Indian Journal of Entomology Online published Ref. No. e24670 DoI. No.: 10.55446/IJE.2024.1670

EFFECTIVENESS OF PACKAGING INTEGRATED WITH PLANT EXTRACTS IN CONTROLLING MAIZE WEEVIL *SITOPHILUS ZEAMAIS*

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ABSTRACT

Maize weevil *Sitophilus zeamais* is one of the storage pests that compromise both quality and quantity of stored maize grains. In Malawi, most smallholder farmers use botanicals like *Tephrosia vogelii* Hook and *Lantana camara* to manage *S. zeamais*. This study was conducted to investigate the effectiveness of packaging integrated with plant extracts in controlling this pest. Ziploc bags, paper cartons, grass jars, paper envelopes and polyethylene terephthalate (PET) water bottles are the common packaging and storage materials for these botanical pesticides used by small holder farmers. This study involved preliminary experiments in which plant extracts within packaging materials were tested, for their efficacy against *S. zeamais* for five months. PET water bottle provided significant (p<0.01) control over other treatments to store the maize seeds against *S. zeamais*. Thereafter, the effect of botanicals packaged and stored for one month in PET water bottle was studied on grain damage caused by the weevils. The inhibition effect of the botanicals on grain damage was significant (p<0.01). This study obtained vital information that can be utilized by farmers as a sustainable way to manage storage pests.

Key words: Actellic, botanical pesticides, grain damage assessment, *Lantana camara*, maize grains, management, packaging material, *Sitophilus zeamais* M., small holder farmers, *Tephrosia vogelii* Hook

Food security in many sub-Saharan African nations, is largely dependent on increased food yield through good agricultural practices (GAP), as well as decreased post-harvest losses. According to research by Midega et al. (2016), post-harvest loss is one of the major obstacles to food security faced by African farmers with limited resources. Protecting crops from such losses would, therefore be a crucial step in ensuring household food security. Maize is one of the most significant grains in the world (Majamanda et al., 2022a) and it serves as both animal feed and staple food crop (Majamanda et al., 2022a; Majamanda et al., 2022b; Sultan et al., 2016; Muhebbullah et al., 2014). In Africa, its most important storage pests are grain weevils (*Sitophilus* spp.) and the angoumois grain moth (*Sitotroga cerealella*), and bruchids (*Acanthoscelides schilsky, Zabrotes subfasciatus* and *Callosobruchus chinensis*) for legumes (Nyirenda et al*.,* 2011). Among the *Sitophilus* spp., *S. zeamais* M. is a notorious pest contributing to reduced maize grain quality and quantity (Phokwe and Manganyi, 2023; Ogendo et al., 2004). As it consumes the endosperm, *S. zeamais* pierces the grain making it susceptible to diseases (Fokunang, 2017). In addition to reducing the viability of the grain, this weevil's activity lowers the grain's nutritional content (Kobia, 2022). Moisture content that rises from insect respiration inside the grain encourages fungal growth, which eventually lowers the grain's quality (Phokwe and Manganyi, 2023; Kobia, 2022; Fokunang, 2017);*S. zeamais* faces causes mycotoxins to assemble inside the grain, reducing quality and making the grain unsafe for human consumption (Kobia, 2022; Fokunang, 2017). Synthetic pestcides have been used and are still being used to deal with maize weevils. However, synthetic pesticides usage has led to problems like environmental contamination, health risks, and pest recurrence (Phokwe and Manganyi, 2023; Nyirenda et al., 2011). Alternatively, in recent years, botanical pesticides which are naturally occurring chemicals extracted from plants are used to provide control against stored grain pests (Adak et al., 2023; Guru-Pirasanna-Pandi et al., 2018). Some of the locally found botanical pesticides which farmers use in controlling storage pests in maize grains are *Tephrosia vogelii* H and *Lantana camara* L. According to Ananda et al. (2017), such botanical pesticides continued effectiveness need to be monitored.

Packaging and storage supplies have been shown to be crucial for the quality, effectiveness, and ultimately dependability of botanical pesticides used in agriculture (Kobia, 2022; Ma et al., 2018). Efficacy of botanical constituents is greatly influenced by the packaging and storage materials (Sharma et al., 2022; Ma et al., 2018). The present study was therefore conducted to test effectiveness of *T. vogelii* and *L. camara* on maize weevil *S. zeamais* within packaging materials.

MATERIALS AND METHODS

The experiment was conducted in the entomology laboratory at the University of Malawi, Chancellor College in 2022. The experiment considered different packaging materials. Paper carton (A4, single wall, 12 x 9 x3 inches), paper envelope (C4, 324 x 229 mm), medium Ziploc bags (17.7 cm x 18.8 cm), polyethylene terephthalate (PET) water bottle (250 ml) and glass jar (500 ml). Grass jars, Ziploc bags and paper cartons were obtained from the entomology laboratory. Paper cartons and pet water bottles were bought from the shop. To preserve the performance of the active substances, a mixture of the leaves, inflorescence, and succulent stems of the two botanicals, *L. camara* L. (elevation 841 m, 36L0751453,UTM 8297023) and *T. vogelii* H. (830 m, 36L0751540, UTM 8296996) were individually dried under shade at room temperature. According to Ogendo et al., (2004), the plant samples were further oven dried in the laboratory. The samples were then extensively pulverized in a mill, creating a fine powder. Then 500 g of each botanical was put into several containers for the experiment, including a glass jar, a PET water bottle, a paper carton, a Ziploc bag, and a paper envelope. After that, they were kept in storage for five months in preparation for the experiment.

In order to validate the presence of the targeted insect species, the extensively infested maize grains were first tested in a lab. Then, in accordance with Haines' (1991) instructions, 200 unsexed adult *S. zeamais* were raised in 1 -litre jars with 500 g of cleaned whole maize grains. Nylon mesh was utilized to cover the top of each container used for growing. Then, a 7-day window was given to the insects for ovipositioning. Following the removal of all adults, each container was left to stand for 25 days while emerging adult insects were watched and stored in different containers based on their age. The insect colony was raised in a lab environment with a temperature range of 17-28°C and a relative humidity (RH) range of 38-69%. A 12 hr-light-to-12 hr-dark photoperiod was maintained. A native variety of maize called 'Kanyani' was used for rearing and was purchased from the Malawian research facility 'Chitedze'.

Maize was de-infested using phostoxin tablets, which were applied under a gas-tight sheet to avoid latent infection. According to recommendations, 5g of phosphine (PH_3) need to be applied/ tonne over a 10-day period (Haines, 1991). After that, laboratory ambient conditions (17-280°C, 38-69% RH) were applied to the deinfested maize. Subsamples utilized for the grain quality assessments were further deinfested at 40^0C in an oven for 4 hr and cooled for 2 hr before use (Ogendo et al., 2004). To evaluate each botanical's ability to kill (*S. zeamais*). A 5.0% w/w concentration of the ground botanical powders from each packing and storage medium was applied separately to 100 g of disinfected maize in 2 ℓ glass jars. The experiment's controls included an untreated sample and the application of the synthetic insecticide, Actellic Super 2% dust @ 0.05% (w/w). Twenty adult *S. zeamais*, 3 to 5 days old, were put into the jars with the various treatments, following Udo's (2005). White muslin material was used to cover the jars, and it was fastened with rubber bands. A completely randomized design (CRD) was used to arrange a total of 12 treatments with three replications. For the treatments, the environmental conditions of 17-28^0C, 38-69% RH, and a photoperiod of 12 light hr: 12 dark hours were maintained. Insect mortality was assessed 24 hr after treatment application. After three probings with a blunt probe, insects were deemed dead if they did not move (Udo, 2005).

Samples of 100 grains were selected and subjected to the best powder (PET water bottles plant extracts) based on the results of the mortality test. Specifically, the assay aimed to assess the powder's inhibition effect on damage caused by natural insect infestation. Each sub-sample was divided into two categories: grains that had not been harmed by insects, and grains that had been harmed. Then, grains were weighed and counted for each group. The calculation of the percent weight loss of maize grains in storage was done according to Haines (1991). Data were analyzed using R programme, version 4.1.2 (2021-11-01), subjected to one-way analysis of variance (ANOVA). Tables were generated using excel. Treatment means were statistically compared by Duncan's New Multiple Range Test (DMRT) using R programme, at $P<0.01$.

RESULTS AND DISCUSSION

Table 1 shows that the differences in the mortalities of *S. zeamais* caused by *L. camara* and *T. vogelli* treatments before they were packaged (@ time zero) were not statistically significant. However, statistically significant differences were observed between plants extracts treatments and their controls, with Actellic 2% super dust (synthetic control) proving to be the best by causing complete (100%) mortality to *S. zeamais*. Pure control proved to be the least performer by causing zero mortality to *S. zeamais*. Because Actellic super dust (synthetic control) is naturally formulated to destroy insects (Kamanula et al., 2010), it was the best in protecting grains against *S. zeamais* in the present study. The active components of the two plants were very potent at time zero, which led to a greater mortality rate for *S. zeamais* exposed to *T. vogelii* and *L. camara* than after 5 months of storage time. Regarding plants' efficiency in causing mortality to *S. zeamais* after 5 months of storage time, there were statistically significant differences ($p < 0.01$). The most effective synthetic control, Actellic Super dust outperformed. The best treatments were from PET water bottles, with *T. vogelii* treatments functioning somewhat better than *L. camara* treatments. Treatments created from the other packaging materials underperformed with no statistically significant changes between them; *S. zeamais* mortality was 100% in the synthetic control and 0% in the pure control, respectively. The mortality were higher in treatments from PET water bottles with *T. vogelii* registering 51.67% and *L. camara* registering 38.33%. Treatments for *L. camara* (Ziploc bag), *L. camara* (paper carton), *L. camara* (paper envelope), *L. camara* (glass jar) *T. vogelii* (Ziploc bag), *T. vogelii* (paper carton), *T. vogelii* (paper envelope) and *T. vogelii* (glass jar) were not significantly different ($p > 0.01$) with respective success rates of 23.35, 25, 15, 25, 23.3, 15, 20 and 26.67% (Fig. 1). The significant ($p<0.01$) mortality induced by *T. vogelii* (PET water bottle) and *L. camara* (PET water bottle) suggests that PET water bottle is an excellent protectant for botanical pesticides. The other packaging materials could not maintain performance of the active ingredients due to air movement which might have decreased the activity (Udo, 2005). According to Islam and Talukder (2005), the active ingredients of botanical pesticides undergo degradation and lose their effectiveness. The effectiveness of the main ingredients can be lost after exposure to sunlight, air, moisture and oxygen (Ananda et al., 2017). This is also in line with the study of Majamanda et al. (2022b), who found that phytochemicals such as carotenoids degrade with exposure to light and increased storage period.

Table 1. Mortality and weight loss in *S. zeamais* treated with botanicals

Treatment	Mortality	Weight loss (%)
Untreated control (pure control)	0.00 ± 0.00^{c}	28.49 ± 0.65^{a}
Lantana camara	9.00 ± 1.0^{b}	11.94 ± 0.74^{b}
Tephrosia vogelli	11.67 ± 2.08^{b}	7.82 ± 0.91^{c}
Actellic super 2% dust (Synthetic control)	20.00 ± 0.00^{a}	0.00 ± 0.00^{d}

Values with different letters are statistically different ($p<0.01$) and values with same letter are not statistically different; Values are means of three replicates

S. zeamais damage to maize grains treated with *T. vogelii* (PET water bottle) and *L. camara* (PET water bottle) shows that there was a significant ($p<0.01$) difference between the treatments over the control in reducing damage caused by *S. zeamais*. *T. vogelii* (PET water bottle) and *L. camara* (PET water bottle) significantly ($p<0.01$) reduced the damage than the untreated control. However, none of the treatments offered complete protection but the level of damage was very low. There is less reduction in damage caused to stored maize using *T. vogelii* (PET water bottle) ($7.82\% \pm 0.91^{c}$) and *L. camara* (PET water bottle) ($11.94\% \pm 0.74^{b}$) after storage time, which indicates the possible presence of feeding deterrence. This suggests that PET water bottle performed better; *T. vogelii* (PET water bottle) ($7.82\% \pm 0.91^{c}$) out perfomed *L. camara* (PET water bottle) (11.94%± 0.74b) in preventing the weight loss. The level of damage observed in the present study could be described as tolerable and could be useful in traditional small holder storage system.

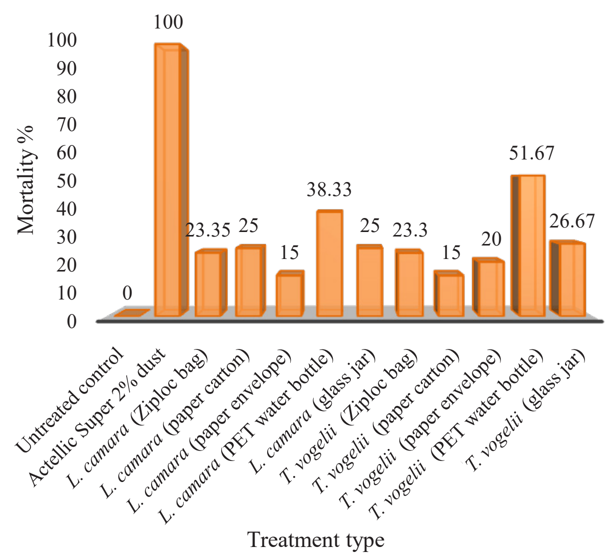

Fig. 1. % mortality of *S. zeamais* with botanicals (5 months storage time in different packaging)

Neither *T. vogelii* (PET water bottle) nor *L. camara* (PET water bottle) offered complete protection probably because the powder from the botanicals might have settled to the bottom of the experimental jars. Similar findings were reported in a study by Niber (1994). The polyethylene terephthalate (PET) water bottle used in the current investigation served as the ideal container for storing *T. vogelii* Hook and *L. camala* L. The results of our research and earlier studies consistently demonstrate that botanical pesticides do not result in mortality rates that are comparable to those of synthetic pesticides. This is because botanical pesticides are made locally without any adjuvants to extend their shelf life or change how they work, it follows that they will eventually lose their efficacy with the passage of time. The farmers can anticipate that by storing their pesticides in PET water bottles, *T. vogelii* Hook and *L. camala* L. will continue to be effective in controlling *S. zeamais*.

ACKNOWLEDGEMENTS

The department of Biological sciences at the University of Malawi, Chancellor College, provided the facilities and equipment needed to carry out the present experiment, for which the authors are grateful.

FINANCIAL SUPPORT

No outside funding was obtained.

AUTHOR CONTRIBUTION STATEMENT

LDN came up with the concept for the study, carried out the experiments, analysed the data, interpreted the findings, and prepared the first paper. JM revised and updated the original copy in addition to contributing to the samples. The text was read and approved by both writers.

CONFLICT OF INTEREST

No conflict of interest.

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(Manuscript Received: September, 2023; Revised: April, 2024;
Accepted: April, 2024; Online Published: May, 2024)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e24670