EFFECTIVENESS OF TWO BOTANICAL INSECTICIDE FORMULATIONS TO TWO MAJOR CABBAGE INSECT PESTS ON FIELD APPLICATION

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(Received: November 11, 2008; Accepted: April 8, 2009)

ABSTRACT

A field application of two botanical insecticide formulations was conducted on cabbage crops in Bogor, West Java, Indonesia to assess the effectiveness of these formulations in reducing two major cabbage insect pest populations. The efficacy of two botanical insecticide formulations, mixtures of *Piper retrofractum* (Piperaceae) and *Annona squamosa* (Annonaceae) (RS) extracts and *Aglaia odorata* (Meliaceae) and *A. squamosa* (OS) extracts at 0.05% and 0.1% was compared to a synthetic pyrethroid, deltamethrin at 0.04% and a microbial insecticide, *Bacillus thuringiensis* at 0.15%. The application of both RS and OS formulations decreased the population of *Crocidolomia pavonana* (F.) (Lepidoptera: Pyralidae) and *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) and the treatments of RS and OS at 0.1% was more effective than synthetic insecticide. The application of RS and OS did not affect the performance of insect pest natural enemies.

Key words: Botanical insecticide, *Crocidolomia pavonana*, *Plutella xylostella*, safety

INTRODUCTION

The cabbage webworm, *Crocidolomia pavonana* (F.), (synonymous to *C. binotalis* Zeller) (Lepidoptera: Pyralidae) and the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) are two major insect pests on cabbage and other cruciferous crops. They often cause heavily damage on cabbage crops particularly in dry season. The common strategy adopted by farmers in overcoming the insect pest population in cabbage crops is by using synthetic insecticides. The use of synthetic insecticides in Indonesia to control insect pests on cabbage and other vegetable crops such as tomato, potato, string bean, as well as broccoli is still intensive due to its efficient, practical use, as well as effectiveness (Dadang *et al*., 2003a; Dadang *et al.*, 2003b). Farmers spray synthetic insecticides 2-3 times/week and the total number of pesticide applications on cabbage cultivation in one season could reach 30-35 times (Rauf *et al*., 2005). Moreover, about 70% of cabbage farmers spent money for pesticides about 25-30% out of the total production input cost.

The misuse and excessive use of synthetic insecticides may cause some undesirable effects not only to the agricultural ecosystem but also to human health due to insecticide residue in food. Insecticide residue in agricultural products particularly in vegetable and fruit products is a growing concern for producers, traders, and consumers in many parts of the world. Therefore, several efforts have been created to reduce the use of synthetic pesticides particularly the use of synthetic insecticides. One of the efforts is the development of botanical insecticides as a novel and safer alternative strategy. Botanical insecticides, which contain plant extracts as active components, are safer as well as environmentally friendlier than synthetic insecticides. Therefore, this research was conducted to assess the effectiveness of two botanical insecticide formulations in reducing the major cabbage insect pests and their impact to natural enemies and cabbage crops in field test.

MATERIALS AND METHODS

Plant Materials

Plant materials used in this experiment were seeds of *Annona squamosa* (Annonaceae), twigs of *Aglaia odorata* (Meliaceae), and inflorescences of *Piper retrofractum* (Piperaceae). All plant materials were air-dried for one week before extracted.

Extraction

Plant materials were cut and then ground using a mill to yield uniform size of powder. The powder of each plant species was soaked in methanol (1:10; w/v) for 48 hours. Each plant extract solution was filtered with filter paper (Whatman No. 1) and methanol was evaporated using a rotary evaporator at 50ºC under reduced pressure (400-450 mmHg) to produce crude extract. Crude extracts were kept under low temperature (-4^{o}C) in the refrigerator until used.

Preparation of Extract Formulation

An appropriate amount of each crude extract was mixed to prepare extract mixtures of *P. retrofractum* and *A. squamosa* (RS*)* and *A. odorata* and *A. squamosa* (OS). The extract mixture was diluted with methanol, and then stirred until getting good homogeneity of extract mixture. Each extract mixture solution was added with water containing Agristik 400 L (a.i. alkylaryl polyglycol ether) as emulsifier and sticker to produce the desired extract mixture concentration. The final concentrations of organic solvent (methanol) and emulsifier were 1% and 0.05%, respectively. Two extract concentrations of each formulation, 0.05% and 0.1% were applied. Water containing 1% organic solvent and 0.05% emulsifier served as a control. In order to compare the effectiveness of botanical insecticide formulations, synthetic insecticides, Decis 2.5 EC (pyrethroid, a.i. deltamethrin) and a microbial insecticide Agrisal WP (*Bacillus thuringiensis*) were used and applied at recommended concentrations of 0.04% and 0.15%, respectively. All insecticides were applied using a lever operated knapsack sprayer. Applications of insecticides were done five times during the experiment with one-week interval between applications.

Cabbage Crop Management

Field application was conducted in 1500 m^2 area of a cabbage field in Bogor, West Java, Indonesia. Cabbage seedlings were transplanted to plots (8 m x 6 m). Each plot consisted of 12 rows of plants and each row consisted of 12 plants, so that each plot contained 144 cabbage plants. The plots were fertilized with chicken manure applied two weeks before transplanting at the rate of 10 ton/ha. Inorganic fertilizers (90 kg/ha urea, 30 kg/ha SP-36, and 30 kg/ha KCl) were applied twice, two and four weeks after transplanting. Weeds were removed mechanically when necessary.

Field Observation

This experiment consisted of seven treatments and three replications. Ten cabbage plants in each plot were randomly selected as plant samples. Number of *C. pavonana* and *P. xylostella* larvae of each plant sample (larval density) was weekly monitored. The first and second observations were conducted before the first application of insecticides, while the third to seventh observations were conducted a week after each insecticide application.

In order to evaluate the effect of application of insecticides on natural enemies especially parasitoids, 10 larvae of *P. xylostella* and *C. pavonana* were collected from each plot separately. Larva were collected at 7, 8, 9, and 10 weeks after transplanting (WAT). All collected larva were reared and fed with free insecticide cabbage leaves in the laboratory until adult emergence. The percentage of parasitization was calculated by the following formulae:

$$\text{Percentage of parasitization} = \frac{\text{Number of parasitized larvae}}{\text{Number of collected larvae}} \times 100\ \%$$

Other supported data were collected such as cabbage production and phytotoxic effect on cabbage crops.

The experiment was arranged based on a complete randomized block design with seven treatments and three replications. The data obtained were analyzed by analysis of variance. The comparison of means were done using Duncan multiple random test at 0.05 level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Plutella xylostella larval population

Before first application of insecticides, the population of *P. xylostella* larvae was weekly monitored since fifth weeks after transplanting (WAT). The average of *P. xylostella* larval populations was 0.06-0.37 and 0.06-0.33 larvae/plant at five and six WAT, respectively.

After first application of insecticides, the population of *P. xylostella* increased slightly on RS 0.1% (0 to 0.05 larvae/plant) but decreased on *B. thuringiensis* treatment (0.33 to 0.11 larvae/plant). Other treatments, OS 0.05% and 0.1%, were able to maintain the larval population on the same level before and after insecticide application. Treatment of deltamethrin showed highly increased larval population from 0.16 to 0.31 larvae/plant (Fig. 1).

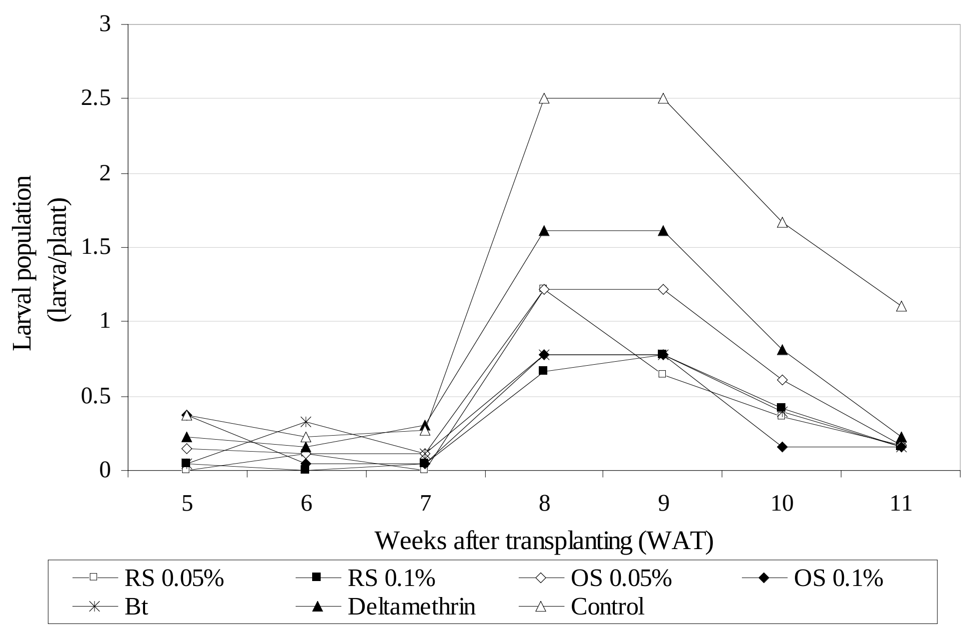

Fig. 1. Development of *P. xylostella* larval population on cabbage crops treated with botanical, synthetic, and microbial insecticides.

After the second application, the larval population on three treatments, RS 0.1%, OS 0.1%, and *Bacillus thuringiensis* slightly increased, but treatments of RS 0.05%, OS 0.05%, deltamethrin, and control highly increased (Fig. 1). The increase in larval population might be caused by new infestation of *P. xylostella* from neighboring cabbage crop areas. In addition, the peak population of *P. xylostella* occurred on the eighth week after transplanting. This phenomenon might be correlated with the increase in the larval population in all treatments.

The larval population decreased on all treatments since ninth week but two treatments, deltamethrin and control, showed higher population than other treatments. It indicates that treatments with botanical insecticides (RS and OS particularly at 0.1%) were more effective than synthetic insecticide. In addition, the formulation of RS showed more effective than OS formulation.

***Crocidolomia pavonana* larval population**

The average larval populations of *C. pavonana* at 5 and 6 WAT were 0.17-0.83 and 0.05-2.23 larvae/plant, respectively. After the first application, the larval population decreased in all treatments except for deltamethrin treatment and control. The larval population increased from 0.05 to 0.78 larvae/plant and from 0.11 to 2.06 on the treatments of deltamethrin and control, respectively (Fig. 2).

The larval populations treated with RS 0.1%, OS 0.1% and *B. thuringiensis* at 8 to 11 WAT were consistently low and the larval populations treated with deltamethrin and control were consistently high. It indicates that two botanical insecticides were more effective to *C. pavonana* than synthetic insecticide and was comparable to *B. thuringiensis*.

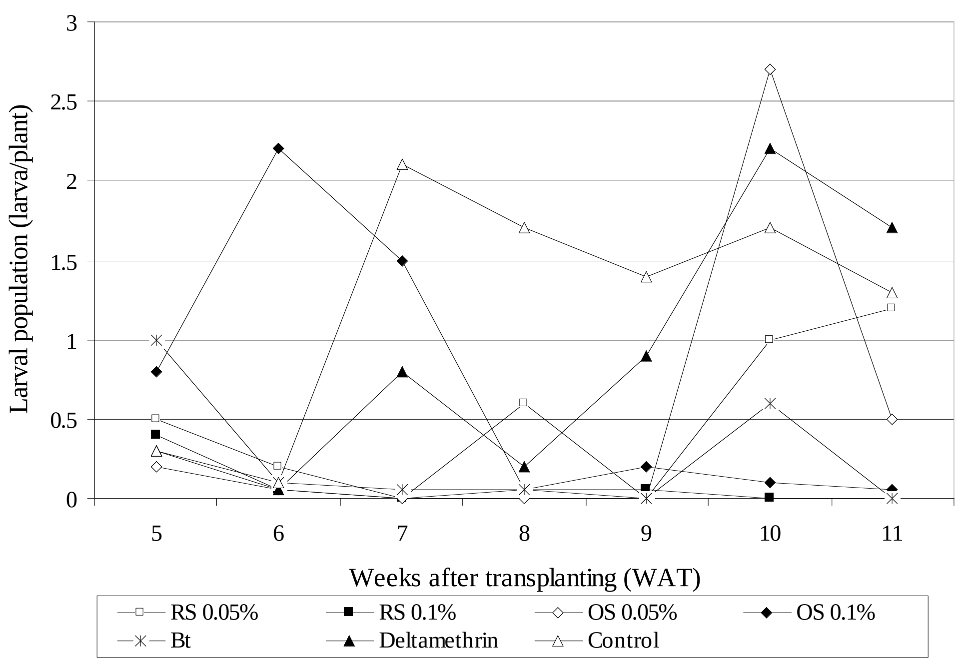

Fig. 2. Development of *C. pavonana* larval population on cabbage crops treated with botanical, synthetic, and microbial insecticides

The effect of two botanical insecticide formulations to *P. xylostella* parasitoid

Treatments of two botanical insecticide formulations did not affect the performance of *Diadegma semiclausum* (Hymenoptera: Ichneumonidae), a parasitoid of *P. xylostella*. Parasitization level on two botanical insecticide formulation treatments were higher than control and deltamethrin (Fig. 3). The percentages of parasitization on RS 0.1% and OS 0.1% at 7, 8, 9, and 10 WAT were 40, 30, 57, and 83% and 58, 53, 50, and 50%, respectively. Meanwhile, the percentages of parasitization on deltamethrin were 0, 50, 40, and 0%, respectively. The application of RS and OS formulation are safe to *D. semiclausum* parasitoid.

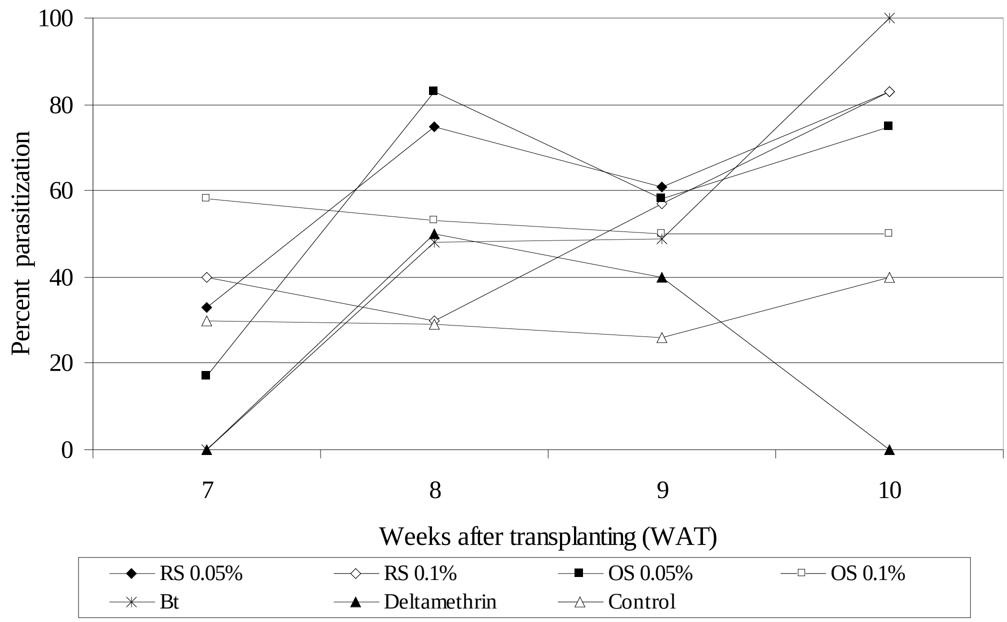

Fig. 3. Development of percentages of parasitization of *D. semiclausum* on cabbage crops treated with botanical, synthetic, and microbial insecticides

The effect of two botanical insecticide formulations on *C. pavonana* parasitoid

The RS 0.1% formulation showed higher percentage of parasitization than control and deltamethrin but the formulation of OS 0.1% showed lower percentage of parasitization (Fig. 4). The percentages of parasitization on RS 0.1% treatment at 7, 8, 9, and 10 WAT were 57, 67, 75, and 25%, respectively and percentages of parasitization of OS 0.1% treatment were 0, 44, 43, and 0%, respectively. Meanwhile, percent parasitization in deltamethrin treatments were 0, 36, 75, and 0%, respectively. These results indicate that the application of the RS formulation is safe for *Eriborus argentiopilosus* (Hymenoptera: Ichneumonidae), a parasitoid of *C. pavonana* but OS formulation affected slightly the performance of the parasitoid.

Intensity of cabbage damage and yield

The intensity of cabbage damage on all insecticide treatments except OS 0.05% treatment was lower than untreated control (Table 1). The intensity of cabbage damage in control plots compared to RS 0.05%, OS 0.05% and deltamethrin treatments did not show any significant difference while RS 0.1%, OS 0.1%, and *B. thuringiensis* treatments showed significant difference. RS 0.1%, OS 0.1%, and *B. thuringiensis* treatments reduced intensity of damage caused by *C. pavonana*. For the RS 0.1%, OS 0.1%, and *B. thuringiensis* treatments, intensity of cabbage damage in RS 0.1% and *B. thuringiensis* treatments was similar but was lower than OS 0.1% treatment.

RS 0.1% treatment produced the highest average yield followed by deltamethrin and *B. thuringiensis* treatments, while RS 0.05% treatment produced lowest yield (Table 1). There was an inconsistent correlation between intensity of cabbage damage and yield. Intensity of cabbage damage on RS 0.05 treatment was lower than deltamethrin treatment but the production of cabbage in deltamethrin treatment was higher than RS 0.05% treatment.

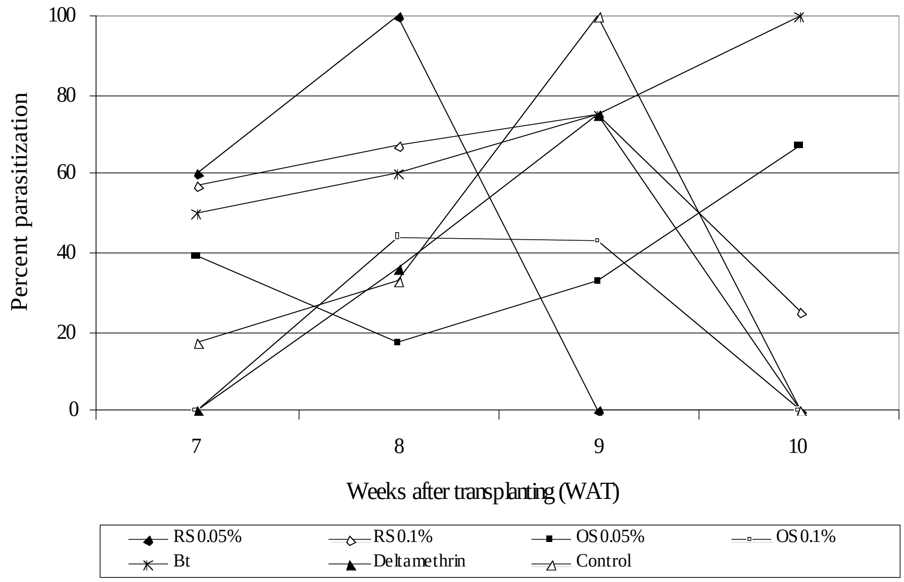

Fig. 4. Development of percentages of parasitization of *E. argentiopilosus* on cabbage crops treated with botanical, synthetic, and microbial insecticides.

Table 1. Yield and percent damage (average) of cabbage.

Treatment	Percent damage (%) ± sd	Yield (kg) ± sd[1)]
RS 0.05%	10.4 ± 1.2[ab]	32.0 ± 6.9[b2)]
RS 0.1%	6.3 ± 2.7[b]	69.0 ± 4.8[a]
OS 0.05%	12.5 ± 1.0[ab]	55.5 ± 7.2[a]
OS 0.1%	8.9 ± 3.2[b]	43.2 ± 1.4[b]
B. thuringiensis	6.3 ± 3.6[b]	60.5 ± 2.9[a]
Deltamethrin	11.0 ± 3.6[a]	62.4 ± 5.2[a]
Control	14.0 ± 2.0[a]	48.0 ± 6.6[b]

[1)] Standard deviation

[2)] Averages in the same column followed by the same letter are not significantly different by DMRT at □=0.05.

DISCUSSION

Two botanical insecticide formulations containing extract mixtures of *P. retrofractum* and *A. squamosa* (RS) and *A. odorata* and *A. squamosa* (OS) have been tested on cabbage crops in order to evaluate the effectiveness of formulations in reducing *P. xylostella* and *C. pavonana* larval population. Overall, these two formulations at 0.1% showed high effectiveness and gave more effective than deltamethrin, a synthetic pyrethroid insecticide. RS 0.1% was slightly more effective against *P. xylostella* than *C. pavonana*, while effectiveness of OS 0.1% was similar to both *P. xylostella* and *C. pavonana* larvae. These results indicate that these two botanical insecticide formulations have the potential to be developed as commercial products.

In single assays, the seed extract of *A. squamosa* exhibited high insecticidal activity against *C. pavonana* larva where LC_{50} was 0.208% (Basana and Prijono, 1994) and at the range of 0.063-0.1% concentration was effective against *P. xylostella* larvae (Istiaji, 1998). Acetogenin compounds such as annonin I and squamosin, isolated from seed of *A. squamosa*, were responsible for toxicity of *A. squamosa*. These compounds together with asimisin caused more toxicity against *P. xylostella* (Ohsawa and Dadang, 1998). Acetogenin will inhibit conversion of ADP to ATP in the ion transport system (Gu *et al*., 1975).

The extract of *P. retrofractum* has been known to have insecticidal activity to *P. xylostella* and *C. pavonana* (Dadang, 1999; Dadang *et al*., 2007). *P. retrofractum* extract at 0.5% gave 100% mortality against instar II of *C. pavonana* (Prijono *et al*., 2006). This extract also showed high knock down effect on several test insects including *P. xylostella* and *C. pavonana*. Other insects that were affected by *P. retrofractum* extract were *Forficula auricularia* (Dermaptera: Forficulidae), *Culex quinguefasciatus* and *Aedes aegypti* (Diptera: Culicidae), and *Coptotermes gestroi* (Isoptera: Rhinotermitidae) (Assabgui *et al*., 1995; Chansang *et al*., 2005; Alfian, 2007). Piperamide compounds which have isobutylamide and methylendioxyphenyl moieties have strong insecticidal activity by inhibiting the impulse current on the axon of the nerve system (Miyakado *et al*., 1989).

A. odorata extract was noted to be effective to several agricultural insect pests including *P. xylostella* and *C. pavonana* larvae. The extract of *A. odorata* at 1.0% produced 92% larval mortality of *C. pavonana* (Dadang *et al*., 2007). Treatment of ethanol twig extract of *A. odorata* caused 100% mortality to *Spodoptera litura* (Lepidoptera: Noctuidae) (Koul *et al*., 1997). Nugroho (1999) isolated six rocaglamide derivate compounds from *A. odorata*, which were responsible for feeding inhibition, mortality, and growth regulatory activity against *Spodoptera littoralis*. Rocaglamide at 80 ppm caused 90% mortality of *C. pavonana* larva (Sudarmo, 2001). In addition, rocaglamide has high toxicity activity against *S. litura* as indicated by LC_{50} and LC_{90} values of 4.8 ppm and 8.76 ppm, respectively (Janprasert *et al*., 1993).

Based on single assay of extract and mode of action, it seems that each extract works on different target site. The combination of each extract in formulation will produce a good botanical insecticide formulation. Dadang *et al*. (2007) reported the strong efficacy of a mixture of *P. retrofractum* with *A. squamosa* and *A. odorata* with *A. squamosa* which produced 100% and 94% mortality when *C. pavonana* larvae were treated with 0.05% extract mixture at 48 hours after treatment. The extract mixture of *A. odorata* and *A. squamosa* gave a synergistic combination with multiple actions, as feeding inhibition and insecticidal activity (Dadang *et al*., 2007).

Generally, the two effective botanical insecticide formulations did not affect the performance of both parasitoids *D. semiclausum* and *E. argentiopilosus* on cabbage crops. Istiaji (1998) mentioned that the increasing of *A. squamosa* extract concentration increased the sensitivity of *D. semiclausum* but did not affect the development and parasitization level of *D. semiclausum*. In the field test, treatment of *A. squamosa* extract did not affect the parasitization level of *D. semiclausum*

(Nurmayanti, 1998). *A. odorata* is highly toxic to *C. pavonana* and *P. xylostella* but not to *E. argentiopilosus*. The *A. odorata* extract works on insects as a stomach poison and not as a contact poison due to weak penetration ability of the active compound on the insect integument. Moreover, *A. odorata* has no repellent effect on the parasitoid, *E. argentiopilosus* adults, so application of this extract did not affect the parasitoid activity in terms of visiting cabbage crops (Sudarmo, 2001). It means that these botanical insecticide formulations are safe for field application and can be combined with the use of natural enemies in cabbage insect pest management program due to its selectivity in action. This result also proved that application of deltamethrin affected the parasitoid population. Deltamethrin is one of the pyrethroid insecticides that is categorized as a broad spectrum, unselective insecticide (Undiarto and Sastrosiswojo, 1997).

The treatment of RS 0.1% gave lowest percent damage and produced highest yield. Treatment of OS 0.1% also gave low percent damage but produced lower yield than deltamethrin treatment. The low cabbage yield may be caused by *A. odorata* extract. Sometimes, the application of *A. odorata* caused phytotoxicity to the crops and inhibited plant growth. This phenomenon should be evaluated. It gives experience to us to evaluate the overall effect before botanical insecticide formulations can be commercialized.

Based on the plant chemical nature, in terms of the concentration of active compounds that is strongly influenced by geographic and climate conditions, the availability of botanical insecticide formulation in the market is necessary. It will assure the quality of botanical insecticide formulation. Moreover, the formulations should contain two or more plant extracts to make the formulation more efficient in using plant materials, more economic in extract and formulation preparations, and more effective in toxicity and slow down the development of insect resistance (Dadang *et al*., 2008). Another important matter in the application of botanical insecticide formulation should be its compatibility with other integrated pest management strategies.

CONCLUSION

Two botanical insecticide formulations containing extract mixtures of *Piper retrofractum* and *Annona squamosa* (RS) and *Aglaia odorata* and *A. squamosa* (OS) showed high efficacy and were more effective than deltamethrin. Between the two formulations, RS 0.1% was more effective against *P. xylostella* than *C. pavonana,* while OS 0.1% gave the same effectiveness against *P. xylostella* and *C. pavonana* larvae. These formulations did not affect the performance of both parasitoids, *D. semiclausum* and *E. argentiopilosus,* on cabbage crops. Treatments with RS 0.1% and OS 0.1% resulted in significant reduction in cabbage damage compared to deltamethrin treatment. In addition, treatment with RS 0.1% produced highest cabbage yield.

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