Goatweed Flower Extract (*Ageratum conyzoides* L.) as a Botanical Insecticide for Pest Control *Crocidolomia binotalis* Z.

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ABSTRACT

Crocidolomia binotalis Z. is an important cabbage plant pest in Indonesia. Nevertheless, pest control strategies depend on synthetic pesticides, negatively impacting ecosystems. Therefore, developing an effective organic pesticide approach to controlling *C. binotalis* is necessary. This research aimed to test the effectiveness of goatweed flower extract (*Ageratum conyzoides* L.) in controlling pest *C. binotalis*. The research consisted of two sets of experiments with two methods: the stomach and contact poison. Each experimental set was arranged in a completely randomized design (CRD) with three replications. The treatments were six levels of extract concentration at 0%, 15%, 30%, 45%, 60%, and 75%. The results showed that the application of *A. conyzoides* flower extract using the stomach and contact poison methods significantly increased the percentage of larval mortality 24 hours after application (haa) and the percentage of total larval mortality. The flower extract treatment of *A. conyzoides* significantly reduced the percentage of leaf area eaten, increased larval mortality, inhibited pupation and imago emergency, and shortened the larval stage's duration. The percentage of larval mortality through contact poison was higher than stomach poison.

Keywords: *Ageratum conyzoides*; Botanical Insecticide; *Crocidolomia binotalis*; Effectiveness

INTRODUCTION

Pests and pathogens are a major limiting factor for production in agricultural cultivation. One such pest is *Crocidolomia binotalis* Z., which poses a significant threat to cabbage plants in Indonesia (Fifi et al., 2022; Tarigan et al., 2021). The damage caused by this pest can significantly reduce the quantity and quality of cabbage production, with agricultural losses reaching almost 100% by *Plutella xylostella* (Fifi et al., 2022; Barita et al., 2018). Currently, synthetic insecticides are the primary method of managing these two pests. Farmers' dependence on synthetic insecticides encourages excessive use of these chemicals (Nurhudiman et al., 2018; Tampubolon et al., 2018). The long-term application of chemical insecticides results in various negative impacts, such as environmental pollution, the eruption of secondary pests, disruption of human health, pest resistance, and resurgence (Wahyudin et al., 2021). Therefore, alternatives or supplements to synthetic pesticides should be explored to mitigate the negative impacts they can cause (Nurhudiman et al., 2018; Tampubolon et al., 2018).

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In recent years, efforts have been made toward obtaining safer alternatives to chemical insecticides for sustainable pest management. Habitat manipulation, a part of conservation biological control, aims to provide floral resources, alternative prey, and shelter to predators and parasitoids to enhance and sustain natural pest suppression. The use of plant extracts as botanical insecticides is also an important provisioning of ecosystem service (Amoabeng et al., 2019). Botanical insecticides contain active ingredients derived from secondary compounds produced by plants. The toxicity of these secondary compounds has various effects on insect behavior or physiology. Some secondary compounds can interfere with the growth and development of immature insects, affect feeding behavior, reduce fecundity, and shorten the survival of insect imago (Sultan et al., 2016; Nurhudiman et al., 2018; Tampubolon et al., 2018).

Among the thousands of plant species studied, goatweed (*Ageratum conyzoides*) is one species that contains bioactive compounds with insecticidal properties (Tampubolon et al., 2018; Katuuk ., 2019; Amoabeng et al., 2019). This plant contains *antijuvenile hormone*, precocene compounds, coumarins, eugenol, HCN, alkaloids, and steroids in the roots, leaves, and flowers (Tampubolon et al., 2018). These toxic compounds can affect the respiration process, inhibit seed growth, and inhibit microbial activity (Cahyati & Sutanto, 2021). Sharifi-Rad et al. (2021) stated that coumarin could convert into dicoumarol, which is a blood anticoagulant and causes death. Several previous studies have shown that goatweed extract can control aphids (*Aulocaphora* sp.) on cucumber (*Cucumis sativus*), where a concentration of 9 % can interfere with their eating ability, as evidenced by the decrease in aphid appetite by up to 20 % and cause a lethargic reaction in aphids, which ends in their gradual death (Sultan et al., 2016). Goatweed extract contains alkaloids; this compound causes pests/insects to lose their appetite and die. Alkaloids can also inhibit insect growth, leading to metamorphosis failure (Dewi, 2016). Meanwhile, concentrations between 1-5 % were able to cause mortality in *Plutella xylostella* larvae (Nurhudiman et al. 2018).

Goatweed can be utilized as a biopesticide because the active ingredients in the leaves can inhibit the development of insecticides either directly or indirectly. However, research investigating the most effective use of this extract is still limited. According to Wahyudin et al. (2021), the mechanisms by which insecticides work can be divided into (1) Based on how they enter the body of insects, they can be categorized into digestive or gastric poisons, contact poisons, neurotoxins, protoplasmic toxins, and systemic poisons; and (2) Based on the chemical composition, insecticides are classified into organochlorines, organophosphates, carbamates, and pyrethroids. Based on the background, this research was conducted to determine the effectiveness of goatweed flower extract (*Ageratum conyzoides* L.) in controlling the pest *Crocidolomia binotalis* Z. The use of the stomach poison method and the contact poison method with different concentration levels of goatweed extract aimed to determine the effectiveness of the chemical content of goatweed as a pesticide against *C. binotalis* Z.

METHODS

Experimental Design

The research was conducted for four months at the Arthropoda Pest Laboratory, Department of Plant Protection, Faculty of Agriculture, University of Lampung. This study consisted of two sets of tests; the first was to examine the effectiveness of goatweed flower extract (*A. conyzoides*) against *C. binotalis* pests using the stomach poison method, and the second was to determine the effects of the contact poison method on *C. binotalis* pests. The research was arranged in a completely randomized design (CRD) with three repetitions and six treatments. The treatments consisted of six concentration levels determined based on the results of preliminary tests, namely 0 %, 15 %, 30 %, 45 %, 60 %, and 75 %. Thus, each research set consisted of 18 research units. In each research unit, 20 third-instar *C. binotalis* larvae were invested.

Preparation and Application of Flower Extract of *Ageratum conyzoides* L.

A. conyzoides flowers were washed and dried indoors for a week. Then, the flowers were ground into powder. 100 g of powder was mixed with 100 ml of solvent (distilled water) and blended until smooth and filtered. As an emulsifier, detergent powder (1 g per liter of water) was used, and to increase the solubility of the powder, acetone (1 %) was added as much as 10 ml per water, and agristic (0.05 %) was added as an adhesive. The resulting extract was a 100 % concentration (aliquot), ready to dilute the extract according to the concentration level to be tested.

Testing of *A. conyzoides* flower extracts was carried out at six concentration levels by diluting the aliquot concentration with solvents (consisting of distilled water, detergent, acetone, and agristic) into test concentrations, namely 0; 15; 30; 45; 60; and 75 ml in 100 ml solution.

Insect breeding test of *C. binotalis* larvae was obtained from cabbage plantations in Gisting Atas Village, Tanggamus Regency. Larvae were obtained, collected, and fed with mustard leaves in an aerated tray with a mixture of soil and sand (1:1 ratio by weight) for pupation. Pupae encased in soil granules were transferred and reared in clear, aerated plastic cages.

Emerging moths were fed with 10% liquid honey (v:v) and continued to be reared until they laid eggs on the prepared mustard leaf pieces. The mustard leaf pieces were transferred to an aerated tray until they hatched. The emerged larvae were reared until sufficient numbers for testing (360 individuals/ experimental set).

Application of Flower Extract on *C. binotalis*

The application stage of *A. conyzoides* flower extract was carried out using the stomach and contact poison methods.

Stomach poison method

The cabbage pieces (7 x 10 cm) were dipped in the test extract for five minutes; the excess liquid was absorbed with tissue paper, then removed with tweezers and aerated for five minutes. Control leaves were dipped in distilled water containing adhesives, acetone, and emulsifiers. The application was made by placing 20 of the 3rd instar of *C. binotalis* larvae in a plastic jar (diameter of 11.5 cm and height of 11.5 cm) and allowing them to feed on the treatment or control leaves for 24 hours. Afterward, the jars were cleaned, and the larvae were fed with untreated leaves. The test insects were observed every day until they became imago.

Contact poison method

The larvae of *C. binotalis* in each experimental set were placed in a petri dish. Then, the extract test was applied through spraying according to the concentration level of the extract tested. The extracted liquid was sprayed on the entire body of the larvae (4 sprays or 4 ml). The larvae were placed in plastic jars and fed with untreated cabbage leaves. The insects were kept for observation every day until they became imago.

Observation

The observed and calculated variables were: 1) Percentage of larval mortality 24 hours after application; 2) Percentage of leaf area consumed; 3) Total larval mortality, which is the percentage of the total number of larvae that died after all the test insects had pupated); 4) Larval lifetime; 5) Percentage of formed pupa; 6) Time to pupation; 7) Percentage of imago emergence; and 8) Duration of imago life.

The leaf area consumed by larvae was explicitly observed when applying *A. conyzoides* flower extract via the stomach poison method. Observations were made 24 hours a day by measuring the leaf area consumed by the larvae (cm^2) using a leaf area meter type LI-300 (Li-cor). The leaf area provided for feeding was 140 cm^2.

Data Analysis

The data obtained were analyzed using analysis of variance (ANOVA). Furthermore, the data were processed with the least significant difference test (LSD) at a significant level of 1 % or 5 % to determine the difference in the mean value between treatments. A probity analysis was conducted to determine the LC 50 value, especially for larva mortality data.

RESULTS AND DISCUSSION

Percentage of Larval Mortality

The results showed that the application of *A. conyzoides* flower extract using the stomach and contact poison methods significantly increased the percentage of larval mortality 24 hours after application (haa) and the percentage of total larval mortality. The results of the stomach poison method after immersion with *A. conyzoides* flower extract at a concentration of 15 % to 75 % were significantly higher than at the concentration of 0 % (control). The percentage of larval mortality at 24 haa was the highest at a concentration of 60 % and 75 %, which was 23.33 %, while the lowest was at a concentration of 15 %, which was 10 %. At a concentration of 15 % extract, larval mortality was not significantly different from those at concentrations of 30 % and 45 % but was significantly lower than those at concentrations of 60 % and 75 %. It can be observed that the percentage of larval mortality 24 haa did not experience a significant increase at the concentration level of 30 % to 75 % (Figure 1).

Similarly, with the contact poison method, the percentage of larval mortality of *C. binotalis* 24 has increased with the increasing concentration of *A. conyzoides* flower extract. The highest percentage of larval mortality at 24 haa was 38.33 % at a 75 % extract concentration.

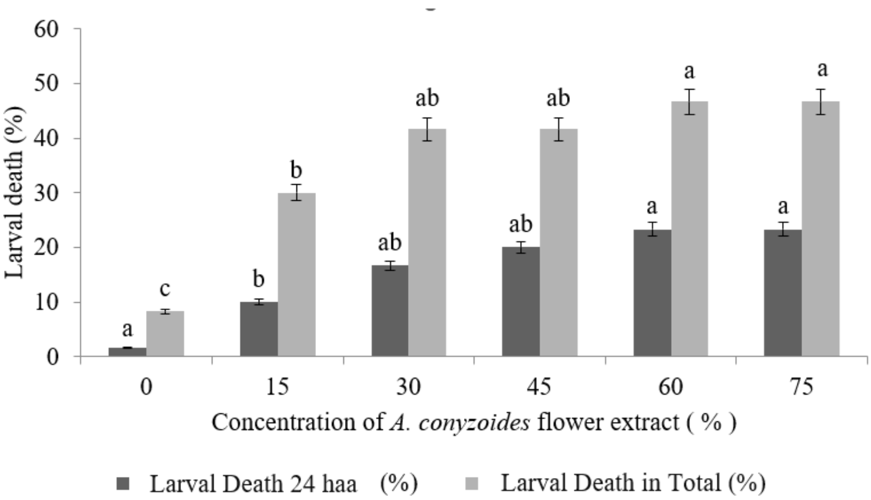

Figure 1. Effects of *A. conyzoides flower extract* concentration treatment through the stomach poison method on the percentage of larval mortality 24 haa. and the percentage of total larval mortality. Bars associated with the same letters are not significantly different at the 5% significance level according to the LSD test.

Still, the increase in the percentage of mortality was not significantly different from those at the concentrations of 30 %, 45 %, and 60 %. The percentage of larval mortality 24 hours after application at a concentration of 15% was significantly higher than that at 0 % concentration (control) but lower than the other treatments (Figure 2). Based on the findings, it is known that the effectiveness of the poison contact method in killing larvae is approximately 15 % better than the stomach poison method.

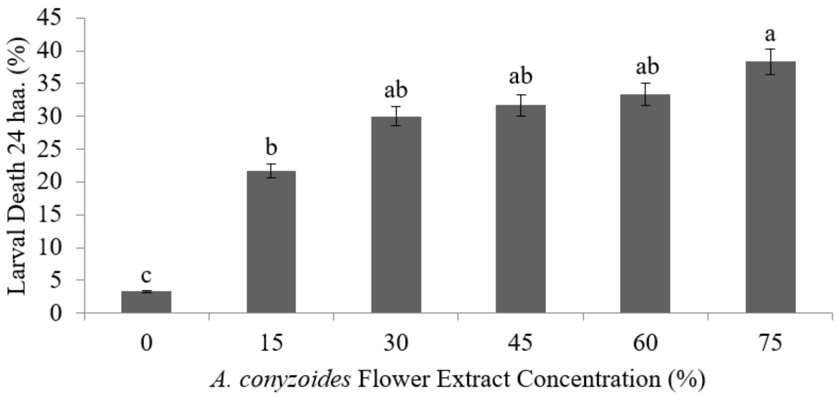

Figure 2. Effects of *A. conyzoides flower extract* concentration treatment through the contact poison method on the percentage of larval mortality 24 haa. Bars associated with the same letters are not significantly different at the 5% significance level according to the LSD test.

The percentage of total larval mortality of *C. binotalis* due to the effect of *A. conyzoides* flower extract treatment through the stomach poison method was relatively low, which was 46.6 7%, so no probity analysis was carried out to determine the LC_{50} value of *A. conyzoides* flower extract treatment. The highest percentage of total larval mortality occurred at the concentration level of 60 % and 75 %, which was 46.67 %. Still, the treatment effect at the two concentrations was not significantly different compared to the concentrations of *A. conyzoides* flower extract of 30 % and

45 %. However, the total larval mortality at a concentration of 15 % was significantly lower than at concentrations of 60% and 75 %. The 15 %-75 % extract concentration was significantly higher than the control (0% concentration). Still, there was no significant increase in the percentage of total larval mortality at concentrations of 30 %, 45 %, 60 %, and 75 % (Figure 1). Slightly different from the stomach poison method, the contact poison method significantly increased the percentage of total larval mortality. The results showed that the percentage of total larval mortality due to the effect of *A. conyzoides* flower extract through the contact poison method exceeded the value of 50 %, which was 60 %. Therefore, probity analysis was conducted to determine the LC_{50} value of *A. conyzoides* flower extract. Based on the results of probity analysis, the concentration level that can cause 50 % of larval mortality is 51.69 %. In addition, a regression equation was obtained, which showed the relationship between the concentration of the extract and the percentage of larval mortality, namely: $Y = 4.05 + 0.56 X$. This means that every 1 % increase in the concentration of *A. conyzoides* flower extract can increase larval mortality by 0.56 %. Without applying *A. conyzoides* flower extract, the larval mortality occurred at 4.05 %.

The stomach poison method, which can cause the death of *C. binotalis* larvae, is thought to be due to the entry of toxic chemical compounds into the insect's body through the digestive system. According to Triharso (1994), toxins enter the body of insects through the digestive system or when ingested, which is closely related to the digestive process. Toxins that enter the mouth are broken down with food by digestive enzymes (salivary enzymes). The entry of these toxins can cause damage to the intestinal tract. In addition, stomach poison that enters the insect's body can be absorbed into the blood and attack the nervous system, causing paralysis (paralysis) and ultimately death. Oguh et al. (2019) also reported that natural pesticides usually target specific sites in the insect, such as the nervous system, resulting in knock-down, lack of coordination, paralysis, and death.

Compared with the stomach poison method, the effect of *A. conyzoides* flower extract treatment through the contact poison method caused a higher percentage of larval mortality in both 24 haa and total larval mortality. This is presumably because the HCN compound in the flower extract of *A. conyzoides* works faster in the insect's body when applied by the contact poison method than the stomach poison method. As Muhidin et al. (2020) reported, HCN compounds are toxic compounds that interfere with the respiratory system. Through the contact poison method, the compound can directly enter the insect's respiratory apparatus through a series of handle holes along the sides of the insect's body (spiracles) (Stejskal et al., 2021). After entering the respiratory system, these toxic compounds affect the central nervous system and can cause rapid paralysis, leading to death. There is much evidence of rapid death from contact poisons, which is 10 minutes after application (Triharso, 1994).

Meanwhile, HCN is less effective when applied by the stomach poison method. This is probably due to the volatile nature of these compounds, which interfere with the respiratory system. Due to its volatile nature, it is possible that the concentration of HCN decreased when the feed was air-dried (for 5 minutes) after being treated with *A. conyzoides* flower extract. Another factor that causes the HCN compound to be less effective is that the poison does not directly hit the target, such as the insect's respiration apparatus. This is different when applied through the contact poison method; HCN compounds can directly hit the insect's respiration apparatus (spiracles) along the sides of the body.

Besides, alkaloid compounds contained in the flowers of *A. conyzoides* specifically interfere with the nervous system of insects (Wahyuni & Loren, 2015). Alkaloids in plants exhibit antibiosis to organisms that ingest them (Metcalf & Luckmann, 1994). Thus, the alkaloid compounds work more effectively through the stomach poison method. However, the possibility of entering the insect's body still exists because application through the contact poison method can affect the insect's mouthparts, allowing alkaloid compounds to enter through the mouth when the insect feeds on host plants. According to Wahyuni & Loren (2015), if the larvae used as test insects die, it may not be solely due to contact with the insecticide but also from ingesting the insecticide. These factors contribute to a higher percentage of larval mortality through the contact poison method than the stomach poison method.

Larval, Pupal, and Imago Stages Duration

The results indicated that the application of *A. conyzoides* flower extract using the stomach poison method significantly shortened the duration of the larval stage but did not significantly affect the pupa and imago stages. On the other hand, the contact poison method had a quietly significant effect on the duration of the larval stage but not on the pupal stage. Furthermore, increasing the concentration of *A. conyzoides* flower extract did not result in different effects on the duration of the larval, pupa, and imago stages when using the stomach poison method (Table 1). The longest larval stage was observed at an extract concentration of 15% to 45%, lasting for 4 days, while the shortest larval stage occurred at a concentration of 75%, lasting for 3.33 days. The data indicated a significant effect of *A. conyzoides* flower extract at concentrations of 15% and 75%, while concentrations of 15%, 30%, 45%, and 60% showed no significant effect (Table 1).

Table 1. Effects of *A. conyzoides* flower extract concentration treatment through the stomach and contact poison methods on the duration of the larval, pupa, and imago stages of *Crocidolomia binotalis*

Concentration (%)	Duration of stage (days)					
	Stomach Poison Method			**Contact Poison Method**		
	Larvae	Pupae	Imago	Larvae	Pupae	Imago
0	5.00 a	8.00	10.33	5.00 a	8.67	8.67
15	4.00 b	8.33	10.33	3.67 b	9.00	8.67
30	4.00 b	8.00	9.33	3.00 bc	8.67	8.67
45	4.00 bc	8.00	10.33	2.67 c	9.67	8.00
60	3.67 bc	8.33	10.00	2.67 c	9.67	6.67
75	3.33 c	8.33	9.67	2.33 c	9.00	7.33
F-count	7.41 **	0.60ns	0.87ns	10.53 **	1.60ns	1.11ns

Note:
** = Different at 1% level of significance
ns = Not significantly different at 1% significance level
Values followed by the same letters in the same column are not significantly different at the 5% significance level according to the LSD test.

In contrast, the contact poison method did not result in different effects on the duration of the larval and pupal stages across concentrations of 15% to 75% (Table 2). Generally, *A. conyzoides* flower extract shortened the larval stage duration as the concentration of the extract increased, influenced by the increasing percentage of larval mortality with higher extract concentration. The shortest larval stage duration was observed at a concentration of 75%, lasting for 2.33 days. However, the reduction in the larval stage duration at these concentrations was not significantly different from concentrations of 45% and 60%. Meanwhile, it was significantly shorter than the larval stage duration at a 15% concentration (Table 2).

Table 2. Effects of *A. conyzoides* flower extract concentration treatment through the stomach and contact poison methods on the percentage of formed pupa and emergence of *Crocidolomia binotalis* imago

Concentration (%)	Duration of stage (days)			
	Stomach Poison Method		**Contact Poison Method**	
	Formed pupa (%)	Appearance of imago (%)	Formed pupa (%)	Appearance of imago (%)
0	91.67 a	85.00 a	90.00 a	78.33 a
15	70.00 b	61.67 ab	55.00 b	46.67 b
30	58.33 bc	50.00 b	50.00 b	43.33 bc
45	58.33 bc	50.00 b	46.67 b	38.33 bc
60	53.33 c	45.00 b	45.00 b	35.00 bc
75	53.33 c	46.67 b	40.00 b	26.67 c
F-count	9.44 **	4.23 *	5.78 **	5.59 **

Note:
** = Different at 1% level of significance
* = Different at 5% significance level
Values followed by the same letters in the same column are not significantly different at the 5% significance level according to the LSD test.

The treatment with *A. conyzoides* flower extract did not significantly affect the duration of the pupal and imago stages. This may be because larvae that successfully formed pupae and emerged as normal imago were relatively resistant to the extract's effects, resulting in unaffected duration of the pupal and imago stages. Nevertheless, the contact poison method was one day more effective than the stomach poison method in reducing the lifespan of insects during the larval stage.

In general, the application of goat weed extract can disrupt physiological processes and induce changes in behavior due to tannin and saponin compounds, which affect the hormonal and nervous systems (Hikmah, 2018). Larvae mature faster but are weak and highly sensitive to physical and chemical pressure, with some failing to pupate and develop into adults (Ngatimin & Uslinawaty, 2019). The contact poison method is purportedly more effective than the stomach poison method in reducing lifespan, allegedly because the contact poison method can reach more bodily systems, such as the respiratory system through inhalation or the circulatory system through the body wall, compared to the stomach poison method, which primarily affects the digestive tract. This aligns with research on *Annona squamosa* L. extract, which was reported to be more effective as a contact poison than stomach poison (Dadang et al., 2011).

The factor causing the duration of the larval stage at a concentration level of 15% to 75 to be significantly shorter when compared to the control is the percentage of larval mortality. The higher the larval mortality percentage, the shorter the larval stage. According to Metcalf & Luckman (1994), the alkaloids contained in plants can allow these plants to have antibiosis properties against organisms that eat them. Antibiotic properties of alkaloid compounds may also be a factor that shortens the larval stage. Based on Table 1, the effect of flower extract treatment of *A. conyzoides* on the duration of pupal and imago stages at concentrations of 15% to 75% was not significantly different compared to the control (0% concentration). This is presumably because the larvae that successfully formed pupae and emerged as normal imago were relatively resistant to the influence of *A. conyzoides* flower extract.

Pupation and Imago Emergence

The results of the application of *A. conyzoides* flower extract using the stomach poison method and contact poison method showed that the treatment of various concentration levels of the flower extract could inhibit the percentage of formed pupa and imago emergence. It was observed that increasing the concentration of flower extract from 15% to 75% did not have a different effect on the percentage of formed pupa and imago emergence. This study revealed that the highest percentage of formed pupa due to the impact of flower extract treatment of *A. conyzoides* was found at an extract concentration of 15%, which was 70.00%, while the lowest percentage of pupae formation occurred at concentrations of 60% and 75%, which was 53.33%. When comparing the application methods, the highest percentage of formed pupa was produced by the extract concentration of 15%, which was 55.00%. In comparison, the lowest percentage of formed pupa was observed at concentrations of 75%, which was 40.00%.

The percentage of larval mortality influenced the decrease in the percentage of imago emergence, but it was also caused by the failure of the defective pupae to emerge as imago. This indicates an inhibition of development from the pupal to the imago stage. According to Vats et al. (2019), this development inhibition is due to *A. conyzoides* plants containing antijuvenile hormone, which inhibits insect development. Additionally, the same result was reported by Poerwanto et al. (2020), who stated that the effect of methanol and ethanol extract of *A. conyzoides* caused inhibition in the pupa phase of *Culex quinquefasciatus* mosquito and larval phase until death. Therefore, it is strongly suspected that this plant's methanol and ethanol extracts have the potential to be larvicidal.

This result suggests that the higher the *A. conyzoides* flower extract concentration, the greater the inhibition of pupation and imago emergence. Likewise, the contact poison method is more effective in inhibiting the pupation and imago emergence than the stomach poison method. This occurs because the toxic compounds that enter the insect's body through the contact poison method disrupt the central nervous system and result in the death of the larvae. In addition, the presence of antijuvenile hormone in *A. conyzoides* (Vats et al. 2019) is thought to be a factor that inhibits the formation of pupae and the emergence of imago.

Percentage Leaf Area Consumed by *C. binotalis*

The results showed that, with increasing concentrations of *A. conyzoides* flower extract, the percentage of leaf area eaten by larvae was lower. However, the increase in extract concentration did not show a consistent pattern to the decrease in the percentage of leaf area consumed by larvae (Figure 3). The highest percentage of leaf area consumed by larvae due to the effect of flower extract treatment of *A. conyzoides* was at a concentration of 75%, which was 60.13%. At concentrations of 15%, 30%, and 45%, the effect of the flower extract of *A. conyzoides* was not significantly different from the

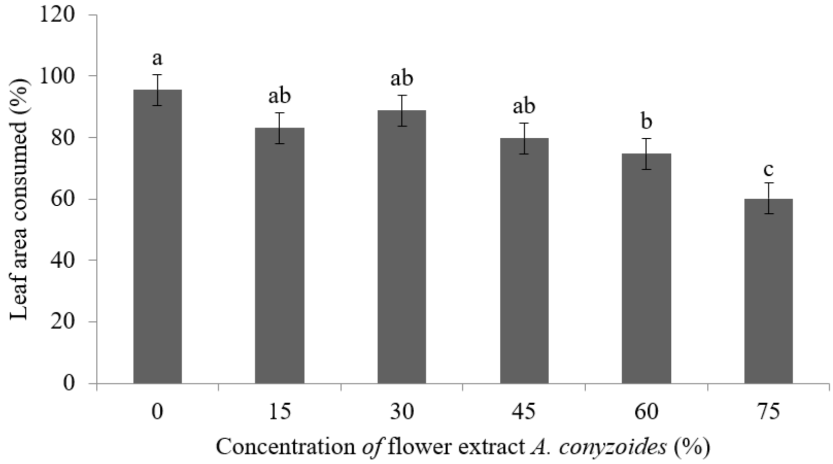

Figure 3. Effects of *A. conyzoides flower extract* concentration treatment through poison method stomach on the percentage of leaf area consumed by *Crocidolomia binotalis* larvae. Bars associated with the same letters are not significantly different at the 5% significance level according to the LSD test.

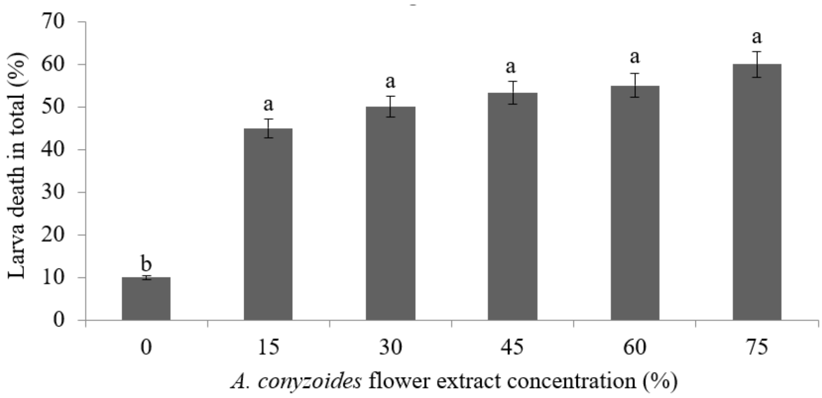

Figure 4. Effects of *A. conyzoides* flower extract treatment through contact poison method on the percentage of total larva mortality. Bars associated with the same letters are not significantly different at the 5% significance level according to the LSD test.

control (0% concentration) (Figure 4). However, there was a significant decrease in the percentage of leaf area consumed by larvae at concentrations of 60% and 75% compared to the control (Figure 3).

The percentage of edible leaf area can be used as an additional parameter in the stomach poison method because the decrease in leaf area consumed by *C. binotalis* larvae indicates that the flower extract of *A. conyzoides* has antifeedant properties against insects. This may be due to coumarin compounds that emit an unpleasant odor and other compounds that cause *A. conyzoides* plants to have a slightly bitter taste for insects (Sultan et al., 2016). Meanwhile, Sari & Armayanti (2018) stated that *A. conyzoides* contain high alkaloids, flavonoids, and tannins, which are concentrated in the leaves. The antifeedant properties against insects might be attributed to alkaloids, as this compound has a bitter taste.

CONCLUSION

Goatweed (*Ageratum conyzoides* L.) flower extract applied through contact poison method was effectively used to control *Crocidolomia binotalis* Z. This can be seen from the results of research showing that administration of goatweed (*Ageratum conyzoides* L.) flower extract significantly increased larval mortality, suppressed percentage of leaf area eaten by larvae, inhibited pupation, suppressed the emergence of imago, and shortened the larval stage duration of *Crocidolomia binotalis* Z.

AUTHOR'S CONTRIBUTIONS

SPN conceptualization, designing, and conducting research. NR research conceptualization. MU analyzes the data, researches it, and writes the result. BS writing and analyzing the research data. BT writing the data research.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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