Bioactivity of Selected Plant Powders against *Prostephanus truncatus* (Coleoptera: Bostrichidae) in Stored Maize Grains

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**Abstract**


Crude powders of *Azadirachta indica*, *Lantana camara*, and *Tephrosia vogelii*, each at six concentrations (0.0, 2.0, 4.0, 6.0, 8.0, and 10% w/w), and Actellic Super™ 2% dust were evaluated for repellence anti-feeding and toxicity to adult *Prostephanus truncatus*. Treatments were laid out in a completely randomised design with four replicates. Results showed that powders were strongly repellent (PR values 73.0–90.0%) and caused 46.2–52.2 and 69.7–85.6% reductions in grain damage and F₁ progeny, respectively. Results showed that powders were weakly toxic to *P. truncatus* causing 40% kill 21 days after treatment compared to 100% kill by Actellic Super™ 2% dust 5 DAT. The findings are discussed in the context of their relevance for integrated pest management options in smallholder agriculture.

**Keywords**: *Azadirachta indica*; *Lantana camara*; *Tephrosia vogelii*; botanicals

Insects cause substantial quantitative and qualitative pre- and post–harvest losses varying in magnitude from 10% to 100% in tropical countries (Mugisha-Kamatenesi et al. 2008) and in Kenya, 10–60% losses of stored cereal and legume grains (Ogendo et al. 2004). These substantial losses are caused by *Sitophilus* spp. and *Sitotroga cerealella* on cereals, *Anthonomus grandis* and *Callosobruchus chinensis* on legumes (Dobie 1991) and more damage in cereals is also caused by tenebrionid beetles and newly introduced *Prostephanus truncatus* in stored cereals and cassava. *P. truncatus* (Horn), being an introduced species and spreading rapidly, has become a major problem in most areas that produce maize and cassava (Ogemah 2003).

In the past few decades the application of synthetic pesticides to control pests of durable stored food products including *P. truncatus* has been the standard practice. However, with evidence that the use of synthetic insecticides poses possible health hazards to warm-blooded animals, risk of environmental pollution, development of resistance by insects and pest resurgence, requirements for effective, affordable and eco-friendly control options have become crucial (Banwo & Adamu 2003; Rajendran & Sriranji 2008). Botanical pesticides, despite having different active constituents and modes of action are target-specific, relatively safe, affordable and readily available. Hence, the readily available botanical pesticide technology for pest management in smallholder agriculture is a viable alternative option.

The insecticidal activity of several plant essential oils, powders and other extracts has been evaluated against several insect pests of cereals and legumes and found to have contact toxicity (Asawalam et al. 2006; Ogendo et al. 2008), repellence (Kéita et al. 2001; Rosman et al. 2007), fumigant toxicity (Lee et al. 2003; Rajendran & Muriladharan 2005), anti-feedant (Saxena et al. 1992; Ogemah 2003) effects. Ogendo et al. (2008) reported that essential oils extracted from aerial parts of *Ocimum americanum*, *Lantana camara* and *Tephrosia vogelii* and monoterpenes

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constituent, eugenol, had concentration, exposure time, species (plant and insect) and plant part-dependent instant and residual repellent potency against adult Tribolium castaneum, Rhyzopertha dominica, Sitophilus oryzae, and Callosobruchus chinensis. Similarly, L. camara has been reported to have anti-oviposition and growth regulating effects against field and storage insect pests (Saxena et al. 2003). Plants have been found to contain triterpenoids, iridoid glycosides, some of which may be responsible for the observed insecticidal properties (Sharma et al. 1995).

However, the larger grain borer, P. truncatus, has received little attention in the area of rationalised use of botanical pesticides, especially of the use of extracts of Azadirachta indica, Lantana camara, and Tephrosia vogelii for the stored product insect control. The purpose of the present study was to evaluate the repellent, feeding deterrence and contact toxicity effects of plant powders of A. indica, L. camara, and T. vogelii on P. truncatus with the hope of finding an effective, affordable and environmentally safe product for use by subsistence farmers.

**MATERIAL AND METHODS**

**Mass rearing of P. truncatus.** Approximately 250 unsexed adult P. truncatus were introduced into 1-l glass jars containing 500 g of Katumani composite B maize grain samples and kept at 25–30°C and 65–70% R.H. and 12:12 h (light:darkness). The insects were allowed to lay eggs for 14 days (Ogemah 2003). The jars were covered using plastic stoppers reinforced on the inside with 0.5 mm wire gauze to prevent the insects from escaping. For each treatment, 20 adult P. truncatus (5–10 days) were released at the centre of the circular base. The treatments were arranged in a Completely Randomised Design (CRD) with 4 replicates per concentration including a no-choice control with untreated maize in all four portions. The top of the basin was covered with a fine wire mesh to prevent the insects from escaping. For each treatment, 20 adult P. truncatus (5–10 days) were released at the centre of the basin. The total number of insects that settled on the control and the treated grains was recorded after 1, 12, and 24 h of exposure. Percent repellence (PR) was calculated and interpreted as described by Talukder and Howse (1993) as follows;

\[
PR = 2(C - 50)
\]

where: C = percent of insects that settled on the untreated grains

**Feeding deterrence (grain damage) studies.** Maize grain samples (100 g) were weighed and...
put into 500 g glass jars and separately treated with *A. indica*, *T. vogelii*, and *L. camara* powders. Each plant powder was evaluated at six rates (0, 2.0, 4.0, 6.0, 8.0, and 10% w/w) and kept at 25–30°C and 65–70% R.H. Thirty unsexed adult *P. truncatus* (5–10 days) were introduced into the treated grains and allowed to feed. After 7 and 21 days, insects were removed and the amount of frass (flour) produced was determined by sieving the samples and weighing the resultant frass (flour). Percent grain damage was computed according to Dobie (1991) as follows:

\[
\text{Weight loss (\%)} = \frac{(\text{UN}_d - \text{DN}_u)}{\text{U}(\text{Nd} + \text{Nu})} \times 100 \quad (2)
\]

where:
- \(U\) – weight of undamaged grains
- \(D\) – weight of insect-damaged grains
- \(Nu\) – number of undamaged grains
- \(Nd\) – number of insect-damaged grains

**Contact toxicity and F\(_1\) progeny studies.** Maize grains (100 g) were weighed into 250 ml glass jars and admixed with *A. indica*, *T. vogelii*, and *L. camara*, powders at six different dosages (0, 2.0, 4.0, 6.0, 8.0 and 10% w/w). Maize treated with synthetic insecticide Actellic Super\(^{TM}\) 2% dust (0.05% w/w) was used as positive control. Twenty (\(N_T\)) unsexed *P. truncatus* adult beetles (5–10 days old) were placed into each experimental jar. A CRD with 4 replicates per treatment was used. The top of each jar was covered using plastic stoppers reinforced on the inside with 0.5 mm wire gauze to prevent the insects from chewing through them. The experimental units were kept at 25–30°C and 65–70% R.H. The number of dead (\(N_D\)) insects in each jar was recorded 1, 3, 5, 7, 14 and 21 days after treatment (DAT). The adult beetles were removed from the grains in experimental jars 21 DAT and the grains returned into the jar and kept for \(F_1\) progeny counts. The number of newly emerged adult \(F_1\) progeny insects was recorded 28, 35, and 42 DAT. The percent reduction in adult emergence or reproduction inhibition rate (IR \%) was computed according to Tapondjou *et al.* (2002) as shown in Eq. 1:

\[
\text{Reproduction inhibition rate (\%)} = \frac{(\text{CN}_N - \text{TN}_N)}{\text{CN}_N} \times 100 \quad (3)
\]

where:
- \(CN_N\) – number of newly emerged adult insects in the untreated control
- \(TN_N\) – number of newly emerged adult insects in the treated grains

**Data analysis.** Data on corrected percent mortality and repellence were first homogenised using log-transformation to correct for heterogeneity of treatment variance (Gomez & Gomez 1984) before being subjected to ANOVA and repeated measures analysis using Statistical Analysis System and means were separated using Tukey’s HSD-test (SAS release 8.02, 2001; Wambua *et al.* 2011). Data obtained from various concentration-response bioassays (contact toxicity and repellence) were further log-transformed before being subjected to probit regression analysis using EPA Probit Analysis Program version 1.4 and LC\(_{50}/\text{RC}_{75}\) values and corresponding 95% fiducial limits were obtained from derived regression equations. The LC\(_{50}\) values in a column were considered significantly different when 95% fiducial limits did not overlap. The RC\(_{75}\) represents the concentration that repels 75% of test insects.

**RESULTS**

**Repellence studies (choice bioassay)**

Percent repellence (PR) results of adult *P. truncatus* to maize grains treated with varying crude powder concentrations of *L. camara*, *T. vogelii*, and *A. indica* are presented (Figure 1, Table 1). The magnitude of repellence of adult *P. truncatus* insects was significantly (\(P < 0.05\)) influenced by plant species, concentration of powder applied, exposure time and corresponding factor interactions. The test plant powders exhibited clear dose-dependent increasing PR values over the 24 h exposure period. At 7.0–10.0% w/w and 24 h exposure, maize grains treated with crude *T. vogelii* and *A. indica* powders equally had the highest PR values of 90 and 88%, respectively, whereas the other plant powder, *L. camara* caused 73% repellence of adult *P. truncatus* insects. The synthetic insecticide, Actellic Super\(^{TM}\) 2% dust, at 0.05% w/w and 24 h exposure, was the most repellant against adult *P. truncatus* with a PR value of 95.0% whereas the untreated maize grains (negative control) had the test insects well distributed in the choice bioassay (PR value 0).

**Feeding deterrence (grain damage) studies**

Results of feeding deterrence expressed as percent damage and weight of frass (flour) arising
from adult *P. truncatus* insect feeding on maize grains treated with varying concentrations of *L. camara, T. vogelii,* and *A. indica* crude powders are presented (Figure 2, Table 2). The percent of grain damage and amount of frass produced due to adult *P. truncatus* were significantly (*P* < 0.05) influenced by plant, concentration applied and plant by concentration interaction effects. A clearly discernible dose-dependent reduction in percent grain damage was observed with *T. vogelii* and *A. indica* powders equally causing the highest suppression (52.2%) of insect damage when benchmarked against the untreated control that recorded the highest damage. Crude *L. camara* powder treatment produced a 46.2% reduction in maize grain damage. Maize grains treated with synthetic insecticide, Actellic Super™ dust, recorded no insect feeding (= no damage) due to the high toxicity of insecticide to the test insects. The overall observed percent damage, in order of a

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Concentration (% w/w)</th>
<th>Exposure time (h)</th>
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</thead>
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<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Actellic Super 0.02%</td>
<td>0.05</td>
<td>95.0 ± 1.4</td>
</tr>
<tr>
<td><em>L. camara</em></td>
<td>2.0</td>
<td>20.0 ± 9.1</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>35.0 ± 8.7</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>60.0 ± 7.1</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>70.0 ± 4.0</td>
</tr>
<tr>
<td>RC&lt;sub&gt;75&lt;/sub&gt;</td>
<td></td>
<td>12.71</td>
</tr>
<tr>
<td><em>T. vogelii</em></td>
<td>2.0</td>
<td>50.0 ± 4.1</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>55.0 ± 2.8</td>
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<tr>
<td></td>
<td>7.0</td>
<td>60.0 ± 4.1</td>
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<tr>
<td></td>
<td>10.0</td>
<td>67.5 ± 4.8</td>
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<tr>
<td>RC&lt;sub&gt;75&lt;/sub&gt;</td>
<td></td>
<td>24.03</td>
</tr>
<tr>
<td><em>A. indica</em></td>
<td>2.0</td>
<td>40.0 ± 4.0</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>73.0 ± 6.8</td>
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<tr>
<td></td>
<td>7.0</td>
<td>70.0 ± 3.9</td>
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<tr>
<td></td>
<td>10.0</td>
<td>78.0 ± 6.8</td>
</tr>
<tr>
<td>RC&lt;sub&gt;75&lt;/sub&gt;</td>
<td></td>
<td>7.09</td>
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Means in a column followed by different letters are significantly different at α = 0.05 by LSD; RC<sub>75</sub> refers to the concentration (% w/w) that repels 75% of the test insects using Probit Regression Analysis.
decreasing level of damage, was untreated control (33.5%), *T. vogelii* and *A. indica* (17.5%), *L. camara* (15.5%) and Actellic Super™ dust (0.0%).

Similar result trends were recorded for the weight of frass resulting from adult *P. truncatus* feeding on maize grains treated with varying concentrations of the three test botanical powders (Table 3). At 10.0% (w/w) and 42 days after treatment, maize grains treated with *T. vogelii* and *A. indica* powders produced the least amount of frass (1.50–1.55 g/100 g) compared to 2.42 g/100 g in *L. camara* treated grains (Table 3). The untreated maize grains produced 2 and 7 times more frass than *L. camara* and *T. vogelii/A. indica*-treated grains.

**Contact toxicity and F₁ progeny studies**

The results of adult *P. truncatus* mortality and F₁ progeny counts are presented (Figures 3 and 4, Table 2). Results showed that the toxicity of crude powders was significantly (*P* < 0.05) influenced by plant, concentration applied, contact duration (days) and corresponding factor interactions. Although the botanical powders produced clear dose-dependent toxicity to adult *P. truncatus*, the end-point mortalities were less than 40% after 21 days of contact with treated maize grains (Figure 3). The concentration of powder applied and duration of contact (days) significantly influenced the percent mortality of adult *P. truncatus* insects. Probit regression analysis of dose-response produced LC₅₀ values of 17.3, 17.6, and 47.0% (w/w) for crude powders of *L. camara, T. vogelii*, and *A. indica*, respectively. The positive control, Actellic Super™ 0.02% dust, at 0.05% (w/w), caused the highest mortality (100%) after 5 days of contact. Thus, the crude powders of *L. camara, T. vogelii*, and *A. indica* were inferior compared to the positive control.

The adult *P. truncatus* F₁ progeny counts in grains treated with crude botanical powders were...
significantly ($P < 0.05$) affected by the plant source, concentration applied and plant by concentration effects. Results showed clear dose-dependent reductions in the adult $P. truncatus$ F$_1$ progeny counts (Figure 4 and Table 3). At the highest concentration (10.0% w/w), crude powders of $L. camara$, $T. vogelii$, and $A. indica$ reduced the F$_1$ progeny counts by 71.6, 69.7 and 85.6%, respectively, compared to the untreated control. Synthetic insecticide, Actellic Super™ 2% dust, at 0.05% (w/w), caused the total inhibition (100%) of adult $P. truncatus$ F$_1$ progeny emergence.

Table 3. Weight of frass (mean ± SE, $n = 4$) produced by adult $P. truncatus$ in maize grains treated with varying concentrations of $L. camara$, $T. vogelii$, and $A. indica$ crude powders (in g/100 g)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Concentration (% w/w)</th>
<th>Contact duration (days)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>21</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Untreated control</td>
<td>0.0</td>
<td>1.75 ± 0.25</td>
<td>4.80 ± 0.45</td>
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</tr>
<tr>
<td>Actellic Super 0.02%</td>
<td>0.05</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td></td>
</tr>
<tr>
<td>$L. camara$</td>
<td>2.0</td>
<td>0.83 ± 0.10</td>
<td>3.35 ± 0.32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>0.78 ± 0.10</td>
<td>2.65 ± 0.29</td>
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<tr>
<td></td>
<td>6.0</td>
<td>0.76 ± 0.09</td>
<td>2.60 ± 0.24</td>
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<tr>
<td></td>
<td>8.0</td>
<td>0.63 ± 0.06</td>
<td>2.46 ± 0.21</td>
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<tr>
<td></td>
<td>10.0</td>
<td>0.52 ± 0.05</td>
<td>2.42 ± 0.20</td>
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<tr>
<td>$T. vogelii$</td>
<td>2.0</td>
<td>1.00 ± 0.15</td>
<td>3.47 ± 0.38</td>
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</tr>
<tr>
<td></td>
<td>4.0</td>
<td>0.79 ± 0.07</td>
<td>2.30 ± 0.24</td>
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<tr>
<td></td>
<td>6.0</td>
<td>0.70 ± 0.05</td>
<td>2.15 ± 0.20</td>
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<tr>
<td></td>
<td>8.0</td>
<td>0.68 ± 0.05</td>
<td>2.05 ± 0.15</td>
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<tr>
<td></td>
<td>10.0</td>
<td>0.43 ± 0.03</td>
<td>1.55 ± 0.15</td>
<td></td>
</tr>
<tr>
<td>$A. indica$</td>
<td>2.0</td>
<td>0.78 ± 0.03</td>
<td>2.52 ± 0.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>0.75 ± 0.02</td>
<td>2.50 ± 0.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.0</td>
<td>0.70 ± 0.03</td>
<td>2.47 ± 0.25</td>
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<tr>
<td></td>
<td>8.0</td>
<td>0.69 ± 0.01</td>
<td>2.15 ± 0.20</td>
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<tr>
<td></td>
<td>10.0</td>
<td>0.55 ± 0.01</td>
<td>1.50 ± 0.16</td>
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Any two treatment means in a column whose standard errors do not overlap are significantly different at $\alpha = 0.05$ by LSD
Feeding deterrence (grain damage) studies

From the results of our study the crude plant powders exhibited strong dose- and contact duration-dependent feeding deterrence as expressed in terms of reduced grain loss/damage (%) and amount of frass produced due to insect feeding activity. As observed in the choice bioassay, grains admixed with crude powders of T. vogelii and A. indica were equally the most deterrent reducing adult P. truncatus grain damage by 52.2% as referenced against the untreated control whereas L. camara powder produced 46.2% reduction.

Grain injury is usually measured by the count-and-loss method, which yields two alternative measures, percentage kernels damaged and percent weight loss (Boxall 1986). In the present study percent damage of seeds was used and amount of flour produced to represent the weight loss indirectly. In the grain damage test, the amount of flour produced by P. truncatus decreased with an increase in the concentration of plant powders applied. The antifeedant property of any plant material would depend on active constituents of plant material. Based on previous studies, much of the antifeedant can be attributed to azadirachtin, which is known to be an important antifeedant compound in neem products (Butterworth & Morgan 1968; Rembold 1995; Ogemah 2003). Azadirachtin has been shown to stimulate the deterrent neurones and to inhibit phagostimulatory neurones in the chemoreceptor cells for various insects (Blaney & Simmonds 1990). The T. vogelii leaves and seeds have also been reported to contain rotenoids (rotenones, tephrosin, daguelin) known to be feeding deterrents (Isman 2007; Adabayo et al. 2007; Ogendo et al. 2008). Therefore, the antifeedant properties in crude powders obtained from these plants could possibly be attributed to the presence of the above chemical constituents.

The results of this study are also comparable to those of other researchers who observed that storage insect pests cause 10–100% losses (Ogendo et al. 2004; Mugisha-Kamatenesi et al. 2008) depending on insect species, storage conditions, type of stored grain. In stored grains, damage accrues at a much higher rate than the weight loss which is proportional to the market value (Comp-ton et al. 1998), a measure of direct importance to the farmer. The destructiveness of P. truncatus in this study can also be explained in terms of its...
behaviour. Adult tunnelling has been estimated to destroy approximately four times as much grain as larval and adult consumption (Demianyk & Sinha 1988), whereas in other storage pests the consumption accounts for most of the loss.

In recent grain storage adaptability studies, similar result trends were observed by Koona et al. (2007) when seeds stored in jute bags impregnated with aqueous extracts of L. camara recorded an 80% reduction in damage by bruchid beetles over a 6-month period. The fact that all the three botanical powders achieved more than 45% reduction in damage and amount of frass produced arising from adult P. truncatus insect feeding holds good promise for their adoption and rationalised use for grain protection in smallholder agriculture. Our findings corroborate Alonso-Amelot & Avila-Núñez (2011)'s quantitative appraisal of grain losses due to insect activity. The observed grain protection properties of crude powder treatments could partly be attributed to a modification of the physical properties of stored maize grains that reduced inter-granular air spaces thereby discouraging insect penetration, feeding, and amount of oxygen available. Based on their weak contact toxicity, the crude plant powders succeeded in inhibiting insect feeding and oviposition. In addition to any chemical principles inherent in the plant powders, the adult insect mortalities recorded were largely due to starvation. Based on previous studies, much of the anti-feeding of test botanicals could be attributed to their bioactive principles, such as azadirachtin, known for their strong feeding deterrence properties (Rembold 1995; Ogemah 2003).

Contact toxicity and F_1 progeny studies

The test botanical powders have shown two distinct effects on adult P. truncatus through mortality and reduced F_1 progeny emergence. The results showed that crude powders of L. camara, T. vogelii, and A. indica had plant specific weak toxicity to adult P. truncatus that was significantly dependent upon the concentration of powder applied and duration of contact with treated maize grains. In the same experiments, the test botanical powders produced clear dose-dependent reductions of adult P. truncatus F_1 progeny counts in which maize grains treated with L. camara, T. vogelii, and A. indica powders recorded 71.6, 69.7, and 85.6% reductions, respectively, compared to the untreated control. The fact that all the three botanical powders, at 10% (w/w) and 21 DAT, caused only 22.8–34.0% kill (LC_{50} values: 17.3–47.0% w/w) of adult P. truncatus insects does not invoke scientific excitement. However, their strong inhibitory effects on the reproductive cycle in which the F_1 progeny were reduced by 70–86% gives a glimmer of hope for use as grain protectants against larger grain borer (LGB). Similar low toxicity levels of neem and other plant powders against LGB and S. zeamais had earlier been reported and low efficacy attributed to the settling of powder particles at the bottom of experimental unit, a phenomenon that was observed in the present study (Cobbina & Appiah-Kwarteng 1989; Niber 1994). However, our findings are significantly inferior to previous studies in which crude powders of L. camara and T. vogelii, at the same concentration and contact duration, caused 90.0 and 93.7% kill of the maize grain weevil, Sitophilus zeamais (Ogendo et al. 2003). In other similar bioassays, A. indica powders caused more than 50% mortality of several stored-product insect pests of maize including P. truncatus (Sharma 1995; Chiranjeevi & Sudharkar 1996). The observed toxic and reproduction inhibition effects of L. camara, T. vogelii, and A. indica could be a result of documented bioactive chemical principles such as isoflavanoids, flavanoids, terpenoids, and azadarachtins among other compounds (Boeke et al. 2004). For example Rahim (1998) reported that azadirachtin, at 5 mg/kg grain, inhibited Rhyzopertha dominica (F.) F_1 progeny production by more than 98% over a 48-week storage period.

It is evident from the above results that the test botanical powders are potential protectants (repellents, antifeedants or toxicants) of stored durable agricultural products against the larger grain borer, P. truncatus and other coleopteran pests. The broad-spectrum bioactivity of these botanical powders coupled with their local availability and processing makes them more acceptable and cost-effective alternatives to synthetic pesticides in smallholder agriculture. Hence, these plant-based products hold good promise for inclusion in integrated pest management (IPM) strategies especially where the emphasis is on ecological and food safety.

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