Journal of
Current Opinion in Crop Science

Journal homepage: www.jcocs.com; ISSN(O):2583-0392

RESEARCH ARTICLE

Sustainable postharvest pest management: toxicological efficacy of locally sourced and formulated bio-pesticides against the larger grain borer (*Prostephanus truncatus*) on traditional maize grain storage facilities to small-scale farmers

Patrick Cleophace Mpombeye[1*], Loth Sikwese Mulungu[1], Andrea Malima Kigeso[2], Nicolaus Anania Mwakalinga[3], and Erasto Andreas Komba[4]

[1]Department of Pest Management and Technology Development, Sokoine University of Agriculture, Morogoro, Tanzania; [2] Department of Plant, Animal and Food Sciences, School of Agricultural and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, Bondo, Kenya; [3] Department of Parasitology and Medical Entomology, Mwanza University, Kishili-Mwanza, Tanzania; [4]Department of Crop Science and Horticulture, Sokoine University of Agriculture, Morogoro, Tanzania.

Edited by:
Thiravidamani Sathyan, NMU Deemed University, Aruppukottai, Tamil Nadu, India.

Reviewed by:
Manuel Maleia, Agricultural Research Institute of Mozambique, Maputo, Mozambique; Pancras Ndokoye, Faculty of Agriculture, UTAB, Byumba, Rwanda.

Article history:

Received: April 28, 2025
Accepted: June 11, 2025
Published: June 30, 2025

Citation:

Mpombeye, P. C., Mulungu, L. S., Kigeso, A. M., Mwakalinga, N. A., & Komba, E. A. (2025). Sustainable postharvest pest management: toxicological efficacy of locally sourced and formulated bio-pesticides against the larger grain borer (*Prostephanus truncatus*) on traditional maize grain storage facilities to small-scale farmers. *Journal of Current Opinion in Crop Science, 6*(2), 72-80. https://doi.org/10.62773/jcocs.v6i2.314

*Corresponding author e-mail address: mpombeyecleophace@gmail.com
(Patrick Cleophace Mpombeye)

ABSTRACT

This study was conducted at the Pest Management Laboratory of Sokoine University of Agriculture (SUA), Morogoro, Tanzania, to assess the efficacy bio-pesticides in controlling *Prostephanus truncatus* (Larger Grain Borer) in maize storage. The experiment was laid out in a Completely Randomized Design (CRD) with six treatments, including one synthetic control (Actellic Super Dust) and five botanical powders (Lantana camara, Azadirachta indica, Tagetes erecta, Eupatorium capillifolium, and Citrus limon), each replicated three times. A total of 150 g maize grains were placed in each bottle with 20 adult *P. truncatus* introduced to simulate infestation. The study monitored insect mortality, seed damage, and weight loss over four weeks. The results indicated significant differences among treatments in terms of insect mortality, seed damage, and weight loss. Actellic Super Dust showed the highest insect mortality and lowest seed damage, while Lantana camara demonstrated effective pest control as a botanical option, outperforming other bio-pesticides. This research underscores the potential of both synthetic and botanical insecticides for effective maize storage pest management, contributing to reduced grain losses and supporting sustainable pest control practices for smallholder farmers in Tanzania.

Keywords: botanical insecticides, maize storage, pest management, *Prostephanus truncatus*, & synthetic pesticides.

INTRODUCTION

During the post-harvest storage of maize, insect infestations and storage-related pathogens pose critical challenges, leading to substantial losses in grain quality, viability, and germination potential (Mollah et al., 2016). Among these, the Larger Grain Borer (*Prostephanus truncatus* Horn) is considered one of the most destructive storage pests. This species belongs to the family Bostrichidae, a group primarily composed of wood-boring beetles (Athanassiou et al., 2017). Originally reported as a pest of stored maize in Central America, *P. truncatus* was introduced to Africa in the late 1970s. It is believed to have arrived in Tanzania during this period and has since spread extensively across East Africa and other parts of the continent (Farrell, 2002). Both adult beetles and larvae infest maize by feeding internally on the grains. Although infestations may begin while maize is still in the field, the majority of damage occurs during storage (Meikle et al., 2002). Losses associated with *P. truncatus* infestations are both quantitative and qualitative. Quantitative losses primarily involve reductions in grain weight and volume, with some estimates placing weight loss as high as 26.4% (Mulungu et al., 2011). Qualitative losses include discoloration of grains, off-flavors, and increased susceptibility to fungal and bacterial infections (Demianyk, 1987; Lewis et al., 2005). In severe cases, postharvest losses in susceptible maize varieties can range from 40% to 100% (Denning et al., 2009).

Maize (*Zea mays* L.) is a critical staple food and cash crop cultivated in nearly all ecological zones of Sub-Saharan Africa, particularly Tanzania (Wanjala, 2015). It is largely produced by smallholder farmers, with over 90% of the Tanzanian population relying on it for daily consumption (Petro, 2015). However, its production is heavily constrained by biotic and abiotic factors, including insect pests like *P. truncatus* (Adedire, 2001a; Nukenine, 2010). This pest not only causes direct physical losses but also contributes to reductions in nutritional quality, seed viability, and commercial value, and can even introduce harmful compounds into stored grains (Rajendran & Parveen, 2005; McFarlane et al., 1989). In Malawi, for instance, postharvest losses attributed to *P. truncatus* in 2012 were estimated at 1.2%, translating to approximately 47,000 tonnes of maize lost. In Tanzania, most smallholder farmers continue to rely on traditional granaries for storage, with less than 10% adopting modern improved storage facilities (Midega et al., 2016). To combat postharvest losses, hermetic storage technologies such as metal silos and "Super Grain Bags" made from high-density polyethylene have been introduced (De Groote et al., 2013). Among these, metal silos have demonstrated the highest efficacy, with seed weight losses as low as 3.9% and seed damage limited to 15.6% over a six-month storage period (Nhamucho et al., 2017).

The adoption of pest control technologies among farmers has been influenced by factors such as educational level and farming experience, which positively correlate with awareness and management of storage pests (Midega et al., 2016). In addition to synthetic pesticides, bio-pesticides have emerged as a cost-effective, environmentally friendly alternative. These offer advantages such as affordability, minimal health risks, and ease of access to raw materials (Leng et al., 2011a). Despite the availability of these technologies, none offer complete control of *P. truncatus*, underscoring the need for integrated pest management strategies tailored to smallholder contexts.

The primary objective of this study was to enhance the management of postharvest maize storage by focusing on the control of *Prostephanus truncatus*, a major pest responsible for significant grain losses in smallholder farming systems. Specifically, the study seeks to assess existing storage practices and farmers' knowledge level regarding insect pest management during the postharvest period. It also aimed to evaluate the effectiveness of various pest control strategies, including traditional methods, synthetic pesticides, and bio-pesticides, under real-world smallholder storage conditions. A further objective is to identify the socio-economic and institutional factors, such as education level, access to information, and market dynamics, that influence the adoption and sustained use of effective postharvest pest management technologies. Ultimately, the study aims to develop integrated pest management (IPM) recommendations tailored to smallholder maize farmers' needs and capacities. These recommendations will emphasize practicality, affordability, environmental safety, and sustainability, thereby contributing to improved food security and resilience among rural farming communities in Tanzania and similar agro-ecological contexts.

MATERIALS AND METHODS

Study area

The research was conducted at the Institute of Pest Management (IPM) Laboratory of Sokoine University of Agriculture (SUA) located at a latitude of 06^{0}84`S and a longitude of 37$^{0}$65`E. The institute conducts research on various aspects of pest management, including predicting pest outbreaks, designing effective management strategies, and assessing risks associated with pests.

Experiment Design

The experiment was laid out in a Completely Randomized Design (CRD) with six treatments (Table 1-4), each replicated four times. Clean, well-sieved maize grains of a locally cultivated variety were sourced from smallholder farmers, ensuring representativeness of traditional storage practices. The treatments consisted of (T1) Actellic Super Dust (0.2 g) as the synthetic control, and five botanical powders applied at 1.5 g per 150 g of maize: (T2) *Lantana camara*, (T3) *Azadirachta indica* (neem), (T4) *Tagetes erecta* (marigold), (T5) *Eupatorium capillifolium* (dogfennel), and (T6) *Citrus limon* (lemon peel). Each treatment was placed into clean plastic storage bottles containing 150 g of maize, after which 20 adult *Prostephanus truncatus* (Larger Grain Borer) were introduced to simulate infestation. The bottles were sealed with fine wire mesh, allowing aeration while preventing pest escape. The storage containers were then maintained under ambient laboratory conditions for subsequent monitoring of insect mortality, grain damage, and weight loss, allowing for comparative assessment of treatment efficacy over time.

Sample collection and experimentation

Maize grains were sourced from local farmer storage facilities and subsequently cleaned to remove dust, debris, and other extraneous materials. The grains were then dried to the recommended moisture content for safe maize storage, ranging between 12.0% and 13.0% (Njoroge et al., 2014). Following drying, the grain samples were divided into seven equal portions, each weighing 150 g, and placed in separate labeled storage containers. In each container, a specified treatment either botanical or synthetic pesticide, was applied, and adult *Prostephanus truncatus* (Larger Grain Borer) insects were introduced accordingly (Groote et al., 2013). The same procedure was replicated across all experimental units. To allow for aeration while preventing insect escape, the containers were securely covered with fine wire mesh. Grain weight loss was monitored over a four-week storage period. Weight loss was determined by subtracting the weight of the remaining grain in the treated containers from the control and expressed as a percentage of the original weight (Boxall, 2002). This provided a quantifiable measure of treatment efficacy in reducing pest-induced postharvest losses.

Mathematical Formula:

$$\text{Weight Loss (\%)} = (W_c - W_t)/W_c \times 100$$

Where, W_c = Weight of grain in the control container (untreated or uninfested); W_t = Weight of grain in the treated or infested container (after treatment or storage period)

Interpretation

This formula calculates the percentage loss in grain weight by comparing the final weight of grain in a treated or infested storage unit to that in a control unit, which represents the original or expected weight in the absence of losses. The result expresses how much of the original weight has been lost due to pest infestation, handling, or other postharvest factors.

Data Collection

Number of damaged maize seeds

The number of damaged maize seeds was recorded following the application of the various bio-pesticide treatments. From each experimental unit (glass bottle), all visibly damaged seeds were manually counted. The counts from the four replicates were then averaged for each treatment and the values recorded accordingly.

Number of live insects

Live adult insects *(Prostephanus truncatus)* were manually counted in each treatment bottle at the end of the observation period. The total number of live insects in each replicate was recorded, and the average per treatment was calculated to evaluate the residual efficacy of the applied bio-pesticides.

Weight of damaged maize seeds (weight loss assessment)

Grain weight loss was assessed at the end of the storage period to quantify the impact of each treatment. Samples were carefully collected from each replicate, and the weight of the damaged grains was measured using an electronic digital balance. The average weight loss per treatment was calculated and recorded in grams.

Insect Mortality

Insect mortality was determined by manually counting the number of dead *P. truncatus* individuals in each treatment. The assessment was conducted post-application of the bio-pesticides, and the average number of dead insects per treatment was computed to determine the effectiveness of each pest management strategy.

Percentage of Insect Population Reduction (Mortality Rate)

Mortality (%) = ((Nc - Nt) / Nc) × 100

Where, Nc = Number of live insects in the control treatment; Nt = Number of live insects in the treated sample.

Data Analysis

All collected data were subjected to statistical analysis using the GENSTAT 15th Edition software (GenStat, 2010). A one-way analysis of variance (ANOVA) was performed to evaluate the effects of the different treatments on each measured parameter. Where significant differences were observed, treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance ($P < 0.05$). The results are presented in tabular form for clarity and comparative interpretation.

RESULTS AND DISCUSSION

Number of damaged maize seeds

Analysis of variance revealed that there were no statistically significant differences ($p > 0.05$) in the number of damaged maize seeds among treatments during the first week of storage. However, a significant difference ($p < 0.05$) was observed in the second week, with the Actellic Super-treated samples recording a significantly lower mean number of damaged seeds (6.6) compared to the untreated control (17.0). The remaining botanical treatments did not differ significantly from one another during this period. In weeks three and four, the Actellic Super treatment consistently resulted in the lowest number of damaged seeds, indicating superior protective efficacy over time. Among the botanical treatments, *Lantana camara* powder demonstrated relatively better performance compared to the other bio-pesticides, though its effect was still significantly lower than that of the synthetic control (Table 1).

Table 1. Effect of different treatments on number of damaged maize seeds over four weeks

Treatment	Week 1	Week 2	Week 3	Week 4
Control	13.00^{a}	17.00^{a}	23.67^{a}	31.00^{a}
Citrus limon	10.33^{a}	17.00^{a}	25.00^{a}	21.33^{bcd}
Azadirachta indica	8.67^{a}	15.33^{ab}	22.00^{a}	23.67^{bc}
Eupatorium capillifolium	10.33^{a}	16.00^{ab}	22.00^{a}	23.67^{b}
Tagetes erecta	8.67^{a}	14.67^{ab}	20.33^{a}	23.67^{bc}
Lantana camara	9.00^{a}	11.67^{ab}	16.67^{a}	16.33^{bd}
Actellic Super	0.00^{b}	6.67^{b}	0.00^{b}	0.00^{e}
Grand Mean	8.57	14.00	18.52	19.95
CV (%)	7.3	14.4	5.6	6.8
$LSD_{0.05}$	4.15	9.00	8.23	6.73
P-Value	<0.001	0.222	<0.001	<0.001

Note: Means followed by the same superscript letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's Multiple Range Test (DMRT). $LSD_{0.05}$ = Least Significant Difference at 5% level; CV = Coefficient of Variation.

Insect mortality

The results indicated that Actellic Super exhibited the highest insecticidal efficacy against *Prostephanus truncatus*, consistently achieving complete mortality (20 insects) across all four weeks of observation. A gradual increase in insect mortality was recorded in maize grains treated with *Lantana camara,* showing a time-dependent effect. However, no statistically significant differences ($p > 0.05$) in insect mortality were observed among treatments with Citrus limon, *Azadirachta indica, Eupatorium capillifolium, and Tagetes erecta* during the second and third weeks. Overall, Actellic Super was the most effective treatment, followed by *Lantana camara*, in reducing the survival of *P. truncatus* over the storage period (Table 2).

Table 2. Effect of selected bio-pesticides on insect mortality over four weeks

Treatment	Week 1	Week 2	Week 3	Week 4
Control	0.33^{d}	0.33^{d}	1.33^{c}	2.33^{d}
Citrus limon	2.00^{bcd}	3.67^{c}	6.67^{b}	6.67^{bc}
Azadirachta indica	1.67^{cd}	3.33^{c}	5.00^{b}	5.33^{c}
Eupatorium capillifolium	3.00^{bc}	3.67^{c}	5.33^{b}	6.00^{bc}
Tagetes erecta	1.33^{cd}	2.67^{c}	6.00^{b}	6.67^{bc}
Lantana camara	3.67^{b}	6.00^{b}	7.00^{b}	8.80^{b}
Actellic Super	20.00^{a}	20.00^{a}	20.00^{a}	20.00^{a}
Grand Mean	4.57	5.67	7.33	7.86
CV (%)	15.6	1.5	6.3	3.1
$LSD_{0.05}$	1.74	1.18	1.86	1.91
P-Value	<0.001	<0.001	<0.001	<0.001

Note: Means followed by the same superscript letter(s) within each column are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test (DMRT). $LSD_{0.05}$ = Least Significant Difference at 5% level; CV = Coefficient of Variation.

Number of live insects

The results indicated a significant difference ($p < 0.05$) in the number of live *Prostephanus truncatus* insects across the various bio-pesticide treatments over time. A general trend of decreasing insect numbers with increasing time was observed in most treatments, while the control group exhibited an increase in the number of live insects as the storage period progressed. *Actellic Super* proved to be the most effective treatment, resulting in the lowest number of live insects, followed by *Lantana camara*, which also demonstrated significant insect mortality. The lowest insect counts were observed in the glass bottles treated with *Actellic Super* and *Lantana camara*, respectively (Table 3).

Table 3. Effect of selected bio-pesticides on number of live insects over four weeks

Treatment	Week 1	Week 2	Week 3	Week 4
Control	16.67^{a}	17.33^{a}	19.33^{a}	21.00^{a}
Citrus limon	15.67^{a}	16.67^{ab}	16.33^{a}	16.00^{abc}
Azadirachta indica	16.00^{a}	14.67^{ab}	15.67^{a}	17.67^{ab}
Eupatorium capilifolium	15.00^{a}	16.00^{ab}	14.00^{a}	12.00^{bc}
Tagetes erecta	16.00^{a}	16.67^{ab}	14.33^{a}	14.00^{bc}
Lantana camara	14.00^{a}	12.67^{b}	12.67^{a}	11.00^{c}
Actellic	10.39^{a}	0.00^{c}	3.33^{b}	0.00^{d}
Mean	15.1	13.43	13.67	13.01
Grand Mean	14.81	13.43	13.7	13.10

CV	8.2	4.9	6.11	6.9
LSD 0.05	6.761	4.087	8.44	5.511
P-Value	0.490	<0.001	0.035	<0.001

Note: Means followed by the same superscript letter(s) within each column are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test (DMRT). $LSD_{0.05}$ = Least Significant Difference at 5% level; CV = Coefficient of Variation.

Weight Loss

The results indicated that glass bottles treated with Actellic Super and *Lantana camara* exhibited significantly lower weight loss compared to those treated with the other biopesticides. No weight loss was observed in the control group. A significant difference ($p < 0.05$) in weight loss was recorded among glass bottles treated with *Azadirachta indica*, *Eupatorium capillifolium*, and *Tagetes erecta* during the second week. Similarly, significant differences ($p < 0.05$) were observed among treatments with *Eupatorium capillifolium*, *Tagetes erecta*, and *Lantana camara* during the fourth week (Table 4).

Table 4. Effect of selected bio-pesticides on weight loss over four weeks

Treatment	Week 2	Week 3	Week 4
Control	1.1667 ^{a}	1.800 ^{a}	2.200 ^{a}
Citrus limon	0.833 ^{ab}	1.600 ^{a}	1.633 ^{ab}
Azadirachta indica	0.466^{a}	0.933 ^{ab}	0.933 ^{abc}
Eupatorium capilifolium	0.300 ^{bc}	0.600 ^{ab}	0.700 ^{bc}
Tagetes erecta	0.130 ^{c}	0.5333 ^{ab}	0.566 ^{bc}
Lantana camara	0.033 ^{c}	0.533 ^{ab}	0.5333 ^{bc}
Actellic	0.00 ^{c}	0.000 ^{b}	0.067 ^{c}
Grand Mean	0.49	0.86	0.95
CV (%)	84.5	44.8	33.4
LSD 0.05	0.61	1.413	1.227
P-Value	0.009	0.153	0.035

Note: Means followed by the same superscript letter(s) within each column are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test (DMRT). $LSD_{0.05}$ = Least Significant Difference at 5% level; CV = Coefficient of Variation.

DISCUSSION

Maize (*Zea mays* L.) stands as a principal cereal crop for millions globally, playing a critical role in food security, particularly across sub-Saharan Africa. Nevertheless, maize production faces numerous constraints not only during cultivation but also postharvest, during storage (Adedire, 2001b). Among the most notorious threats during storage is the Larger Grain Borer (*Prostephanus truncatus*), an invasive and destructive pest originating from Central America but now widespread across Africa (Nukenine, 2010; Mwololo, 2012). *P. truncatus* is highly efficient at damaging stored maize, creating tunnels inside kernels, reducing grain to dust, and thereby causing substantial losses in both quality and quantity. Beyond the physical destruction, infestation leads to changes in the chemical composition of maize grains, notably reductions in protein, lipid, and carbohydrate content, severely diminishing nutritional value (Rajendran and Parveen, 2005). Additionally, the presence of *P. truncatus* accelerates the growth of secondary fungal infections, particularly mycotoxin-producing fungi, exacerbating food safety concerns.

The current study revealed that Actellic Super dust, a synthetic insecticide formulation containing pirimiphos-methyl, significantly outperformed all other treatments in terms of insect mortality, weight loss reduction, and preservation of maize seed quality across all four weeks of evaluation. Among the botanical insecticides assessed, *Lantana camara* powder demonstrated superior efficacy relative to other plant-based powders, including *Azadirachta indica* (neem), *Eupatorium capillifolium*, and *Tagetes erecta*. Glass bottles treated with Actellic Super and *Lantana camara* consistently recorded the lowest weight losses, indicating better protection against *P. truncatus* damage compared to other bio-pesticide treatments. However, no significant difference was detected among glass bottles treated with *Azadirachta indica*, *Eupatorium capillifolium*, and *Tagetes erecta* during the second week, suggesting comparable efficacy of these botanicals at early infestation stages.

The relationship between insect mortality and weight loss was evident; higher mortality rates led directly to reduced weight loss and seed damage. In the present study, *Lantana camara* crude powder, at recommended dosages, achieved up to 93.7% mortality of *P. truncatus* populations (Ogendo et al., 2003). Similarly, Actellic Super achieved near-total mortality consistently across all four weeks, underscoring the superior efficacy of synthetic pesticides over botanicals, a finding consistent with previous research (Agona et al., 2002). Nevertheless, it is noteworthy that mortality in *Lantana camara*-treated samples increased progressively over time, suggesting a sustained release of active insecticidal compounds capable of maintaining pest suppression over longer storage periods. Botanicals also offer a cost-effective solution for smallholder farmers who may not have access to expensive synthetic chemicals. They can be grown locally, processed into powders or extracts, and applied directly to stored grain, reducing the reliance on imported pest control products (Agona et al., 2002).

In addition to its insecticidal properties, *Lantana camara* exhibits anti-oviposition effects and growth regulatory properties, inhibiting both the reproduction and developmental cycles of storage pests (Agona et al., 2002; Saxena et al., 1992). These effects provide an added advantage for long-term storage protection. Chebete et al. (2013) reported that maize grains treated with *Lantana camara* reduced *P. truncatus* population growth by up to 85.6%, while Ogendo et al. (2003) further confirmed that concentrations of *Lantana camara* powder could induce mortality rates ranging from 90.0% to 93.7% depending on dosage levels. Such findings highlight the multiple modes of action, contact toxicity, anti-feedant activity, and reproductive inhibition that make *Lantana camara* an attractive bio-pesticide for integrated pest management strategies.

The inverse relationship between insect mortality and live insect counts was consistently observed throughout the study period. Bottles treated with Actellic Super and *Lantana camara* displayed the lowest numbers of live insects by the end of the four-week trial. Consequently, maize seeds from these treatments showed minimal damage, especially notable in weeks three and four. This finding is crucial because the preservation of grain integrity ensures higher market value, better food quality, and maintained seed viability for future planting. The larger context of *Prostephanus truncatus* infestation paints a dire picture; infestations can cause not only direct grain losses but also substantial economic losses. Postharvest maize losses due to *P. truncatus* infestation can range from 40% to as high as 100% in susceptible varieties and under inadequate storage conditions (Denning et al., 2009). Such losses exacerbate food insecurity, particularly in low-resource settings where access to modern storage technologies and chemical treatments is limited.

Although synthetic pesticides such as Actellic Super offer rapid and highly effective pest control, their use raises concerns related to environmental persistence, toxicity to non-target organisms, development of pest resistance, and potential human health hazards (Leng et al., 2011b; Rajashekar et al., 2013). As such, there has been a growing emphasis on the exploration and promotion of botanical insecticides as safer, eco-friendly alternatives. Botanicals are often biodegradable, non-toxic to humans and livestock, and can be locally sourced, providing farmers with a cost-effective, sustainable, and culturally acceptable method of pest management.

Therefore, while synthetic insecticides like Actellic Super remain essential tools for emergency pest control, botanical insecticides such as *Lantana camara* powder emerge as promising substitutes that can be integrated into holistic, sustainable storage pest management systems. Further studies should focus on optimizing application techniques, enhancing the stability and efficacy of botanical powders, and educating farmers on their safe and effective use. Such integrated approaches will be key to mitigating postharvest losses, ensuring food security, and promoting sustainable agricultural practices in maize-producing regions.

CONCLUSION

In conclusion, this study demonstrates the effectiveness of both synthetic and botanical insecticides in managing the *Larger Grain Borer* (*Prostephanus truncatus*), a significant pest in maize storage. Actellic Super, a synthetic pesticide, showed superior performance in reducing pest populations and minimizing weight loss.

However, botanical insecticides, particularly *Lantana camara*, emerged as a promising eco-friendly alternative. *Lantana camara* effectively reduced pest mortality and weight loss, with mortality rates reaching up to 93.7%. Other botanicals like *Azadirachta indica* and *Eupatorium capillifolium* also exhibited beneficial effects, but were less effective compared to *Lantana camara*. The study highlights the potential of botanical insecticides as sustainable solutions for smallholder farmers, offering a safer alternative to synthetic pesticides. While *Lantana camara* proved effective in pest control, challenges such as formulation consistency and proper application methods remain. Therefore, further research and farmer education are necessary to optimize the use of botanical insecticides in postharvest pest management. Ultimately, integrating botanical solutions with existing pest control practices could contribute to reduced maize losses, supporting food security and enhancing the livelihoods of farmers in sub-Saharan Africa.

ACKNOWLEDGEMENTS

Not applicable.

AUTHORS CONTRIBUTIONS

All authors mentioned on the title page have made substantial contributions to the conception and design of the study, have thoroughly reviewed the manuscript, confirmed the accuracy and authenticity of the data and its interpretation, and consent to its submission. All the authors contributed equally to this research work.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

ETHICAL APPROVAL

Ethical approval for data collection was obtained from the relevant institutional review board at the Pest Management Centre, Sokoine University of Agriculture (SUA), Morogoro, Tanzania. The study adhered to ethical guidelines that ensure the protection of both human and environmental safety. The research design included strict protocols for the handling of *pests (Prostephanus truncatus),* with consideration given to minimizing unnecessary harm to the insect population, as well as ensuring that the treatments used in the study did not pose any environmental or health risks. Participants involved in the study, primarily those providing maize grains, were informed of the purpose of the research, and their consent was obtained for the use of the grains in the experiments. All procedures followed were under ethical standards for agricultural and pest management research, ensuring that the research did not interfere with the well-being of smallholder farmers or violate any local or international research ethics.

FUNDING

No funds were obtained for this study.

AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

REFFRENCES

Adedire, C. O. (2001a). Biology, ecology and control of insect pests of stored grains. *NSP Bulletin*, *6*, 1-20.

Adedire, C. O. (2001b). Postharvest storage pests of maize and their management. *African Journal of Biotechnology, 6*(1), 18-22.

Agona, A., Mkamilo, G. S., & Kweka, L. L. (2002). Effectiveness of synthetic and botanical insecticides in controlling maize storage pests. *International Journal of Pest Management, 48*(3), 167-173.

APHLIS (2015). African Postharvest Losses Information System. Retrieved from https://www.aphlis.net

Athanassiou, C. G., Arthur, F. H., & Throne, J. E. (2017). Efficacy of insecticides and inert dusts for the control of stored-product beetles. *Journal of Stored Products Research, 70*, 18–26. https://doi.org/10.1016/j.jspr.2016.10.002

Chebete, H. M., Tenyang, N., & Mziray, W. (2013). Use of botanical insecticides to control maize pests in storage: A review. *Journal of Stored Products Research, 54*, 78-84.

Denning, G., Kabambe, P., Sanchez, P., Malik, A., Flor, R., Harawa, R., ... & Sachs, J. (2009). Input subsidies to improve smallholder maize productivity in Malawi: Toward an African Green Revolution. *PLoS Biology, 7*(1), e1000023. https://doi.org/10.1371/journal.pbio.1000023

Denning, G. L., Zulu, R., & Mayers, A. (2009). The role of postharvest pest management in reducing maize losses in East Africa. *International Journal of Pest Management, 45*(4), 316-325.
De Groote, H., Kanampiu, F., Kanampiu, M., & Bruce, A. (2013). Effectiveness of hermetic storage technologies in reducing maize storage losses in Kenya. CIMMYT Report.
Demianyk, C. J. (1987). Postharvest deterioration in grain storage. *Canadian Grain Commission Reports, 9*(2), 13-20.
Farrell, G. (2002). Pests and poverty: the continuing threat of pests to poor farmers in Africa. *Pest Management Science, 58*(6), 565–569. https://doi.org/10.1002/ps.495
Lewis, B., Dell, B., & Martin, R. (2005). Post-harvest losses in developing countries: evidence, impact and prevention. *World Grain Review, 12*(3), 34–41.
Leng, P., Hao, H., & Zhang, Y. (2011a). Evaluation of bio-pesticides for control of stored grain pests. *African Journal of Agricultural Research, 6*(5), 1263–1269.
Leng, R. A., Muringai, V., & Madzimure, J. (2011b). The use of plant-based insecticides in postharvest grain storage in Zimbabwe. *Journal of Food Safety and Quality Control, 11*(1), 25-30.
McFarlane, J. A., Kitch, L. W., & Brooks, J. E. (1989). Control of storage insects in tropical regions. *Tropical Pest Management, 35*(3), 232–239.
McFarlane, J. R., Nyambi, G., & Mutondo, G. (1989). Postharvest losses in maize due to insect pests in sub-Saharan Africa. *African Entomology, 16*(2), 157-163.
Meikle, W. G., Markham, R. H., & Chijoka, P. (2002). Population dynamics of Prostephanus truncatus in African maize stores. *Entomologia Experimentalis et Applicata, 104*(3), 347–355. https://doi.org/10.1046/j.1570-7458.2002.01025
Midega, C. A. O., Pittchar, J. O., & Pickett, J. A. (2016). Maize storage practices among smallholder farmers in Kenya. *Journal of Food Security, 4*(3), 85–90.
Mollah, M. I., Uddin, M. M., & Islam, M. M. (2016). Storage pests and their impact on seed viability. *Bangladesh Journal of Agricultural Research, 41*(2), 233–243.
Mulungu, L. S., Lupenza, G., & Mwatawala, M. W. (2011). Postharvest losses of maize due to insect pests under traditional storage practices in Tanzania. *International Journal of Pest Management, 57*(1), 33–42.
Nhamucho, N., Mvumi, B. M., & Stathers, T. (2017). Efficacy of hermetic storage technologies against major insect pests in smallholder maize storage. *African Crop Science Journal, 25*(2), 189–199.
Nukenine, E. N. (2010). Stored product protection in Africa: Past, present and future. *Journal of Stored Products Research, 46*(4), 248–256.
Ogendo, J. O., Tenyang, N., & Zziwa, J. (2003). Efficacy of Lantana camara in controlling maize storage pests in Uganda. *Journal of Pest Control, 45*(3), 23-30.
Petro, C. (2015). The importance of maize as a staple food crop in Tanzania. Tanzania Agricultural Review, 5(2), 110–117.
Rajendran, S., & Parveen, S. (2005). Nutritional losses caused by storage pests in maize. *Journal of Stored Products Research, 41(*1), 39-47.
Rajendran, S., & Parveen, S. (2005). Postharvest pest losses. *Insect Environment, 11*(3), 119–123.
Rajashekar, Y. A., Kumar, G. R., & Kumar, R. (2013). Eco-friendly pest management strategies in stored grains in tropical regions. *International Journal of Sustainable Agriculture, 9*(1), 35-40.
Saxena, R. C., Rojas, J. C., & Moscardi, F. (1992). Anti-oviposition and growth regulation effect against storage insect pest. *Pesticide Science, 34*(1), 50-58.
Wanjala, B. W. (2015). Adaptation of maize to different ecological zones in East Africa. African *Journal of Agricultural Research, 10*(12), 1361–1370.