was non–irritant to the skin of New Zealand White Rabbits, Minimally irritating (M1) to the eyes (New Zealand White Rabbits) and A non-sensitizer to the skin of guinea pigs. In addition the Human Risk Assessment, shows that with the use of safety accessories such as gloves, full-sleeved shirts and light footwear as recommended on the label, means the bags are absolutely safe for handling in households hence no safety measures are required. The Dietary Risk Assessment, based on the GEMS calculation, % accepted daily intake is only 20–40% of the ADI of deltamethrin; residues in stored commodities in the sacks will not exceed the ADI & thereby not be detrimental to human beings consuming the food. A summary of the successful multi country commodity field and lab studies will be presented.

Keywords: food security, post harvest storage, new innovation, safe, effective

1. Introduction

Stored grain is susceptible to damage and consumption by insects such as the lesser grain borer (*Rhyzopertha dominica*), larger grain borer (*Prostephanus truncatus*), maize weevil (*Sitophilus zeamais*), and red flour beetle (*Tribolium castaneum*). If insects are not controlled, losses can be 20-80% a few months after harvest (Cao et al., 2002; APHLIS, 2011). This decreases food security and contributes to malnutrition in these countries that struggle to provide adequate food for their nutritional needs. Insects in stored grain can be controlled using techniques such as pre-storage sanitation, using insecticides, aerating to reduce grain temperatures, adding diatomaceous earth, and creating oxygen-free conditions (Stathers, 2008; Harien and Subramanyam, 1990; Murdock, 2003). These intensive management practices can reduce grain losses to less than 1%.

Most grain is stored in bags in developing countries, and subsistence farmers store 50-75% of grain on-farm (Baloch, 1999).

2. New Innovative Concept

A novel and innovative tool; an insecticide-incorporated polypropylene bag is designed to protect commodities (grains and seeds) against destructive insect pest infestation during storage. ZeroFly® Storage Bag is a woven polypropylene bag developed for postharvest storage of cereal grains, pulses, oilseeds and seeds. Deltamethrin (DM) insecticide is incorporated into the individual fibers, which provide powerful killing action against stored product insects before they can infest the grain/seed packed in the bag. Preliminary tests show 100% bio-efficacy and that no insect can bore/chew through the ZeroFly® Storage Bag. Therefore the product is efficiently protecting stored crops by preventing insects' entry after bagging.

3. Materials and Methods

3.1. Objectives and measurable outcomes

The primary objective pursued in these studies was: to determine the field efficacy (indoor storage) of Vestergaard's (VF) ZeroFly® Storage Bags as compared to common polypropylene bags (commonly used by warehouse operators) as negative control. Monthly monitoring of stored commodity's quality parameters was conducted.

Measures:

1. Insect infestation, insect-damaged grains and weight loss discolored during indoor storage (grain quality/grading).
2. Deltamethrin levels still present at acceptable levels in the ZeroFly® Storage Bags at the end of the storage period.

Outcome:

Robust scientific data supporting the usefulness of ZeroFly® Storage Bags as a tool to protect stored commodities and improve post-harvest storage practices, increasing food security in the most vulnerable regions.

Measures:

1. Insect infestation (number of live & dead insects per working sample).
2. Insect-damaged and discolored grains (grain quality/grading).
3. General physical condition of the bags over of the storage period.
4. Deltamethrin levels still present at acceptable levels in the ZeroFly® Storage Bags during the storage period.

Example of suggested trial design:

A randomized block design. Test hypothesis: grain quality (insect infestation, insect-damaged and discolored grains) is superior for ZeroFly® Storage Bags as compared to control bags after up to 24 months of storage. Proper initial fumigation/cleaning of commodities is recommended before bagging.

The bags were stacked separately per crop and distributed randomly across the storage area. Nevertheless, the treatment type will be well separated by distance (at least 2-3 m) as previous results have shown a high level of community effect of the ZeroFly® Storage Bags. The trial durations were up to 24 months of storage, with monthly sampling.

Outcome	**Measure**
Grain quality	Live insects
	Dead insects
	Insect damaged grains
	Undamaged grains
	Broken grains
	Discolored grains
	Molded grains
	Foreign matter
	Weight loss
	Moisture content

SOP I3.5.1 Holes (made by insects)

The sampled bags will be inspected for holes made by insects and the number of holes counted. Insect damage on the entrance side of the holes is characterized by scratches and deep scars (Riudavets, Salas and Pons, 2007). Photographs will be taken of holes observed on 3 (three) x 10 (ten) cm^2 surface, chosen at random, and marked with permanent marker. At the end of the trial, 3 (three) marked (sampled) bags for each treatment arm/location will be sent for further physical and chemical examination.

SOP I3.5.2 Insect infestation level

Samples taken from each selected bag will be weighed and recorded. The total maize per stack will carefully pooled together and 1 kg of grain will be retained for further analysis. The extra maize will not be returned to the bags. Grain will be sieved at the laboratory, passed through sieves (No. 10 or 12, 2 mm mesh size) to recover live and dead insects and the numbers (live and dead counted separately) and species will be recorded. Live and dead insects will be identified carefully and the numbers of each recorded. Insects will be identified to species level using insect identification keys (Ortega, 1986) and Pictorials. The retained quantity of 500 g of commodities will be separated (using a grain sample divider Riffle or a Boerner divider), after removal in insects, into following working samples:

A: 250 g for damaged grains (insect or other damage/discoloration)
C: 250 g to be analysed for Moisture Content
D: 250 g for reference (archive)

Any working samples that will not be used, will be kept on storage until the end of the trial.

SOP I3.5.3 Moisture content

Moisture content of samples will be tested monthly.
The observed Moisture Content will be used to make any corrections to the final weight loss/gain of the grains (as weight loss is depended on Moisture Content too) and will also be evaluated as a Grain quality parameter.

SOP I3.5.4 Insect-damaged grains

Insect damaged grain will be sampled monthly, as it represents an important grain quality parameter.

Minimum working samples for identification of insect damaged grain is 200 g of small grain maize and 250 g of large grain maize (FAO).

SOP I3.5.5 Damaged/discolored grain

Damaged and discolored grain will be sampled monthly.

> Maize: Codex Standard 153-1985 outlines that 'maize shall be free from abnormal flavours, odours and living insects. Moisture content should be no more than 15.5% m/m. Filth are impurities of animal origin (including dead insects) and no more than 0.1% m/m is permissible. Damaged/blemished grains are outlined as follows: grains which are insect or vermin damaged, stained, diseased, discoloured, germinated, frost damaged, or otherwise materially damaged. A maximum of 7.0% damaged kernels are permissible, of which diseased grains must not exceed 0.5%. A maximum of 6.0% broken kernels is allowed, following ISO 5223-1983 (4.50 mm metal sieve).

The Neergaard (1977) method for rating discoloration in grain would be used. For this, 100 grains are randomly sampled and examined using a x100 hand lens. The ratings are as follows (NB. ensure % discoloration should be recorded and not only rating):

Discoloration ratings

Rating	% Discoloration	International quality standard
1	Free	Excellent
2	1-10	Good
3	11-25	Poor quality
4	26-50	Bad quality
5	Over 50	Very bad quality

Percentage damaged plus discolored grain will be compared between treatments.

SOP I3.5.6 Weight loss/gain of grain

The sampled grain will be assessed for weight loss using the count and weight method of Gwinner et al. (1996):

$$\text{Weight loss (\%)} = \frac{((W_u \times N_d) - (W_d \times N_u)) \times 100}{W_u \times (N_d + N_u)}$$

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.
or
In case of extensive damage, the following formula may be applied to the entire bag:
((Initial weight - final weight)/Initial weight) * 100
NB Final weight is the weight of the bag at the time of sample.

Corrections should be applied if the bag was previously sampled.

The initial weight of the bags (at T_0) and weight at 6 months (T_{end}) must be recorded for all bags, as changes in weight relate to moisture content and/or infestation level. See also Moisture content sub-heading above. The sampled bags' weight will be corrected (weight of removed samples).

Summary of physical grain tests:

Tests required	Measure
Weight loss/gain of bags (SOP I3.5.6)	Weight bags at initiation (=50kg of commodity)
Weight loss/gain of grain (SOP I3.5.6)	Weight grain samples
Moisture content (SOP I3.5.3)	Moisture content of monthly samples (SOP I3.5.3)
Insect infestation level (SOP I3.5.2)	Insect counts, species identification (SOP I3.5.2)
Insect-damaged grain (SOP I3.5.4)	Insect-damaged grain identification & count (SOP I3.5.4)
Damaged/discolored grain (SOP I3.5.5)	Damaged/discolored grain identification & count (SOP I3.5.5)

Statistical analysis: ANOVA will be performed to compare data on grain quality (damaged kernels and insect counts, treated vs control bags) collected from all locations. Data will be pooled (all treated vs all control bags), and analyzed by individual location (treated vs control in each facility).

N.B. The detailed results are the available upon request following permission of the named institutions.

4. Conclusions

All key target pests were controlled within all main agro-ecological zones, 11 countries, various commodities and protection more than 1 year. The ZeroFly® Storage Bag protects not only from external infestation, providing an early barrier to insects trying to penetrate the bags but also internal infestation (pre-bagging under smallholder storage conditions). In addition insects contacting the bag are killed, therefore reducing the warehouse insect populations. For large scale warehouses an initial fumigation of grain before storage is recommended, according to FAO directives, to ensure 0% damage. Further investigations are ongoing with field trials in different countries, Kenya, Zambia, Ghana, India, Vietnam, under a variety of ecological settings, for up to 2 years duration. Protection of seeds, especially high value hybrids, is being conducted with Kenya Seed Corporation. Other storage commodities are being tested including; dried fish and flour.

Acknowledgements

The studies were conducted by independent research institutions available upon request.

References

African Post Harvest Losses Information System, 2011. Available at http://www.aphlis.net [last accessed 30 Sept 2011].

Baloch, U.K., 1999. Wheat: post-harvest operations. Pakistan Agricultural Research Council. Edited by D. Mejia, AGSI/FAO.

Cao, D., Hart, K., Pimentel, D., 2002. Postharvest Crop Losses (Insects and Mites), Chapter 299, Encyclopedia of Pest Management. Pimentel, D (Ed.), CRC Press.

Costa, S.J., 2014. Reducing food losses in Sub-Saharan Africa (improving post-harvest management and storage technologies of smallholder farmers.) An 'Action Research' evaluation trial from Uganda and Burkina Faso. August 2013 – April 2014. http://documents.wfp.org/stellent/groups/public/documents/special_initiatives/WFP265205.pdf. Retrieved January 14, 2015.

Cruz J.F., Diop, A., 1989. Agricultural engineering in development: warehouse technique. FAO Agricultural Services Bulletin 74. http://www.fao.org/docrep/017/ap702e/ap702e.pdf.

Grain Storage Techniques. FAO Agricultural Services Bulletin No. 109., 1994. http://www.fao.org/docrep/t1838e/T1838E00.htm#Contents.

Gwinner, J., Harnisch, R., Muck, O., 1996. Manual on the prevention of post harvest seed losses, post harvest project, GTZ, D-2000, Hamburg, FRG, p. 294.

Harein P.K., Subramanyam, B., 1990. Controlling Indian meal moths in stored shelled corn and soybeans. Agricultural Extension Service Bulletin No. AG-FS-0996.

Maize in human nutrition, 1992. FAO, Rome.

Murdock, L.L., Seck, D., Ntoukam, G., Kitch, L., Shade, R.E., 2003. Preservation of cowpea grain in Sub-Saharan Africa: Bean/cowpea CRSP contributions. Field Crops Research 82, 169–78.

Neergaard, P., 1977. Seed Pathology. Vol. I, Vol II. John Wiley & Sons, Inc., New York. 1187 pp.

Ortega, C.A., 1986. Insect Pests of Maize: a guide for field identification. Maize Program, CIMMYT. Mexico, D.F, 6-641.

Riudavets J., Salas, I., Pons, M.J., 2007. Damage characteristics produced by insects pest in packaging film. Journal of Stored Products Research 43, 564-570.

Stathers, T.E., Riwa, W., Mvumi, B.M., Mosha, R., Kitandu, L., Mngara, K., Kaoneka, B., Morris, M., 2007. Do diatomaceous earths have potential as grain protectants for small-holder farmers in sub-Saharan Africa? The case of Tanzania. Crop Protection 27, 44–70.

http://www.gipsa.usda.gov/publications/fgis/handbooks/grain-insp/grbook2/corn.pdf (Section 4.12, Infested Corn).

http://www.gipsa.usda.gov/publications/fgis/handbooks/grain-insp/grbook1/bk1ch2.pdf (Section 2.5, Sampling Sacked Grain).