Efficacy of plant extracts for reducing larval populations of the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) and cabbage webworm, *Crocidolomia binotalis* Zeller (Lepidoptera: Pyralidae), and evaluation of cabbage damage

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**Abstract**

The efficacy of four plant extracts, *Alpinia galanga* Sw. (Zingiberaceae), *Amomum cardamomum* Auct. (Zingiberaceae), *Cyperus rotundus* L. (Cyperaceae), and *Gomphrena globosa* L. (Amaranthaceae) were evaluated against the diamondback moth, *Plutella xylostella* L. and the cabbage webworm *Crocidolomia binotalis* Zeller larvae on cultivated cabbage. Treatments with 0.5% *A. galanga* and *G. globosa* extracts significantly reduced *P. xylostella* larval density, and the percentage of infested plants, proving to be more effective than a standard insecticide Decis7 2.5EC (deltamethrin). Moreover, *G. globosa* significantly reduced the intensity of cabbage damage caused by *P. xylostella*. Treatment with 0.5% *A. cardamomum* extract reduced the percentage of *P. xylostella*-infested plants and the intensity of cabbage damage. However, the plant extracts did not effectively reduce *C. binotalis* larval density, the percentage of infested plants or the intensity of cabbage damage. Phytotoxic effects on cabbage plants were not observed in any extract treatment.

**Key words:** Plant extracts, field efficacy, *Plutella xylostella*, *Crocidolomia binalis*

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**INTRODUCTION**

The attack on cabbages by insect pests and diseases are major problems faced by cabbage growers. The diamondback moth, *P. xylostella* L., together with the cabbage webworm, *Crocidolomia binotalis* Zeller often cause both quantitative and qualitative losses in many producing areas in Indonesia, resulting in decreased income for growers. These lepidopteran pests are a serious limiting factor in cabbage production. The application of synthetic insecticides is the main means of controlling these insect pests, particularly *P. xylostella*. However, the failure of these applications has been reported in many cabbage production areas. The development of insect resistance, particularly in *P. xylostella* larvae, may be the main reason for the failure to control these insect populations. In Indonesia, *P. xylostella* has become resistant to most major classes of insecticides. The same pattern in the development of *P. xylostella* resistance was also reported in Thailand, Taiwan, Japan, Malaysia, the United States, and Central America (Talekar and Shelton, 1993). Cruciferous crops are important for the human diet and the economic stability of the farmer and, thus we should develop a rational and sustainable management strategy for these insect pests.

During the last two decades, considerable efforts have been directed toward screening plants in order to determine their biological activity against insects. Results revealed that many plant extracts possess biological activity against various insect species. Furthermore, laboratory and field experiments were conducted to evaluate plant biological activity against cabbage pests (Hough-Goldstein and Hahn, 1992; Foon and Tong, 1993; Prijono and Hassan, 1993; Hermawan et al., 1994; Qiu et al., 1998). Numerous plant extracts or plant-derived compounds can potentially be incorporated into an alternative and novel strategy to control various insect pests, including *P. xylostella* and *C. binotalis*. Plant chemicals are biodegradable and selective in their activity, suggesting that their application would be environmentally acceptable and compatible with integrated pest management (IPM) programs as well as being effective in countering insect resistance. This study, therefore, was con-
ducted to discover plant species that are effective in controlling cabbage pests. The objectives were to evaluate the efficacy of four plant extracts against *P. xylostella* and *C. binotalis* in field conditions and to evaluate the phytotoxic effect of plant extracts on cabbage plants.

**MATERIALS AND METHODS**

**Plant materials.** Four plant extracts, *Alpinia galanga* Sw. (Zingiberaceae, rhizomes), *Amomum cardamomum* Auct. (Zingiberaceae, fruits), *Cyperus rotundus* L. (Cyperaceae, tubers), and *Gomphrena globosa* L. (Amaranthaceae, seeds) were purchased from local markets in Bogor (West Java) and Malang (East Java), Indonesia.

**Extraction.** All air-dried plant parts were cut and ground into powder in a mill. Powder from each plant species was extracted by soaking in ethanol for 48 h (1:2.5; w/v). Each plant extract solution was filtered by filter paper and ethanol was then evaporated by using a rotary evaporator under reduced pressure to give a crude extract. Crude extract yields from 3,782 g of *A. galanga*, 3,780 g of *A. cardamomum*, 4,100 g of *C. rotundus*, and 3,925 g of *G. globosa* were 162.1, 165.8, 188.0, and 109.8 g, respectively. All crude extracts were stored under low temperature at -10°C in a refrigerator until use.

**Preparation of extract solutions.** An appropriate amount of each extract was diluted with ethanol, and water containing emulsifier Latron 777L (alkyl glycerol phthalate) was then added to produce the desired extract concentration. The final concentrations of ethanol and emulsifier in each extract solution were 0.75% and 0.02%, respectively. Two extract concentrations, 0.5 and 0.25%, of each plant extract were applied. Water containing 0.75% ethanol and 0.02% emulsifier served as a control. In order to compare the efficacy of extracts to conventional insecticides, Decis 2.5EC (a.i. deltamethrin, a pyrethroid insecticide often used by local growers in Indonesia) was used as a standard insecticide and applied at the recommended rate (2 ml/l). All treatments were applied using a lever-operated knapsack sprayer at the rate of 2 l/plot. The first application was conducted 11 weeks after transplanting and continued at one week intervals. The first observation was done one day before the first application, and the next observation one week after application. In total, four observations and three applications of plant extract were conducted.

**Cabbage plant management.** Field efficacy tests were conducted in a 814 m² area of a cabbage field in Bogor, Indonesia from June to September, 1998. Cabbage seedlings were transplanted to plots (6×3.5 m). Each plot consisted of 8 rows of plants with 75 cm spacing between rows and 50 cm between plants, so that each plot contained 56 plants. To maintain the cabbage plants, they were sprayed with a microbial insecticide Dipel 7WP containing *Bacillus thuringiensis* at the recommended rate of the active ingredient twice at one-week intervals before the application of plant extracts. Fertilizer (3 kg urea, 6 kg TSP and 9 kg KCl) was applied twice, once after transplanting and once after cabbages had formed a head, and weeds were removed mechanically when necessary.

**Censuses and analysis.** The arrangement plots were of a randomized block design with three replications. Ten plants in each plot were randomly selected for sampling. The number of larvae per plant (larval density), the percentage of larva-infested plants, and the intensity of cabbage damage were observed. The larvae of two species, *P. xylostella* and *C. binotalis*, were observed with no distinction of stage.

The mean number of *P. xylostella* or *C. binotalis* larvae per plant in each replication of treatment was transformed into log(x+1), and the mean percentages of larva-infested plants and of intensity of cabbage damage were transformed into arcsine prior to the analysis of variance (ANOVA). The least significant difference (LSD) (p=0.05) was employed to compare the means between treatments.

The percentage intensity (*I*) of cabbage plant damage was calculated by the following formula:

\[ I = \left( \frac{\Sigma (n \cdot v)}{N \cdot V} \right) \times 100, \]

where *n* = number of plants at a certain category of damage, *v* = category of damage, *N* = total number of selected plants (10), and *V* = the highest value of damage category (6).

The *v* values of damage were categorized as follows: 0, no plant damage; 1, 0<x≤5%; 2, 5<x≤20%; 3, 20<x≤40%; 4, 40<x≤60%; 5, 60<x≤80%; and 6, x>80%.
RESULTS

Larval density

The first observation was completed 11 weeks after transplantation (one day before the first application). Both mean numbers of *P. xylostella* and *C. binotalis* larvae showed no significant difference among the treatments. This tendency continued until the day before the second application at 12 weeks after transplantation (Fig. 1). After the third application, treatments with *A. galanga* (0.5%) and *G. globosa* (0.5%) resulted in smaller numbers, 1.0 and 0.7 larvae/plant, respectively, of *P. xylostella* than Decis7 2.5EC (8.7 larvae/plant) and non-treatment (3.7 larvae/plant) (Fig. 1). A small mean number of 0.7 larvae/plant was also seen in *C. rotundus* (0.25%) treatment.

Treatment with Decis7 2.5EC resulted in a small number of 0.3 *C. binotalis* larva/plant (Fig. 1). Among all 4 extract treatments, *C. rotundus* (0.5%) treatment resulted in the smallest number of 6.3 *C. binotalis* larvae/plant.

Larva-infested plants

Treatments with *A. galanga* (0.5%), *A. cardamomum* (0.5%) and *G. globosa* (0.5%) showed a significantly lower percentage (16.7%) of *P. xylostella*-infestation than the 66.7% infestation resulting from treatment with Decis7 2.5EC (Table 1). Decis7 2.5EC treatment resulted in a low percentage (6.7%) of *C. binotalis*-infested plants compared to all plant extract treatments. Among plant extract treatments, *G. globosa* (0.5%), *A. cardamomum* (0.5%) and *A. galanga* (0.25%) tended to result in lower percentages (10.0, 13.3 and 13.3%, respectively) of infested plants than other treatments.

Intensity of cabbage damage

The intensity of cabbage damage caused by *P. xylostella* was significantly lower in the treatment with *A. cardamomum* (0.5%) and *G. globosa* (0.5%) than in the non-treatment control and Decis7 2.5EC treatments, which were 18.9% and 22.2%, respectively (Table 2). Treatment with *A. cardamomum* (0.5%) tended to result in a lower percentage of intensity of cabbage damage caused by *C. binotalis* than control and other plant extract treatments, but it was higher than Decis7 2.5EC treatment after the third application.

DISCUSSION

The extracts of *A. galanga*, *A. cardamomum*, *C. rotundus* and *G. globosa* resulted in high mortality against *P. xylostella* larvae by our feeding method in the laboratory assay (Dadang et al., 1996). In addition, active compounds from *C. rotundus* and *A. galanga* have been isolated and elucidated as α-cyperone and 1′-acetoxychavicol acetate (Dadang et al., 1996, 1998). These results prompted us to conduct the present research in order to test their efficacy on cabbage cultivation under field conditions.

Two plant extracts, *A. galanga* and *G. globosa* at 0.5%, significantly reduced *P. xylostella* larval density and proved more effective than Decis7 2.5EC. The failure to control larval density with Decis7 2.5EC is likely to be due to the development of resistance by *P. xylostella* to this insecticide. According to Budiman (1996), cabbage growers in Bogor...
<table>
<thead>
<tr>
<th>Treatments</th>
<th>11&lt;sup&gt;a&lt;/sup&gt;</th>
<th>12</th>
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<th>14</th>
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<tr>
<td></td>
<td>Px&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Cb</td>
<td>Px</td>
<td>Cb</td>
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<td></td>
<td>$F=0.3900$</td>
<td>$F=1.0000$</td>
<td>$F=0.9300$</td>
<td>$F=0.5600$</td>
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<tr>
<td>G. globosa (0.5%)</td>
<td>$p=0.9254$</td>
<td>$p=0.4742$</td>
<td>$p=0.5244$</td>
<td>$p=0.8087$</td>
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<td>G. globosa (0.25%)</td>
<td>16.7±5.7 a&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.0±0.0 a</td>
<td>6.7±5.7 b</td>
<td>0.0±0.0 a</td>
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<td>A. cardamomum (0.5%)</td>
<td>26.7±5.7 a</td>
<td>0.0±0.0 a</td>
<td>6.7±5.7 ab</td>
<td>50.0±10.0 a</td>
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<td>A. cardamomum (0.25%)</td>
<td>23.3±15.3 a</td>
<td>0.0±0.0 a</td>
<td>10.0±10.0 a</td>
<td>30.0±10.0 a</td>
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<td>A. galanga (0.5%)</td>
<td>20.0±10.0 a</td>
<td>0.0±0.0 a</td>
<td>6.7±5.7 ab</td>
<td>46.7±5.8 a</td>
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<tr>
<td>A. galanga (0.25%)</td>
<td>30.0±17.3 a</td>
<td>3.3±5.7 b</td>
<td>53.3±11.5 a</td>
<td>60.0±10.0 a</td>
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<td>C. rotundus (0.5%)</td>
<td>17.3±5.7 a</td>
<td>0.0±0.0 a</td>
<td>3.3±5.7 b</td>
<td>46.7±5.8 a</td>
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<tr>
<td>C. rotundus (0.25%)</td>
<td>13.3±5.7 a</td>
<td>0.0±0.0 a</td>
<td>3.3±5.7 ab</td>
<td>53.3±11.5 a</td>
</tr>
<tr>
<td>Decis® 2.5EC</td>
<td>23.3±15.7 a</td>
<td>0.0±0.0 a</td>
<td>3.3±5.7 ab</td>
<td>60.0±10.0 a</td>
</tr>
<tr>
<td>Control</td>
<td>3.3±11.5 a</td>
<td>0.0±0.0 a</td>
<td>6.7±5.7 ab</td>
<td>60.0±10.0 a</td>
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</table>

<sup>a</sup>Weeks after transplantation.

<sup>b</sup>Px: *Plutella xylostella*, Cb: *Crocidolomia binotalis*.

<sup>c</sup>Means in the same column followed by the same letter are not significantly different (LSD, $\alpha=0.05$).
Table 2. Percentage intensity of damage caused by *P. xylostella* and *C. binotalis* larvae on cabbage plants treated with several plant extracts

<table>
<thead>
<tr>
<th>Treatments</th>
<th>11&lt;sup&gt;a&lt;/sup&gt;</th>
<th>12</th>
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<tr>
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<td>Px&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Cb</td>
<td>Px</td>
<td>Cb</td>
</tr>
<tr>
<td><em>G. globosa</em> (0.5%)</td>
<td>2.8±1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.0±4.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
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<td><em>G. globosa</em> (0.25%)</td>
<td>4.4±0.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.5±6.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6±1.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><em>A. cardamomum</em> (0.5%)</td>
<td>3.9±0.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.6±3.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3±2.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><em>A. cardamomum</em> (0.25%)</td>
<td>2.8±1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.8±3.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1±0.9&lt;sup&gt;a&lt;/sup&gt;</td>
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<td><em>A. galanga</em> (0.5%)</td>
<td>7.2±0.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.7±4.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7±4.6&lt;sup&gt;a&lt;/sup&gt;</td>
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<td><em>A. galanga</em> (0.25%)</td>
<td>3.3±1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.6±2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.6±0.9&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td><em>C. rotundus</em> (0.5%)</td>
<td>2.8±0.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.8±0.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7±2.8&lt;sup&gt;a&lt;/sup&gt;</td>
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<td><em>C. rotundus</em> (0.25%)</td>
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<td>10.6±6.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7±2.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Decis&lt;sup&gt;c&lt;/sup&gt; 2.5EC</td>
<td>4.4±1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.0±1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1±1.9&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>Control</td>
<td>6.1±2.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0±0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.1±0.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7±4.7&lt;sup&gt;a&lt;/sup&gt;</td>
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</table>

<sup>a</sup> Weeks after transplantation.
<sup>b</sup> Px: *Plutella xylostella*, Cb: *Crocidolomia binotalis*.
<sup>c</sup> Means in the same column followed by the same letter are not significantly different (LSD, α=0.05).
use insecticides such as Decis7 2.5EC as the main tool to control P. xylostella both before and after cabbage transplantation. Repeated and continuous chemical spraying has resulted in the development of resistance by P. xylostella to insecticides (Morallo-Rejesus, 1985).

A high efficacy of A. galanga and G. globosa was shown in both laboratory and field experiments in the present study. Thus, the use of A. galanga and G. globosa might be effective in overcoming the resistance of P. xylostella. Unfortunately, C. rotundus and A. cardamomum did not efficiently reduce the P. xylostella population in the field. This may be due to the rapid degradation of the active compound under field conditions.

No treatment showed significant differences in reducing the C. binotalis larval population. Larval population density of C. binotalis tended to be higher in plant extract treatments than with Decis7 2.5EC. The development of resistance by C. binotalis to insecticide has been rarely reported, indicating that this insecticide remains effective against C. binotalis.

The effectiveness of A. galanga and G. globosa extracts was also shown by the reduction of P. xylostella-infested plants. Furthermore, G. globosa and A. cardamomum effectively reduced the percentage intensity of cabbage damage by P. xylostella. Quality of cabbage production is an important factor in setting a price at market. A low percentage of infested plants and intensity of cabbage damage improved the yield of cabbages both quantitatively and qualitatively.

Treatment with Decis7 2.5EC resulted in lower percentages of C. binotalis-infested plants and of the intensity of cabbage damage. Treatments with 0.5% A. cardamomum, A. galanga and G. globosa were slightly effective on C. binotalis-infested plants, and 0.5% A. cardamomum effectively reduced the percentage intensity of cabbage damage.

An effective dose of plant extracts may cause negative side effects (phytotoxicity) in cabbage plants. Therefore, it is important to monitor this effect on treated cabbage plants. No plant extracts showed phytotoxicity towards cabbage plants in the present study. Our preliminary study in a green house showed that phytotoxicity occurred if cabbage plants were sprayed with plant extracts at 0.75% (unpublished data).

In general, although A. galanga and G. globosa were effective only against P. xylostella, these plant extracts can be applicable to cabbage pest management by reducing the use of conventional insecticides spray in an integrated pest management program. P. xylostella occurs just after cabbage transplantation, earlier than C. binotalis. At this stage, cabbage growers should apply A. galanga or G. globosa extract to prevent an increase in the P. xylostella population. Moreover, conventional insecticides can be applied if growers find a large population of C. binotalis. This control program reduces the intensity of conventional insecticide use and shows the efficacy of A. galanga and G. globosa extracts in maintaining quality and quantity of cabbage production.

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