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*Full Length Research Paper*

# Evaluation of efficacy of a long lasting insecticide incorporated polypropylene bag as stored grain protectant against insect pests on cowpea and maize

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**Efficacy of long-lasting polypropylene storage bags incorporated with deltamethrin insecticide developed by Vestergaard Frandsen SA. to protect grains (cowpea and maize) from stored products insect damage was compared to grains admixed with Permethrin at 2.5 ppm stored in Polypropylene (PP) bags and untreated grains stored in PP bags investigated in the laboratories of Nigerian Stored Products Research Institute, Ilorin, Kwara State, Nigeria in 2013. *Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae), *Sitophilus zeamais* L. (Coleoptera: Curculionidae), *Rhyzopertha dominica* Fab. (Coleoptera: Bostrichidae) and *Tribolium castaneum* Herbst. (Coleoptera: Tenebrionidae) adults were used as test insects to determine the contact-sensitivity of each pest to deltamethrin insecticide treated storage bags nd PP bags for different exposure times; attack to stored grains by preventing pest entry or exit through treatment storage bags as well as effect of insect infestation on grain quality. Test insects exposed to deltamethrin insecticide treated storage bags recorded 90% knockdown compared to 0% in untreated PP bags after 72 h and adults could not chew/bore through the deltamethrin insecticide treated storage bags either from inside or outside at 72 h respectively after treatment compared to untreated PP bags where adult test insects chewed/bored either from inside or outside within 24 h. Control set up by retaining insects without feed to check mortality recorded 65-90% death of the test insects due to starvation after 7 days. Simulated study on insect infestation of grains in deltamethrin insecticide treated storage bags compared to grains treated with Permethrin at 2.5 ppm and stored in PP bags recorded higher percentage mortality of the test insects in deltamethrin insecticide treated storage bags than in PP bag. There was no change in moisture content, crude protein, ash, fiber, oil, carbohydrate of cowpea or maize grains stored in treatment bags after 6 months storage period. The deltamethrin insecticide treated storage bags are recommended because of their ability to control the target insects or pests in general. Further study to conduct a field trial using the insect incorporated bags in selected household and traders grain stores was recommended.**

**Key words:** deltamethrin insecticide treatedstorage bags, test insects, chew/bore, stored grains, grain quality.

## INTRODUCTION

It has been estimated that 25% of the global food production, including 600 to 800 million tons of cereals, are lost during post-harvest processes annually (Cao et al., 2002). Twenty percent of 25% of the losses in grains is due to insect and mite damage in storage, a loss of $25.8 billion USD. Post-harvest losses are generally 1 to 5% greater in the developing countries compared to developed ones, but this figure can vary depending on the product/crop, the pests and the country/region (Cao et al., 2002). The post-harvest loss in Nigeria is estimated at ₦48 billion annually (Adejumo and Raji, 2007). *Callosobruchus maculatus*, *Sitophilus zeamais*, *Rhyzopertha dominica* and *Tribolium castaneum* are major insect pests of stored cowpea and maize in the tropics and including Nigeria (Bekele et al., 1997; Asawalam and Emosairue, 2006). Insect infestation in stored food commodities reduces quality and quantity of food available for human consumption (Rajendran, 2005). Losses caused by these insects include: weight loss; discoloration and changes of flavor; mould formation; reduced nutritional value due to lowered protein levels and poor germination of seed due to embryo damage (FAO, 1985). Potential contaminants from insects include excreta (uric acid), secretions, exuviate (cast skins) and webbing (Rajendran, 2005), as well as both living and dead insects. Live insects in grain can also cause additional problems. Respiring insects produce water, $CO_2$ and heat. Grain is hygroscopic and therefore adjusts its moisture content to that of the surrounding atmosphere.

Higher infestations result in high moisture content of the grain and the grain also heats up in the areas of high insect activity (called hotspots). As grain is a poor conductor of heat, the hotspots remain but the insects seek cooler spots to lay eggs, where another hotspot is formed. Where damp grain heating occurs, (where the temperature of grain is greater than 15°C), moulds form and mycotoxins can be produced, which further reduces the quality of the grain and can pose a serious health hazard. Hermetic storage of grains using sealed plastic bags has been found to be effective in controlling live infestations within the bag so far, only with cowpea and rice. The hermetic atmosphere produces conditions (reduced oxygen levels) that are unsuitable for the development of insects, fungi and also reduces grain activity. However, some bacteria and yeasts can develop in oxygen depleted environments and fermentation can occur at high moisture levels, whereby $CO_2$ is partially decomposed to form alcohols, lactic and acetic acid (Rodriguez et al., 2002b).

The use of Insecticide-impregnated jute bags or prophylactic tarps is common throughout Asia as a useful alternative (Rai et al., 1987; Yadav and Singh, 1994; Payne, 2002; Mishra and Pandey, 2014). This has had varied success for several reasons, mainly the need to retreat grains is time consuming and is susceptible to error from the person applying insecticide and disposal of waste/ left over insecticide can have negative impact on the environment if not done correctly. However, the use of insecticide-impregnated jute bags or prophylactic tarp has not received much attention as pest control management for stored grains in Nigeria. Vestergaard Frandsen SA have developed storage bags, a polypropylene bag incorporated with insecticide, Deltamethrin, at the rate of 3 g/kg ± 25% (equivalent to 318 mg/m$^2$ ± 25%). According to the manufacturer, the active ingredient deltamethrin is incorporated into individual yarns and is slowly released onto the surface of the material in a controlled and sustained manner. The commodities stored in the bag are therefore continuously protected against insect infestation for lifetime of the product. In addition, the bags repel insects hence restricting their movements between bags. The bags are therefore expected to provide long term protection after fumigation and at the same time maintain grain quality parameters important to the end market. This study was conducted to verify the manufacturer's claims of efficiency of the deltametrin storage bags in grain (maize and cowpea) protection against insect pests as compared to admixing the grains with Permethrin dust before bagging or bagging in untreated Polypropylene (PP) woven bags, which are the methods and/or practices for grain storage in Nigeria.

## MATERIALS AND METHODS

All the experiments were carried out in the laboratories of Nigerian Stored Products Research Institute, Ilorin, Nigeria located on Latitude 8°30'N and Longitude 4°35'E at ambient temperature 28.29±0.6°C and 71.77±2.4% relative humidity (read from LASCAR EL-USB-2 LCDRH/Temp. Data Logger) from April to September 2013. Vestergaard Frandsen SA storage bags, a polypropylene bag incorporated with insecticide, Deltamethrin has trade name ZeroFly®.

### Grain samples

Yellow maize variety SWAM 1 was purchased from National Agricultural Seed Council, in Ibadan, Oyo State, Nigeria while Ife Brown cowpea variety was obtained from Institute of Agricultural

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Research and Training (I.A.R & T) in Ibadan. The grains were kept in a domestic deep freezer at -18 ±1°C for 7 days to kill any hidden bruchid beetles and or weevils. After 7 days, the cold-treated grains were removed and kept on the laboratory table to equilibrate to the ambient atmospheric condition prior to experiment. The grains were sieved to remove any dirt then sorted to remove extraneous materials. Only clean and wholesome grains were used for the experiments.

**Insect cultures**

*Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae), *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae), *Rhyzopertha dominica* Fab. (Coleoptera: Bostrichidae) and *Tribolium castaneum* Herbst. (Coleoptera: Tenebrionidae) were cultured in glass Kilner jars with meshed lids for the study in the Insectary of Entomology Department. Adult insects obtained from stock cultures of *C*. *maculatus* maintained on Ife Brown, a susceptible cowpea cultivar were reared (95% grain and 5% yeast), while *S. zeamais*, *R. dominica* and *T*. *castaneum* were reared on yellow maize variety SWAM 1 (95% grain and 5% yeast) in 300 ml glass Kilner jars at ambient temperature and rh of 28°C and 70%. Voucher specimens of *S. zeamais, R. dominica, T. castaneum* and *C. maculatus* that were used in this study were deposited in the insectary of Entomology department of Nigerian Stored Products Research Institutes, Headquarters, Ilorin, Kwara State, Nigeria under lot numbers 001, 050, 100 and 150 respectively.

**Bioassay**

***Contact exposure to fabric samples***

In the first experiment the deltamethrin insecticide treated storage bags (VF) and Polypropylene (PP) bags were each cut into sizes of 25 cm × 25 cm, and the upper part of the upstanding bags coated with non-sticky polytetrafluoroethylene emulsion (PTFE) Fluon to ensure insect did not escape through the tops of the bags. Twenty (0 to 3 days old) adults of *C*. *maculatus* were introduced into each treatment bag. The bag was sewn using electric bag closer machine (Guru Model). Four bags each of the fabric samples were then kept erect inside a 5L transparent plastic bucket. There were three replicates of VF bag or PP. Each VF or PP bag was observed for 6, 12, 24, 48, 72 h and daily to 7 days for insect knockdown and mortality. Knockdown of adult insects was determined using a blunt probe. Insects that moved their bodies when prodded were considered knockdown; those incapable of moving were considered dead (Dyte and Forster, 1973). In a similar experiment, 20 (1 week old) adult of *S. zeamais*, *R*. *dominica* and *T*. *castaneum* respectively were introduced into each VF or PP bag and similar procedure above was applied.

***Ability of each pest species to bore/chew through fabric sample***

In a second experiment to determine the ability of each pest species to bore/chew through fabric, VF or PP bags of 25 cm × 25 cm size were used. The insects used for this test were 0 to 3 day old adults of *C*. *maculatus* and 1 week old adults of *S*. *zeamais*, *R*. *dominica* and *T*. *castaneum* respectively. The insects were put outside or inside each VF and PP bags in the following way. For each insect species, 20 unsexed adults were put in each bag and sealed. The sealed bags were put inside 5L transparent plastic bucket which contained 500 g of cowpea for *C. maculatus*, or maize for *S. zeamais*, *R. dominica* and crushed maize for *T. castaneum*. The bucket was covered with low density nylon tied with new clean thin rubber bands tightly to prevent escape of insects. This was to investigate the ability of the insects to chew from inside of the bag to outside into the bucket.

The second batch was made up of 500 g cowpea or maize grains in the VF or PP bags placed in 5 L transparent plastic bucket which contained 20 adults of each insect under test. This was to investigate the ability of the insects to bore from outside into the bags. The different bags were examined at 15 and 30 mins, 1, 2, 4, 8, 24, 48 h and daily to 7 days, to observe how long the insects took to bore/chew through the bags. Dead insects were counted, the number of insects found in the bags or in the bucket and the number of holes if any made into each VF bag by the insects. In a set up similar to the one described above but with PP bags only, Permethrin 0.06% a. i. dust was admixed with 500 g cowpea or maize or crushed maize at the recommended dose rate of 0.03 g to serve as positive control. A control was run by retaining twenty test insects alone in a plastic bucket throughout the experimental period without feed to check for mortality, if any due to starvation. There were three replicates of each insect species and VF or PP bags. The set-up was kept in dark condition at 28.29 ± 0.6°C and 71.72 ± 2.4% relative humidity.

***Effect of the deltametrin insecticide treated storage bags on grain quality***

In a third experiment, to determine the effectiveness of the VF bags against insect pests in stored grains as compared to untreated control Polypropylene (PP bags), the procedure given in the second experiment was followed. The only difference was that infestation was simulated by infesting grains inside (VF or PP) bags with 20 adult test insects and each bag placed in plastic bucket. Live or dead insects in the treatment bags were counted at day 35 for *C*. *maculatus, S*. *zeamais*, *R*. *dominica* and *T*. *castaneum* adult insects respectively. The grains were sieved and damage/holes to bags were recorded. The Ife Brown cowpea or yellow maize variety SWAM 1 for the study had their initial moisture content, protein, ash, crude fiber and damage of the grains determined as element of grain quality. The same parameters were determined again 6 months post-treatment and kernel damage assessed to check if there were any effects on the grain quality. The method by Association of Official Analytical Chemists (2000) was employed in the determination of the above parameters. There were two set up, one for insect exit and the other for insect entry, all laid out in complete randomized design.

**Data analysis**

LT 50 and LT95 values for knockdown and mortality of each insect species by the fabric sample were estimated from log-dose probit mortality regression fitted by computer and the goodness of fit of the regression lines were determined by $X^2$ test (Finney, 1978). Data on proximate composition of the grains were subjected to one way analysis of variance (ANOVA) while significantly different means were separated using Student Newman Keuls (SNK) test; P=0.05.

## RESULTS AND DISCUSSION

Tables 1 to 2 show contact-sensitivity of each test insect species to deltamethrin-impregnated Vestergaard Frandsen (VF) bags and the currently used untreated polypropylene (PP) woven bags, assessed as insect

**Table 1.** LT50 for Knockdown of different insect species in ZeroFly® (VF) and Polypropylene (PP) bags.

| Insect species | Treatment | Regression equation | Slope (± SE) | LT50 (95% Confidence limits) | X2 | (df): | Efficacy Factor |
|---|---|---|---|---|---|---|---|
| *C. maculatus* | VF | Y = 1.88X – 1.92 | 1.88 ± 0.42 | 0.94 (1.81 – 3.90) | 30.87 | (45) | 10.07 |
| | PP | Y = 0.90X – 1.92 | 0.90 ± 0.51 | 9.47 (5.83 – 12.53) | | | |
| *R. dominica* | VF | Y = 0.80X – 1.20 | 0.80 ± 0.45 | 0.79 (0.07 – 1.36) | 29.45 | (33) | 5.84 |
| | PP | Y = 0.12X – 1.20 | 0.12 ± 0.18 | 4.61 (0.60 – 7.39) | | | |
| *S. zeamais* | VF | Y = 3.36X – 3.11 | 3.36 ± 1.12 | 1.25 (0.83 – 1.76) | 17.1 | (27) | 9.60 |
| | PP | Y = 0.30X – 3.11 | 0.30 ± 0.24 | 12.00 (7.47 – 14.33) | | | |
| *T. castaneum* | VF | Y = 1.14X – 1.60 | 1.14 ± 0.44 | 0.74 (0.27 – 1.11) | 23.21 | (36) | **7.03** |
| | PP | Y = 0.21X – 1.60 | 0.21 ± 0.15 | 5.20 (2.32 – 7.37) | | | |

NB: Efficacy factor is derived by dividing the higher $LT_{50}$ value with the smaller $LT_{50}$ value

knock down and mortality. When the knock down or mortality values (probits) were regressed on time (log), the lethal time (LT50) values in both knockdown and mortality of VF bags in all test species were found to be consistently smaller (i.e. at faster rate) than those of PP bags (Tables 1 to 2). For instance, the time taken to knock down 50% of exposed *R*. *dominica* adults (LT50) were 0.79 d (18.96 h) and 4.61 d in VF and PP bags respectively. This is faster than that of *S*. *zeamais* which recorded 1.25d and 1.22d for VF and PP bags respectively (Table 1). This is an indication that the VF bags had higher contact toxicity in knocking down and killing exposed insects more rapidly than PP bags. The fastest LT50 mortality rate was recorded in *C*. *maculatus* assay 0.28 d or 6.72 h (VF) compared to other species. Efficacy factor in *C*. *maculatus* assay shows that the rate of knock down of the bruchid adults was 10.07 times faster in VF bags than in PP bags. This is repeated at varying levels in other species (Table 2). The slopes of the log-probit lines in all VF bags were steeper than those of PP bags in all test species (Tables 1 to 2), reflecting greater insecticidal activity in the VF bag treatment. The confidence limits of the LT50s in the VF and PP bag treatments did not overlap in all the test species, indicating that the VF treatment bag was significantly more active than the PP bags. Our study showed that VF bags storage bag exhibited full bioefficacy against the four exposed species of grain beetles. All four beetle species were rapidly knocked down and killed on exposure to the bag. VF storage bag is said to work by establishing long-lasting insecticidal protection around bagged commodities. When pests come into contact with the bag in an attempt to reach the stored commodities, they get a lethal dose of the pyrethroid insecticide, deltamethrin, incorporated into the polypropylene yarns and are knocked down and eventually killed (Jacob et al., 2014; Wasala et al., 2016). The active ingredient, deltamethrin is approved by Food and Agricultural Organization (FAO) of the United Nation (UN) for use in agriculture and by World Health Organization (WHO) in public health; this product is considered safe for farmers and consumers (ZeroFly® brochure, 2015). High rate of knock down observed in our work is in consonance with findings in other published works with deltamethrin insecticide treated bags. Jacob et al. (2014) obtained >93% knock down of *S. zeamais* after 6h of exposure to the VF storage bags. The high rate of mortality recorded in *C*. *maculatus* could be as a result of VF bag-induced mortality together with natural starvation -induced mortality because this pulse beetle does not feed (Haines 1991). The higher rate knock down and kill of *R*. *dominica* by deltamethrin in the VF bag as opposed to lower rate observed in *S*. *zeamais* is due to taxomonical differences between the two beetle species. Bostrichids (for example *R*. *dominica*) are known to be most effectively controlled by pyrethroids- deltamethrin while Curculoinids (for example *S*. *zeamais*) are best controlled by organophosphorous compounds (Gwinner et al., 1990). Our finding is in agreement with Stathers (2002) study which reported that deltamethrin at 0.5 and 0. 25 ppm caused high percentage knockdown of *P*. *truncatus* within 7 days and prevented progeny emergence during 8-week period.

Figure 1 shows the ability of test insects to bore/chew through fabric samples by the making of holes. It was observed that none of the test insect species could make any hole through the deltamethrin insecticide treated storage bag (VF) while holes were made in the Polypropylene bag (PP) by *S. zeamais*, *R. dominica* and *T. castaneum*. Although just a single hole was made at 7day in the case of *R. dominica* and *T. castaneum* while 3 holes were made by *S. zeamais* in the PP bags.

**Table 2.** LT50 for Mortality of different insect species in ZeroFly® (VF) and Polypropylene (PP) bags.

| Insect Species | Treatment | Regression equation | Slope (± SE) | $LT_{50}$ (95% Confidence limits) | $X^2$ | (df) | Efficacy Factor |
|---|---|---|---|---|---|---|---|
| *C. maculatus* | VF<br>PP | Y = 1.50X – 1.59<br>Y = 0.70X – 1.59 | 1.50 ± 0.53<br>0.70 ± 0.32 | 0.28 (1.23 – 3.94)<br>8.94 (4.09 – 12.61) | 34.90 | (45) | 31.93 |
| *R. dominica* | VF<br>PP | Y = 1.05X – 1.43<br>Y = 0.15X – 1.43 | 1.05 ± 0.43<br>0.15 ± 0.16 | 0.78 (0.24 – 1.21)<br>5.42 (2.04 – 7.96) | 27.36 | (38) | 6.95 |
| *S. zeamais* | VF<br>PP | Y = 3.48X – 3.21<br>Y = 0.28X – 3.21 | 3.48 ± 1.22<br>0.28 ± 0.26 | 1.22 (0.75 – 1.70)<br>12.13 (7.30 – 4.42) | 16.49 | (26) | 9.94 |
| *T. castaneum* | VF<br>PP | Y = 0.95X – 1.38<br>Y = 0.39X – 1.38 | 0.95 ± 0.45<br>-0.39 ± 0.15 | 0.52 (0.07 –0.89)<br>4.93 (1.34 – 7.39) | 23.63 | (35) | 9.48 |

NB: Efficacy factor is derived by dividing the higher $LT_{50}$ value with the smaller $LT_{50}$ value.

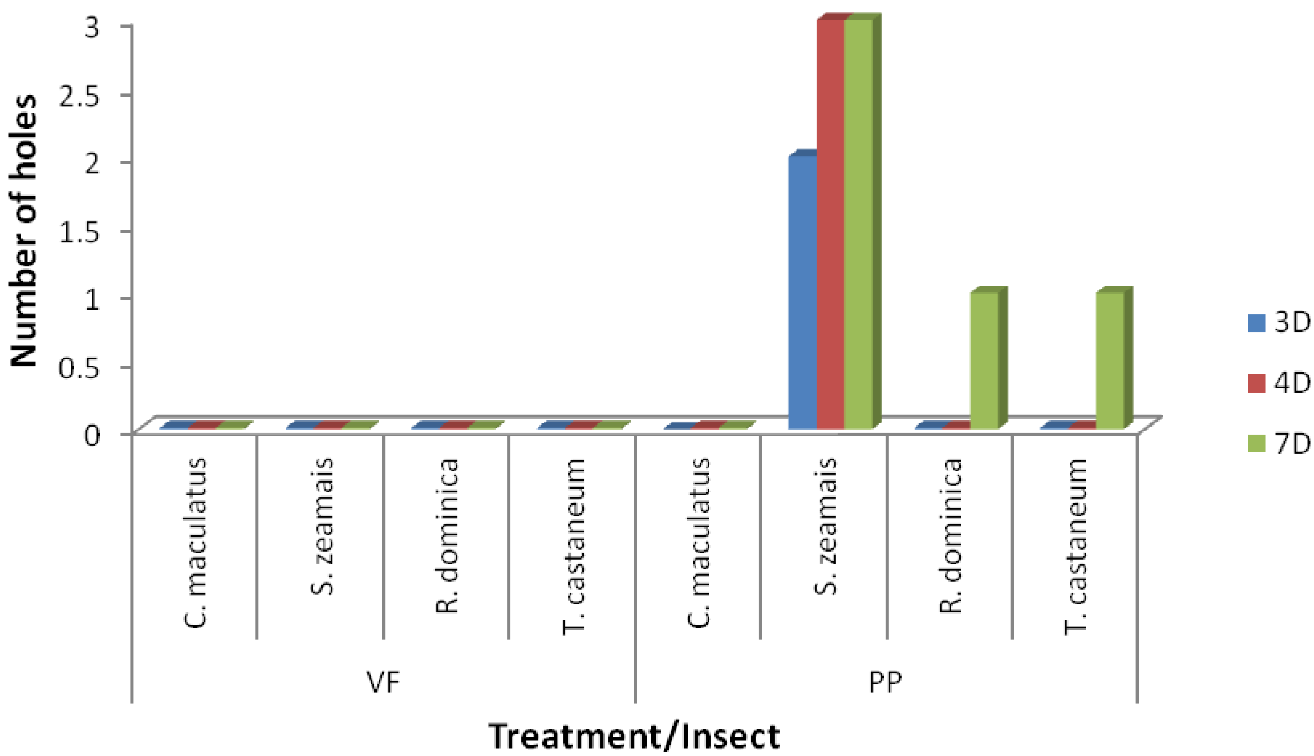


**Figure 1.** Ability of insect to bore/chew through fabrics.

Results from our study confirmed reports from multicountry studies which showed that deltamethrin insecticide treated bags are very effective and stored products insects such as maize weevil, cowpea beetle, red flour beetle and lesser grain borer amongst others, were unable to bore or chew through the bags. The reason may be because the yarns are multilayered (ZeroFly Brochure, 2015). In another finding, only *S. zeamais* was able to make holes into the PP bags as from day 3. According to a report by Mackean and Mackean (2016), *S. zeamais* have their heads prolonged into a long snout with their mouth located at the end of the snout and this enable them bore. Meanwhile, *C. maculatus*, *R. dominica* and *T. castaneum* posses chewing mouthparts that are not as strong as those of *S. zeamais*. Results of control set up by retaining insects

**Table 3.** Effect of starvation on Insect species.

| Insect species | Exposure time | (No. of dead insects) | Mortality |
|---|---|---|---|
| | 15 min | 0 | 0 |
| | 30 min | 0 | 0 |
| | 24 h | 2 | 10 |
| | 48 h | 4 | 20 |
| *C. maculatus* | 72 h | 7 | 35 |
| | 4 Days | 8 | 40 |
| | 5 Days | 11 | 55 |
| | 6 Days | 11 | 55 |
| | 7 Days | 13 | 65 |
| | 15 min | 0 | 0 |
| | 30 min | 0 | 0 |
| | 24 h | 4 | 20 |
| | 48 h | 10 | 50 |
| *S. zeamais* | 72 h | 11 | 55 |
| | 4 Days | 16 | 80 |
| | 5 Days | 16 | 80 |
| | 6 Days | 18 | 90 |
| | 7 Days | 18 | 90 |
| | 15 min | 0 | 0 |
| | 30 min | 0 | 0 |
| | 24 h | 5 | 25 |
| | 48 h | 9 | 45 |
| *R. dominica* | 72 h | 14 | 60 |
| | 4 Days | 15 | 75 |
| | 5 Days | 16 | 80 |
| | 6 Days | 16 | 80 |
| | 7 Days | 17 | 85 |
| | 15 min | 0 | 0 |
| | 30 min | 0 | 0 |
| | 24 h | 2 | 10 |
| | 48 h | 6 | 30 |
| *T. castaneum* | 72 h | 9 | 45 |
| | 4 Days | 10 | 50 |
| | 5 Days | 12 | 60 |
| | 6 Days | 14 | 70 |
| | 7 Days | 15 | 75 |

without feed presented in Table 3 show that 65 to 90% of the insect species died due to starvation within 7 days. Williams (1984) reported that all insect species sealed in the 0.15 mm polythene bags died within 14 days of confinement except the larvae of *T*. *granarium* that died before 28 days. The result of the simulated study on insect infestation of grains in the VF bags and treated grains with Permethrin in PP bags showed effect of treatments (fabrics) on F1 progeny production at 35 days Table 4). The mean number of F1 progeny differ from one insect species to another, hence the difference in their percentage F1 progeny production. The progeny emergence was reduced significantly in all the treatments in relation to the untreated control. The percentage reduction in F1 progeny production for *C. maculatus*, *S. zeamais*, *R. dominica* and *T. castaneum* ranged from 95.90 to 100%; 81.90 to 84.30%; 96.95 to 100% and 96.85 to 100%, respectively. This shows that VF bags

**Table 4.** Effect of treatments (Fabric) on F1 Progeny Production at 35 days.

| Insect Species | Treatments | Mean no of emerged progeny ± SE | Percentage Reduction in Progeny relative to control (%) |
|---|---|---|---|
| *C. maculatus* | VF (Entry) | 0.33 | 99.18 |
| | VF (Exit) | 0.00 | 100.00 |
| | PP Treated (Entry) | 1-67 | 05.90 |
| | PP Treated (Exit) | 1.00 | 97.74 |
| | PP (Entry) Control | 40.67 | - |
| | PP (Exit) Control | 40.33 | - |
| *S.zeamais* | VF (Entry) | 6.67 | 82.76 |
| | VF (Exit) | 6.33 | 84.30 |
| | PP Treated (Entry) | 7.00 | 81.90 |
| | PP Treated (Exit) | 7.00 | 82.64 |
| | PP (Entry) Control | 38.67 | - |
| | PP (Exit) Control | 40.33 | - |
| *R. dominica* | VF (Entry) | 0.00 | 100.00 |
| | VF (Exit) | 0.00 | 100.00 |
| | PP Treated (Entry) | 1.00 | 97.73 |
| | PP Treated (Exit) | 1.33 | 96.95 |
| | PP (Entry) Control | 44.00 | - |
| | PP (Exit) Control | 43.67 | - |
| *T.castaneum* | VF (Entry) | 0.33 | 99.21 |
| | VF (Exit) | 0.00 | 100.00 |
| | PP Treated (Entry) | 1.00 | 97.62 |
| | PP Treated (Exit) | 1.33 | 96.85 |
| | PP (Entry) Control | 42.00 | - |
| | PP (Exit) Control | 42.33 | - |

Mean of three replicates.

could protect grains from infestation during storage. These results support the findings of Rai et al (1987) that jute bags and jute cloth made cover impregnated with deltamethrin revealed good protection values 5 months after treatment compared to existing method of prophylactic treatment (repeated prophylactic spray on the bags at 3 L of dilution per 100 square meter areas) against *R. dominica* and *T. castaneum*. Mishra and Pandey (2014) also found deltamethrin 2.5WP at 40 mg/kg$^{-1}$ wheat most effective of 8 treatments against *S. oryzae* after 3 months of storage. Singh et al. (1998) and Pathak et al. (2002) found deltamethrin effective when wheat was dusted at 3ppm. The result of this study indicates that different insect species vary in their susceptibility or tolerance to pyrethroid, possibly because of their different behavior. Reduction of progeny production is a major function of any control measure as it is crucial for long-term stored-products protection (Wakil et al., 2013). In our assay, *S. zeamais* was found to be more tolerant to pyrethroid as compared to other insect species because it had the lowest value for percentage F1 progeny reduction. This stands in accordance with previous reports by some scientists where they stated that *Sitophilus* specie was found tolerant to pyrethroid while other insect species such as, lesser grain borer and red flour beetle were susceptible leading to low or no progeny production (Samson and Parker, 1989; Arthur, 1994a).

In a similar trend, high values obtained from percentage reduction in F1 progeny for *C. maculatus, R. dominica* and *T.castaneum* may be as a result of insect mortality. This result also corroborate with the report by Wasala et al. (2016), where he found that dead insect bodies were observed on outer surface of the insecticide incorporated bags (VF bags) but no live or dead insects were found on untreated bag surface during storage time. There was no damage of grains after 6 months storage. Similar result was reported by Pathak and Jha (2001) that deltamethrin was most effective of all treatments after

**Table 5.** Effect of *Callosobruchus maculatus* (F.) infestation on proximate composition of Ife brown cowpea in VF and PP treatment bags after 6 months.

| Treatments | M.C.(%) | Crude protein (%) | Ash(%) | Oil content (%) | Fibre(%) | Carbohydrate(%) |
|---|---|---|---|---|---|---|
| Initial value | 9.27$^{a}$ | 23.36$^{b}$ | 4.31$^{c}$ | 1.94$^{a}$ | 2.26$^{c}$ | 59.67$^{b}$ |
| VF + grain | 11.57$^{b}$ | 22.74$^{b}$ | 3.63$^{b}$ | 2.01$^{b}$ | 1.89$^{c}$ | 58.86$^{b}$ |
| PP + treated grain | 12.33$^{b}$ | 21.83$^{a}$ | 3.51$^{b}$ | 2.06$^{b}$ | 1.74$^{ab}$ | 58.52$^{ab}$ |
| PP + untreated grain | 13.40$^{b}$ | 21.61$^{a}$ | 3.28$^{b}$ | 2.14$^{c}$ | 1.66$^{a}$ | 57.33$^{a}$ |

Means within a column followed by same letter are not significantly different: Student Newman Keuls (SNK) test; P=0.05

**Table 6.** Effect of *Sitophilus zeamais* (Motsch), *Rhyzopertha dominica* (Fab.) and *Tribolium castaneum* (Herbst.) infestation on proximate composition of yellow maize variety SWAM 1 in VF and PP treatment bags after 6 months

| Treatments/ *S. zeamais* | M.C. (%) | Crude protein (%) | Ash(%) | Oil content (%) | Fibre (%) | Carbohydrate (%) |
|---|---|---|---|---|---|---|
| Initial value | 10.92$^{a}$ | 10.15$^{b}$ | 1.33$^{a}$ | 4.33$^{a}$ | 1.79$^{a}$ | 71.51$^{b}$ |
| VF Control | 12.58$^{b}$ | 10.02$^{b}$ | 1.32$^{a}$ | 4.37$^{ab}$ | 1.74$^{a}$ | 69.95$^{a}$ |
| VF with insects | 13.26$^{c}$ | 9.83$^{a}$ | 1.31$^{a}$ | 4.45$^{bc}$ | 1.70$^{a}$ | 69.28$^{a}$ |
| PP Control | 13.45$^{cd}$ | 9.78$^{a}$ | 1.31$^{a}$ | 4.52$^{c}$ | 1.69$^{a}$ | 69.17$^{a}$ |
| PP with insects | 13.76$^{d}$ | 9.70$^{a}$ | 1.29$^{a}$ | 4.52$^{c}$ | 1.68$^{a}$ | 69.00$^{a}$ |
| **Treatments/ *R. dominica*** | **M.C(%)** | **Crude protein (%)** | **Ash (%)** | **Oil content (%)** | **Fibre (%)** | **Carbohydrate (%)** |
| Initial value | 10.92$^{a}$ | 10.15$^{d}$ | 1.33$^{b}$ | 4.30$^{a}$ | 1.79$^{a}$ | 71.51$^{b}$ |
| VF Control | 12.97$^{b}$ | 9.97$^{cd}$ | 1.33$^{b}$ | 4.28$^{a}$ | 1.71$^{a}$ | 70.16$^{a}$ |
| VF with insects | 13.12$^{b}$ | 9.80$^{bc}$ | 1.26$^{ab}$ | 4.39$^{b}$ | 1.64$^{a}$ | 69.16$^{a}$ |
| PP Control | 13.23$^{bc}$ | 9.75$^{b}$ | 1.24$^{ab}$ | 4.46$^{b}$ | 1.61$^{a}$ | 69.51$^{a}$ |
| PP with insects | 13.58$^{c}$ | 9.50$^{a}$ | 1.18$^{a}$ | 4.54$^{c}$ | 1.61$^{a}$ | 69.46$^{a}$ |
| **Treatments/ *T. castaneum*** | **M.C.(%)** | **Crude protein (%)** | **Ash (%)** | **Oil content (%)** | **Fibre (%)** | **Carbohydrate (%)** |
| Initial value | 10.92$^{a}$ | 10.15$^{b}$ | 1.33$^{a}$ | 4.33$^{a}$ | 1.79$^{a}$ | 71.51$^{b}$ |
| VF Control | 12.58$^{b}$ | 9.82$^{a}$ | 1.30$^{a}$ | 4.52$^{c}$ | 1.77$^{a}$ | 69.95$^{a}$ |
| VF with insects | 13.26$^{c}$ | 0.15$^{b}$ | 1.31$^{a}$ | 4.52$^{c}$ | 1.74$^{a}$ | 69.17$^{a}$ |
| PP Control | 13.45$^{cd}$ | 9.70$^{a}$ | 1.51$^{b}$ | 4.37$^{ab}$ | 1.70$^{a}$ | 69.28$^{a}$ |
| PP with insects | 13.80$^{d}$ | 9.78$^{a}$ | 1.32$^{a}$ | 4.45$^{bc}$ | 1.70$^{a}$ | 69.00$^{a}$ |

Means within a column followed by same letter are not significantly different: Student Newman Keuls (SNK) test; P=0.05.

180 days of storage on treated wheat. The results of proximate composition analysis on Ife brown cowpea are presented in Table 5. There were significant differences (P<0.05) in initial values in the levels of moisture, ash and oil content and final values 6 months after in the VF bags which is in agreement with the report of Adegunwa et al (2012), while crude protein, fiber and carbohydrate were not significantly (P>0.05) different. There were significant differences (P<0.05) between the crude protein and fiber in VF and PP bags. Irrespective of the treatment bags, the composition of moisture, ash, oil content and carbohydrate were not significantly (P>0.05) from each other and from untreated control. This result is in agreement with the report of Tessema et al. (2015) who obtained decrease in crude fat, seed moisture and carbohydrate of chickpea over 6 months of storage. The pattern of gradual increase in the percentage moisture content of cowpea and maize was similar for all treatment bags and insect type. This may be as a result of metabolic activities of the insects in infested grains and relative humidity during the experimental period. There were significant differences (P<0.05) in the levels of moisture, crude protein and oil content in the grains infested with *S. zeamais* in VF and PP bags and untreated control. However, there was no significant difference (P>0.05) between levels of ash, fiber and carbohydrate in maize grains infested with *S. zeamais* in VF or PP bags (Table 6). The results are similar to Osipitan et al. (2012) that reported reduction in protein and starch depletion of these nutrients as a result of

infestation by *S*. *zeamais*. There was no significant difference (P>0.05) in proximate compositions in the grains infested with *R*. *dominica* in VF and PP bags, however, there were significant differences (P<0.05) between the treated grains and untreated control (Table 6). Irrespective of the treatment bags, ash, oil content, fiber and carbohydrate were not significantly different (P>0.05) from each other and from untreated control. However, the levels of crude protein and moisture were significantly different (P<0.05) in the grains infested with *T*. *castaneum* in the VF and PP bags and in the untreated control. Further study on field trials using VF bags to reduce insect attack by preventing movement of insects between bags and providing long term protection after fumigation is recommended.

## Conclusion

Deltamethrin insecticide treated storage bags (VF) was more effective than untreated PP bags containing Permethrin treated grains in protecting stored grains from infestation by stored products insect pest while maintaining the grain quality. The VF storage bag was more effective in preventing entry of *C*. *maculatus*, *S*. *zeamais*, *R*. *dominica* and *T*. *castaneum* adult or boring through bags either from inside or outside than Polypropylene bags containing Permethrin treated grains at 2.5 ppm. The deltamethrin insecticide treated storage bag (VF) could be used in pest control strategy by smallholder farmers at farm level as well as in warehouses by traders and household for storage of grains to maximize profit at developing inexpensive and reduced-risk alternatives to synthetic insecticides that can be compatible with Integrated Pest Management (IPM) approaches in the protection of stored grains.

## Conflict of Interests

The authors have not declared any conflict of interests.

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