Development-inhibiting activity of some tropical plants against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)

M.A. Haque1, H. Nakakita*, H. Ikenaga, N. Sota

National Food Research Institute, Tsukuba, Ibaraki 305, Japan

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Abstract

Thirteen tropical plants were evaluated for development-inhibiting activity against *Sitophilus zeamais*. The bioassays were carried out by incorporating seeds or leaves at various dose levels into an artificial diet for the test insect. It was found that seeds of *Basella alba* and leaves of *Operculina turpethum* and *Calotropis gigantea* were potent in delaying development and in reducing adult emergence, and hence the capacity for population increase. At 0.5% concentration, adult emergence in tests with *B. alba*, *O. turpethum* and *C. gigantea* was reduced by 62, 95 and 70%, respectively. In *B. alba* and *C. gigantea*, the development periods were 2.2 and 1.8 times those in the control and the capacities for increase/day were only 0.0324 and 0.0328 compared with 0.1004 in the control. *B. alba*, *O. turpethum* and *C. gigantea* were active at concentrations as low as 0.01, 0.05 and 0.1%. The potential of these materials in insect pest management is discussed. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Tropical plants; Capacity for increase; Population growth; *Sitophilus zeamais*

1. Introduction

Insects often cause extensive damage to stored grains and grain products and this may
amount to 5–10% in the temperate zone and 20–30% in the tropical zone (Nakakita, 1998). At present, pest control measures in storage rely heavily on the use of synthetic insecticides and fumigants. Their indiscriminate use in storage, however, has sometimes led to a number of problems including toxic residues in food grains (Fishwick, 1988) and environmental pollution (Wright et al., 1993; WMO, 1995). These problems together with the development of insect resistance (Yusof and Ho, 1992) mean that their use has been, or may be, restricted globally. Currently, only two fumigants, methyl bromide and phosphine, are widely used against stored product insect pests. According to the 1997 decision of the 9th Montreal Protocol, however, methyl bromide, a proven ozone depleter in the atmosphere, will be phased out by 2005 in advanced countries and by 2015 in the developing countries. Furthermore phosphine resistance is becoming more common (Champ and Dyte, 1976; Tyler et al., 1983) and is a matter of considerable concern. Thus, there is an urgent need to develop safe alternatives to conventional insecticides and fumigants to protect stored grains and grain products from insect infestations.

Plant products and their secondary metabolites are receiving increasing attention in stored product pest management. Botanical insecticides, in comparison to synthetic insecticides, may be safer for the environment, may be less expensive and usually can be easily processed and used by farmers and small-scale industries. The effectiveness of many plant derivatives for use against stored grain pests has been reviewed by Jacobson (1958, 1975, 1983, 1989). The activity of plant products so far reported includes insecticidal, repellent or antifeedant effects (e.g. Talukder and Howse, 1995; Huang and Ho, 1998). Studies on the growth inhibitory effects of plant products on stored grain insects, however, are scanty. Joseph et al. (1994) studied the growth inhibitory effects of some commercially available plant extracts on Tribolium castaneum (Herbst). In this communication we report the development-inhibiting activity of a variety of tropical plant materials against Sitophilus zeamais Motschulsky.

2. Materials and methods

2.1. Test insects

The maize weevil, S. zeamais used in this study was obtained from a laboratory culture maintained on brown rice in a dark room at 25 ± 1°C and 75 ± 5% r.h. Adult weevils, 1–2 weeks old, were sexed and kept separated in the experimental environment for 5–7 days before commencement of the bioassays.

2.2. Test materials

Seeds, leaves or both of 13 tropical plants collected from Bangladesh and Thailand were tested for their insect growth inhibitory activities (Table 1). None of the plants from which the test materials were collected were known to have been treated with systemic pesticides. After harvesting, test materials were air dried in room conditions for about 2 weeks.
2.3. Preparation of test materials for bioassay

The bioassay was carried out by incorporating the test materials into rice pellets. For this purpose, each test material was ground separately in a motorized high speed grinder and sieved through a 300 μm aperture mesh screen to obtain fine powder. Similarly, brown rice was powdered in a motorized grinding machine and sieved through a 40 holes/mm² mesh screen. Then a known amount of test material powder was mixed thoroughly with brown rice powder using a mortar and pestle to give a 10% concentration of the test material. From this stock, test concentrations were made up by further mixing with brown rice powder in a motorized mixer at medium speed for 45 min. Water at a ratio of 1:2 (v/w) was then added to each test material, mixed thoroughly into a dough and a cake of about 6 mm thickness was prepared. Rice pellets were cut from this cake with a teflon tube (5 mm diameter × 6 mm height) and were dried either in a drying chamber at 20°C and 20% r.h. overnight, or in an oven at 55°C overnight. In the untreated control rice pellets were made from brown rice powder only. Before commencing bioassays the dried rice pellets were held in a controlled environment room at 25 ± 1°C and 75 ± 5% r.h. for 5–7 days to equilibrate them to 14% moisture content.

Table 1
Effect of feeding a 0.5% concentration of different tropical plant materials on the development of *Sitophilus zeamais*

<table>
<thead>
<tr>
<th>Name of plant</th>
<th>Parts tested</th>
<th>Progeny per parent</th>
<th>Development time (d)</th>
<th>Capacity for increase/day</th>
<th>Adult weight (mg) Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>% Inhibition</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td><em>Abrus fruticulosus</em> Wallich</td>
<td>Seed</td>
<td>24.0 ± 3.0</td>
<td>0.8</td>
<td>32.7 ± 0.6</td>
<td>0.0950</td>
</tr>
<tr>
<td><em>Abrus precatorius</em> L.</td>
<td>Seed</td>
<td>29.0 ± 2.7</td>
<td>0</td>
<td>32.5 ± 0.8</td>
<td>0.1008</td>
</tr>
<tr>
<td><em>Annona reticulata</em> L.</td>
<td>Leaf</td>
<td>23.6 ± 3.1</td>
<td>2.5</td>
<td>32.6 ± 1.1</td>
<td>0.0932</td>
</tr>
<tr>
<td><em>Annona reticulata</em> L.</td>
<td>Seed</td>
<td>22.0 ± 3.9</td>
<td>9.1</td>
<td>36.8 ± 0.7</td>
<td>0.0816</td>
</tr>
<tr>
<td><em>Annona squamosa</em> L.</td>
<td>Seed</td>
<td>20.6 ± 3.2</td>
<td>14.9</td>
<td>37.5 ± 0.5</td>
<td>0.0790</td>
</tr>
<tr>
<td><em>Aphananmixis polystachya</em> Parker</td>
<td>Leaf</td>
<td>27.0 ± 6.7</td>
<td>0</td>
<td>32.3 ± 0.7</td>
<td>0.0970</td>
</tr>
<tr>
<td><em>Aphananmixis polystachya</em> Parker</td>
<td>Seed</td>
<td>17.6 ± 2.7</td>
<td>27.3</td>
<td>37.7 ± 0.9</td>
<td>0.0732</td>
</tr>
<tr>
<td><em>Basella alba</em> L.</td>
<td>Seed</td>
<td>9.2 ± 4.4</td>
<td>62.0</td>
<td>65.9 ± 2.9</td>
<td>0.0324</td>
</tr>
<tr>
<td><em>Calotropis gigantea</em> R. Brown</td>
<td>Leaf</td>
<td>7.2 ± 3.4</td>
<td>70.3</td>
<td>54.8 ± 2.7</td>
<td>0.0328</td>
</tr>
<tr>
<td><em>Datura metel</em> L.</td>
<td>Leaf</td>
<td>26.0 ± 9.9</td>
<td>0</td>
<td>30.7 ± 0.5</td>
<td>0.0991</td>
</tr>
<tr>
<td><em>Datura metel</em> L.</td>
<td>Seed</td>
<td>26.0 ± 4.1</td>
<td>0</td>
<td>32.1 ± 1.1</td>
<td>0.0961</td>
</tr>
<tr>
<td><em>Operculina turpethum</em> Peter</td>
<td>Leaf</td>
<td>1.2 ± 1.1</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Polygonum serrulatum</em> Lagasca</td>
<td>Leaf</td>
<td>26.8 ± 8.5</td>
<td>0</td>
<td>31.7 ± 0.9</td>
<td>0.0987</td>
</tr>
<tr>
<td><em>Ricinus communis</em> L.</td>
<td>Leaf</td>
<td>27.2 ± 9.0</td>
<td>0</td>
<td>31.1 ± 0.8</td>
<td>0.1007</td>
</tr>
<tr>
<td><em>Sapium sebiferum</em> Roxburgh</td>
<td>Seed</td>
<td>29.2 ± 3.6</td>
<td>0</td>
<td>32.7 ± 0.7</td>
<td>0.1000</td>
</tr>
<tr>
<td><em>Vitex negundo</em> L.</td>
<td>Leaf</td>
<td>27.0 ± 3.4</td>
<td>0</td>
<td>30.6 ± 0.6</td>
<td>0.1048</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>24.2 ± 2.8</td>
<td></td>
<td>30.3 ± 0.3</td>
<td>0.1004</td>
</tr>
<tr>
<td>LSD at 1%</td>
<td></td>
<td>85</td>
<td></td>
<td>0.23</td>
<td></td>
</tr>
</tbody>
</table>

\[a\text{ }n=6.\]
2.4. Bioassay

Twenty pre-conditioned rice pellets (approximately 2 g) were placed in each vial (25 mm diameter × 55 mm height) and incubated along with two pairs of adult *S. zeamais* for 5 days in a dark room at 25 ± 1°C and 75 ± 5% r.h. The mouth of each vial was closed with a perforated lid. Five vials were maintained at each concentration and for the control. After 5 days, the adult weevils were removed and the vials, along with rice pellets seeded with eggs, were left in the same environment until the adults emerged. Vials were checked weekly and the surface cleaned if necessary until adult emergence. At emergence, the F₁ adults were counted daily and discarded until there was no more emergence for a period of 2 weeks. The developmental time (egg + larva + pupa) was determined as the period between the mean of the oviposition period and the day of each adult emergence. In those cases where low progeny emergence and prolonged developmental time were noticed, 10 adults, on the day of their emergence, were randomly selected and their individual weight was recorded. The capacity for increase was calculated by using a formula slightly modified from that of Laughlin (1965):

\[
r_c = \log_e R_0 / T_d
\]

where, \( r_c \) = capacity for increase; \( R_0 \) = net reproduction rate (total number of F₁ adults emerging, divided by the number of parents present) and, \( T_d \) = time of development of a generation (a median period of oviposition to F₁ emergence).

Screening for insect resistance was carried out in two phases. In the primary screening, a test concentration of 0.5% was used and those showing a high level of activity were selected for secondary screening and were assayed at lower doses (0.2, 0.1, 0.05 and 0.01%).

2.5. Data analysis

The data were analyzed using analysis of variance (ANOVA) and the least significant difference (LSD) test was used to separate means.

3. Results

Leaves of *O. turpethum* and *C. gigantea* and seeds of *B. alba* were identified as the most effective plant materials (Table 1). Adult emergence was significantly lower for these materials than for all other treatments \((P < 0.01)\). The reduction was 62, 70 and 95% for *B. alba* seeds, *C. gigantea* leaves and *O. turpethum* leaves, respectively. Although several other plant materials significantly prolonged \((P < 0.01)\) development, insects reared on *C. gigantea* leaves and *B. alba* seeds took about twice as long to develop as the control insects. The capacities for increase after exposure to *B. alba* seeds and *C. gigantea* leaves were markedly lower than in the control. Too few adults emerged from *O. turpethum* treatment to enable calculation of the development period and the capacity for increase. The adults were also significantly lighter \((P < 0.01)\) after exposure to leaves of *O. turpethum* and *C. gigantea* and *B. alba* seeds.

In view of the demonstrated potency of leaves of *O. turpethum* and *C. gigantea* and *B. alba* seeds, these materials were further tested at low doses, 0.01–0.20%, and the results are shown
Table 2
Effect of feeding at different concentrations of leaves of *Operculina turpethum* and *Calotropis gigantea*, and seeds of *Basella alba* on the development of *Sitophilus zeamais*

<table>
<thead>
<tr>
<th>Plant materials</th>
<th>Conc. (%)</th>
<th>Progeny per parent Mean ± SD</th>
<th>% Inhibition</th>
<th>Development time (d) Mean ± SD</th>
<th>Capacity for increase/day Mean ± SD</th>
<th>Male adult weight (mg) Mean ± SD</th>
<th>Female adult weight (mg) Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Operculina turpethum</em> Peter</td>
<td>0.2</td>
<td>18.0 ± 3.1</td>
<td>36.6</td>
<td>35.1 ± 1.3</td>
<td>0.0784</td>
<td>2.29 ± 0.28</td>
<td>2.41 ± 0.27</td>
</tr>
<tr>
<td>Leaf</td>
<td>0.1</td>
<td>19.0 ± 6.6</td>
<td>33.1</td>
<td>31.0 ± 1.1</td>
<td>0.0882</td>
<td>2.73 ± 0.30</td>
<td>2.67 ± 0.21</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>20.6 ± 4.1</td>
<td>27.5</td>
<td>30.6 ± 0.5</td>
<td>0.0926</td>
<td>2.71 ± 0.28</td>
<td>2.88 ± 0.23</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>25.0 ± 5.3</td>
<td>12</td>
<td>29.5 ± 0.5</td>
<td>0.1025</td>
<td>2.96 ± 0.13</td>
<td>2.93 ± 0.25</td>
</tr>
<tr>
<td><em>Calotropis gigantea</em> R. Br.</td>
<td>0.2</td>
<td>19.4 ± 5.1</td>
<td>31.7</td>
<td>36.6 ± 1.4</td>
<td>0.0787</td>
<td>2.17 ± 0.41</td>
<td>2.05 ± 0.35</td>
</tr>
<tr>
<td>Leaf</td>
<td>0.1</td>
<td>23.6 ± 3.5</td>
<td>16.9</td>
<td>31.9 ± 0.6</td>
<td>0.0947</td>
<td>2.40 ± 0.29</td>
<td>2.39 ± 0.29</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>25.2 ± 2.3</td>
<td>11.3</td>
<td>30.3 ± 0.6</td>
<td>0.1018</td>
<td>2.83 ± 0.19</td>
<td>2.69 ± 0.31</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>25.0 ± 4.9</td>
<td>12</td>
<td>29.8 ± 0.6</td>
<td>0.0998</td>
<td>2.98 ± 0.28</td>
<td>2.98 ± 0.25</td>
</tr>
<tr>
<td><em>Basella alba</em> L.</td>
<td>0.2</td>
<td>17.6 ± 3.9</td>
<td>38</td>
<td>47.8 ± 2.1</td>
<td>0.0572</td>
<td>2.23 ± 0.17</td>
<td>2.31 ± 0.19</td>
</tr>
<tr>
<td>Seed</td>
<td>0.1</td>
<td>17.2 ± 3.8</td>
<td>39.4</td>
<td>41.1 ± 0.7</td>
<td>0.0664</td>
<td>2.43 ± 0.25</td>
<td>2.49 ± 0.25</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>20.0 ± 5.9</td>
<td>29.6</td>
<td>38.1 ± 0.9</td>
<td>0.0738</td>
<td>2.80 ± 0.29</td>
<td>2.79 ± 0.20</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>21.8 ± 6.5</td>
<td>23.2</td>
<td>35.4 ± 0.6</td>
<td>0.0806</td>
<td>2.74 ± 0.23</td>
<td>2.97 ± 0.21</td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td>28.4 ± 2.7</td>
<td>7.3</td>
<td>29.4 ± 0.2</td>
<td>0.1083</td>
<td>3.08 ± 0.14</td>
<td>3.13 ± 0.18</td>
</tr>
<tr>
<td>LSD at 1%</td>
<td></td>
<td>7.3</td>
<td>1.46</td>
<td></td>
<td></td>
<td>0.28</td>
<td>0.28</td>
</tr>
</tbody>
</table>

in Table 2. *O. turpethum* leaves and *B. alba* seeds significantly reduced the adult emergence at concentrations as low as 0.05% (*P* < 0.01), while such an effect was observed in *C. gigantea* leaves at 0.2%. The developmental periods were significantly longer (*P* < 0.01) at the higher two doses in *O. turpethum* and *C. gigantea*. As a consequence, the capacity for increase was markedly lower after consuming diet containing leaves of *O. turpethum* and *C. gigantea*. In *B. alba* seeds, the developmental periods were significantly longer (*P* < 0.01) at all the doses tested. The adult weights, both male and female, decreased with increasing dose.

4. Discussion

This is the first record of insecticidal activities of the *B. alba* family Basellaceae (=Caryophyllaceae). It is speculated that the activity may be due to ribosome-inactivating proteins (RIPs) similar to those isolated by Bolognesi et al. (1997) from *Basella rubra* seeds.

This is also the first record of insecticidal activity of *O. turpethum*, a member of the family Convolvulaceae, which is common in tropical countries. Khan and Zaim (1992) reported that extracts from leaves of *O. turpethum* showed broad spectrum virus inhibitory activity in plants, presumably by producing some active virus-neutralizing agents probably a proteinase inhibitor. Proteinase inhibitors are common in plants, particularly in legumes, cereals and solanaceous crops, and their growth inhibitory activities against insects are well documented.

The current work has also confirmed the insecticidal properties of *C. gigantea*, a member of the family Asclepiadaceae which is a well known medicinal plant. Several cardenolides known
to be toxic to insects have been isolated from *C. gigantea* and different members of this family
and other related families (Pal and Sinha, 1980; Seiber et al., 1982). In addition, flavonol
glycosides have been isolated from *C. gigantea* (Sen et al., 1992). Very recently, Pari et al.
(1998) isolated giganticine, a novel non-protein amino acid, from the methanol extract of the
root bark of *C. gigantea* and found that giganticine has a significant antifeedant activity
against nymphs of *Schistocerca gregaria* (Forskal).

In this study, we used the crude powder of the test materials, which exhibited their toxic
effect at very low concentration. The pure active substances are likely to show their potency at
much lower doses. Recent progress in genetic engineering enables the introduction of specific
genes into the desired plant hosts. The isolation and transfection of plant genes coding for
entomotoxic compounds is a promising approach to insect pest control. Therefore, further
research on the isolation and mechanisms of action of their active substances are promising
approaches for insect pest management.

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