Repellent effects of bamboo vinegar, pyrolygenous acid, and Sasanqua saponin granules on the Valencia slug, *Lehmannia valentiana* (Férrussac) (Mollusca: Gastropoda)

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The Valencia slug, *Lehmannia valentiana* (Férrussac), is a serious plant pest in Japan, and several unregistered chemicals are currently being sold as slug repellents. We investigated the efficacy of bamboo vinegar, pyrolygenous acid, and Sasanqua saponin granules as slug repellents. Our results showed that these materials are much less effective repellents than registered pesticides. Furthermore, these materials are much more expensive than registered pesticides.

Keywords: Valencia slug, *Lehmannia valentiana*, Repellent effect, Bamboo vinegar, Pyrolygenous acid, Sasanqua saponin granules

Introduction

Slugs (Mollusca: Gastropoda) are serious pests of field crops, greenhouses, nurseries, home gardens, and landscapes (Kaya, 2001). The most common slug in Japan is the Valencia slug, *Lehmannia valentiana* (Férrussac), formerly known as *Limax marginatus* Muller (Tanaka et al., 2005a). *L. valentiana* originates from Europe, and was introduced into Japan in the 1950s (Kurozumi, 2002). The slug has been recorded from every district in Yamaguchi Prefecture, Japan, including coastal and mountainous areas (Kanô et al., 2001), suggesting that it can live in very diverse environments. The slug shows plant-climbing behavior and has been reported to damage vegetables (e.g., eggplant and cabbage), fruits (e.g., citrus), flowers (e.g., scarlet sage, petunia, and marigold) (Shibao et al., 2001), and greenhouse crops (South, 1992). Slugs are restricted by their capacity to retain water. Consequently, in dry conditions they become inactive, moving deep into the ground, where they do not cause crop damage (Kaya, 2001). This behavior makes it difficult to develop control strategies and to evaluate the efficacy of slug-control treatments.

There are various compounds that have been registered as slug-control treatments. Such compounds contain metaldehyde, thiodicarb, and ferric phosphate (FAMIC, 2009). Metaldehyde granules and thiodicarb granules are highly effective slug-control treatments (Tanaka and Shibao, 2007). Although its pesticide registration has expired, XMC granules (Kunimoto, 1998) and plastic sheets (Namesheet®: Sumitomo Chemical Co., Ltd.) that contain the cationic surfactant bis-hydroxyethyl-dodecylamine are also highly effective methods of controlling slugs (Shibata et al., 1991; Tanaka et al., 2005b).

Bamboo vinegar (‘chikusakueki’ in Japanese) and pyrolygenous acid (‘mokusakueki’ in Japanese) are sold as deterrents of small animals (e.g., cats and dogs). Sasanqua saponin granules are sold as a slug repellent. Bamboo vinegar is a byproduct of bamboo charcoal production that is obtained after cooling the smoke. It has characteristic sour, smoky, and medicinal odors. Bamboo vinegar has been used as an insecticide, a bactericide, a deodorant for treating malodor from pets, and also as a folk medicine (Akakabe et al., 2006). It contains many compounds, including formaldehyde (Ruttanavut et al., 2009). Pyrolygenous acid is a reddish-brown wood distillate that has similar components to bamboo vinegar (Takei and Hayashi, 1968). Sasanqua saponin granules contain saponic acid. The name saponin is derived from its characteristic to form soap-like bubbles when it is dissolved in water.
Sasanqua saponin destroys erythrocytes and is very toxic to fish (Kato, 1998). Although they are used as slug-repellents, the repellent effects of these materials against slugs have never been reported.

The purpose of the present study was to investigate the repellent effects of bamboo vinegar – pyroligneous acid – and Sasanqua saponin granules on L. valentiana. We evaluated the repellent effects of these materials using the screening method developed by Tanaka et al. (2001). In addition, the repellent effect of Sasanqua saponin granules was evaluated in 3.3 m² plot areas using the method recommended by the manufacturer.

Materials & Methods

Research area

All experiments were conducted at the citrus open field at the Research Institute of Environment, Agriculture and Fisheries, Osaka Prefectural Government (Habikino, Osaka, Japan ; 34.5°N, 135.6°E).

Tested materials

Four materials were purchased from Kohnan Shoji Co., Ltd, as follows: bamboo vinegar, ‘Lifelex Chikusakueki 1.5L’; pyroligneous acid, ‘Lifelex Mokusakugeni 1.5L’, hereafter referred to as BV-LC (manufacturer: unknown); pyroligneous acid, ‘Rappa Mokusakueki’, hereafter referred to as PA-LM (manufacturer: unknown) and ‘Rappa Mokusakueki’, hereafter referred to as PA-RM (manufacturer: Taiko TEC Co., Ltd.) ; and Sasanqua saponin granules, ‘Namekujinigenige’, hereafter referred to as SS-N (manufacturer: JOY agris Co., Ltd.). In these experiments, the tested materials were legally used for a research purpose under Article 11 of the Agricultural Chemicals Regulation Law.

Experiment 1

In experiment 1, we tested the repellent effects of BV-LC, PA-LM, PA-RM and SS-N in field plots. The experiment comprised 30 experimental plots, each 20 cm × 20 cm (= 400 cm²) in size. The 30 plots were divided into six groups. Within each group, four plots were treated with chemical treatments, and one was left untreated (control). Each plot was at least 3 m away from neighboring plots, to avoid contamination or interaction effects.

In the evening of June 23, 2009, undiluted BV-LC, PA-LM, and PA-RM were applied to assigned plots at a rate of 6 ml/400 cm² (= 150 ml/m²) using a hand sprayer. SS-N was applied to assigned plots at a rate of 6 g/400 cm² (= 150 g/m²) by hand.

A six-sided pyramid trap (11 cm base diameter × 8 cm height; Hodogaya Chemical Co., Ltd.) containing 1 g metaldehyde granules (Namekiri; Nihon Nohyaku Co., Ltd.) (hereafter referred to as metaldehyde trap) was set at the center of each plot area in the evening of June 23 (0 d after treatment) and again on June 27 (4 d after treatment), 2009. The number of trapped slugs in each trap was counted the next morning. The efficacy of each treatment (%) was calculated as follows: 100 × [(total number of slugs trapped in the untreated plot) - (total number of slugs trapped in each treatment plot)] / (total number of slugs trapped in the untreated plot).

Experiment 2

We tested the repellent effects of SS-N in experiment 2. A total of 12 experimental plots were established around three citrus trees. Each plot was 1.8 m × 1.8 m (= 3.3 m²) in size (Fig. 1). In the evening of July 13, 2009, SS-N was applied to six plots at a rate of 6 g/400 cm² (= 150 g/m²) by hand. The other six plots were left untreated.

Fig. 1 Diagram of experimental system used to test repellent effects of Sasanqua saponin granules, Namekujinigenige. Circles indicate stem of each tree. SS-N = Sasanqua saponin granules, Namekujinigenige; Un = Untreated.
A metaldehyde trap was set at the center of each plot in the evening of July 22 (9 d) and July 28 (15 d), 2009. The number of trapped slugs in each trap was counted the next morning. The efficacy of the control treatment was calculated as described for experiment 1.

In this paper, we use the terms 'control efficacy' and 'repellent effect' interchangeably.

Statistical analysis
For experiment 1, we used Tukey’s HSD tests ($p = 0.05$) to analyze differences in mean numbers of slugs in metaldehyde traps between treated and untreated plots. For experiment 2, we used Student’s $t$-tests ($p = 0.05$) to analyze differences in mean numbers of slugs in metaldehyde traps between treated and untreated plots. We used the statistical software package R version 2.9.1 (R Development Core Team, 2009; http://www.R-project.org) for all statistical analyses.

Meteorological data
Temperature and precipitation data were collected at the Research Institute of Environment, Agriculture and Fisheries, Osaka Prefectural Government.

Results and Discussion
Table 1 shows the mean numbers of Valencia slugs trapped by metaldehyde traps in treated and untreated plots. There were no significant differences among the mean numbers of the slugs trapped 0 d

### Table 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>Number of slugs / trap (0d)</th>
<th>Control efficacy</th>
<th>Number of slugs / trap (4d)</th>
<th>Control efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>BV-LC</td>
<td>6</td>
<td>18.2 ± 7.5</td>
<td>18.7</td>
<td>6.8 ± 4.3</td>
<td>24.4</td>
</tr>
<tr>
<td>PA-LM</td>
<td>6</td>
<td>26.0 ± 5.1</td>
<td>-31.3</td>
<td>3.5 ± 3.7</td>
<td>50.0</td>
</tr>
<tr>
<td>PA-RM</td>
<td>6</td>
<td>17.0 ± 9.7</td>
<td>23.9</td>
<td>2.8 ± 0.8</td>
<td>59.5</td>
</tr>
<tr>
<td>SS-N</td>
<td>6</td>
<td>20.2 ± 11.7</td>
<td>9.7</td>
<td>5.8 ± 4.7</td>
<td>16.7</td>
</tr>
<tr>
<td>Untreated</td>
<td>6</td>
<td>22.3 ± 6.7</td>
<td>(—)</td>
<td>7.0 ± 6.4</td>
<td>(—)</td>
</tr>
</tbody>
</table>

1) BV-LC = bamboo vinegar, "Lifelex Chikusakueki 1.5L*"; PA-LM = pyroligneous acid, "Lifelex Mokusakugeneki 1.5L*"; PA-RM = pyroligneous acid, "Rappa Mokusakueki*"; SS-N = Sasanqua saponin granules, "Namekujinigenige*".

2) Number of traps per treatment.

3) Mean (± SD) numbers of the tree slugs trapped by metaldehyde granules were not significantly different at the 5% level by Tukey HSD.

4) Control efficacy (%) = $100 \times \left( \frac{\text{total number of slugs trapped in the untreated plot}}{\text{total number of slugs trapped in each treatment plot}} \right) / \left( \text{total number of slugs trapped in the untreated plot} \right)$.

### Table 2

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>Number of slugs / trap (9d)</th>
<th>Control efficacy</th>
<th>Number of slugs / trap (15d)</th>
<th>Control efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-N</td>
<td>6</td>
<td>2.0 ± 2.2</td>
<td>40.0</td>
<td>4.8 ± 3.9</td>
<td>-31.8</td>
</tr>
<tr>
<td>Untreated</td>
<td>6</td>
<td>3.3 ± 2.6</td>
<td>(—)</td>
<td>3.7 ± 2.3</td>
<td>(—)</td>
</tr>
</tbody>
</table>

1) SS-N = Sasanqua saponin granules, "Namekujinigenige*".

2) Number of traps per treatment.

3) Mean (± SD) numbers of the tree slugs trapped by metaldehyde granules were not significantly different at the 5% level by $t$-test.

4) Control efficacy (%) = $100 \times \left( \frac{\text{total number of slugs trapped in the untreated plot}}{\text{total number of slugs trapped in the treatment plot}} \right) / \left( \text{total number of slugs trapped in the untreated plot} \right)$.
after the treatment (18.2 in BV-LC, 26.0 in PA-LM, 17.0 in PA-RM, 20.2 in SS-N, and 22.3 in the control) (Table 1 : Tukey HSD test, \(P > 0.05\) for each comparison). The control efficacy was calculated as 18.7% for BV-LC, 31.3% for PA-LM, 23.9% for PA-RM, and 9.7% for SS-N. At 4 days after treatment, mean numbers of the slugs were 6.8 in BV-LC, 3.5 in PA-LM, 2.8 in PA-RM, 5.8 in SS-N, and 7.0 in the control. There was no significant difference in the number of trapped slugs among the treatments (Table 1 : Tukey HSD test, \(P > 0.05\) for each comparison). The control efficacy was calculated as 2.4% for BV-LC, 50.0% for PA-LM, 59.5% for PA-RM, and 16.7% for SS-N.

In experiment 2 we evaluated the control efficacy of SS-N using the method recommended by the manufacturer. At 9 and 15 days after treatment, there was no significant difference between the mean numbers of Valencia slugs trapped by metaldehyde traps in SS-N plots (2.0 at day 9, 4.8 at day 15) and control plots (3.3 at day 9, 3.7 at day 15) (Table 2 : Student t-test, \(P > 0.05\)). The control efficacy of SS-N at 9 days after treatment was calculated as 40.0% and that at day 15 was \(-31.8\%\).

During experiment 1 (June 23-28), daily maximal temperatures ranged from 27.6°C to 30.8°C, and total precipitation was 29.0 mm. The daily maximal temperatures during experiment 2 (July 13-29) ranged from 25.9°C to 33.9°C, and total precipitation was 159.5 mm. Udaka et al. (2007) reported that the survival rate of juvenile slugs exposed to 34°C for 1 h was 94%. Therefore, we assumed that the weather did not affect slug survival in these experiments.

The results of experiments 1 and 2 show that the mean numbers of slugs trapped by metaldehyde traps in treated plots were not significantly different from those in untreated plots. To evaluate the efficacy of repellents, the Japan Plant Protection Association (JPPA) has set the following standards: 100 - 90% 'highly effective', 90 – 70% 'effective', 70 – 50% 'mildly effective' and less than 50% 'minimally effective' (JPPA, 2009). Based on these evaluation criteria, PA-LM and PA-RM can be classified as 'mildly effective' at 4 d after treatment. The other treatments are classified as 'minimally effective'.

Thiodicarb granules and metaldehyde granules showed 98.8% and 98.5% control efficacy, respectively, 3 d after each treatment (Tanaka and Shibao, 2007). Therefore, these two treatments can be classified as 'highly effective'. Namesheet® was also 'highly effective', showing 100% control efficacy at 6 weeks (Tanaka et al., 2001). Thus, the efficacy of BV-LC, PA-LM, PA-RM, and SS-N in controlling slugs is much lower than that of these 'highly effective' commercial pesticides. In addition, BV-LC, PA-LM, PA-RM, and SS-N are relatively expensive treatments (per 10 are, ¥45,800 for BV-LC, ¥38,000 for PA-LM, ¥92,400 for PA-RM, and ¥171,000 for SS-N). These materials are much more expensive than metaldehyde granules, for example, Namekiiru® (¥2,100 per 10 are).

The Agricultural Chemicals Regulation Law was established to improve the quality of agricultural chemicals and to ensure their safe and proper use. To achieve this, a registration system was introduced to regulate the sale and use of agricultural chemicals (FAMIC, 2009). Because it is difficult to accurately estimate the efficacy of controlled chemicals in controlling slugs, many unregistered materials have been distributed as slug repellents. In the present study, we confirmed the effectiveness of the screening method by Tanaka et al. (2001), using their method to estimate the effectiveness of such unregistered materials. Our results show that the tested unregistered chemicals are 'mildly effective' or 'minimally effective' as slug repellents.

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References


