Vol. 14, No. 3 (2025): 887 - 898 http://dx.doi.org/10.23960/jtep-l.v14i3.887-898

Agricultural Engineering
UNIVERSITY OF LAMPUNG

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Secondary Metabolites of Babandotan (*Ageratum conyzoides* L.) and Putri Malu (*Mimosa pudica* L.) to Control Fall Armyworm (*Spodoptera frugiperda*)

Dewi Anggraini[1], Wiwin Windriyanti[1], Sri Wiyatiningsih[1,✉]

[1] Master's Program in Agrotechnology, Faculty of Agriculture, UPN "Veteran" East Java, Surabaya, INDONESIA.

Article History:

Received : 11 February 2025
Revised : 26 March 2025
Accepted : 30 March 2025

Keywords:

Bioinsecticide,
Spodoptera frugiperda,
Zea mays.

Corresponding Author:
✉ sri.wiyatiningsih@upnjatim.ac.id
(Sri Wiyatiningsih)

ABSTRACT

Corn (Zea mays) production in Indonesia has experienced fluctuations due to infestations of the fall armyworm (Spodoptera frugiperda). Utilizing botanical pesticides derived from Ageratum conyzoides (Babandotan) and Mimosa pudica (Putri Malu) is a method to control the fall armyworm and maintain stable corn production. This study aims to identify the active compounds and determine the effective concentration of A. conyzoides and M. pudica extracts in reducing S. frugiperda populations. The research was conducted from June to November 2024 at the Pest Laboratory of the UPT Plant Protection Unit in Surabaya. The study was designed using a Completely Randomized Design with a single factor: different concentrations of plant extracts, replicated five times. Observed parameters included phytochemical tests, GC-MS compound screening, larval symptoms, mortality rate, pupae formation, and imago formation. The results showed that A. conyzoides and M. pudica extracts at the highest concentration (1%) significantly affected mortality rates, pupation, and adult emergence. Both extracts contained flavonoids, tannins, and triterpenoids, which effectively controlled S. frugiperda populations.

1. INTRODUCTION

Corn (*Zea mays* L.) is an important cereal food crop commodity in Indonesia after rice. Referring to data from the National Food Agency, the largest use of local corn is for feed needs, which reached 9.78 million tons or around 72.48% of the total national corn need in 2021 (Badan Pangan Nasional Republik Indonesia, 2023). The high need for corn supply must be accompanied by high productivity. However, in the field, some factors are often encountered that cause yield loss in corn production. One of the causes of decreased corn production is caused by plant pest organisms. According to data on the cumulative area of additional pest attacks in the 2023/2024 rainy season report, the corn pest attack released by the East Java Food and Horticulture Crop Protection UPT was 1,052.91 hectares, dominated by fall armyworm (*Spodoptera frugiperda* J.E).

In early 2019, fall armyworm pest *S. frugiperda* was found on corn plants in the Sumatera area (Nonci *et al.*, 2019). This pest attacks the plant growth point which result in the failure of the young shoots or leaves. Larvae of *S. frugiperda* have a high ability to eat. *Spodoptera frugiperda* is polyphage, some of its main hosts are food crops from the Graminae group such as corn, rice, wheat, sorghum, and sugarcane so that the existence and development of the population need to be controlled.

In overcoming pest attacks on corn plants, farmers generally still use synthetic pesticides in the hope that agricultural product yields can increase. The use of synthetic pesticides is increasing year by year. The high use of pesticides is not balanced with the level of understanding of farmers in applying pesticides as recommended, resulting in water, soil, and air pollution, and affecting the health of farmers, farmer families, and other consumers (Tarigan *et* *al.*, 2024). There are negative impacts caused by the use of chemical pesticides, so farmers need to be made aware to start an integrated pest control system (PHT). Integrated control of *S. frugiperda* can be carried out through the application of environmentally friendly vegetable insecticides as an alternative to synthetic pesticides.

Plant-based insecticides derived from plant-based active ingredients that contain primary and secondary metabolite compounds play an important role for plants, one of which is protecting plants, both from biotic (plant pest organism disorder) and abiotic stress (Mithöfer & Boland, 2012). The content of secondary metabolite compounds that are insecticidal in nature such as flavonoids, terpenoids, phenolics, tannins, alkaloids, and essential oils are found in plants that live freely in the wild so it is necessary to study their potential as a vegetable insecticide to control the *S. frugiperda* pest.

Babandotan weed (*Ageratum conyzoides* L.) is an aromatic weed that can grow all year round. *A. conyzoides* weed is known to contain secondary metabolites such as flavonoids, alkaloids, terpenoids, chromenoids, chromons, benzofurans, coumarins, essential oils, sterols and tannins (Kamboj & Saluja, 2008). In the field of OPT control, the secondary metabolite content produced by *A. conyzoides* is known to function, among others as an insecticide (Balfas & Willis, 2016; Rohimatun *et al.*, 2021).

In addition to *A. conyzoides*, the sensitive plant (*Mimosa pudica* L.) is also a type of weed that can be used as a plant insecticide because of the content of chemical compounds that can inhibit the dietability of insects. Several scientific studies have explored the potential of the embarrassed princess plant as a natural insecticide. Research by Syarifah (2020), shows that the weed plant of the embarrassed daughter is also able to increase mortality in *Spodoptera litura* larvae. Putri malu weed is easy to obtain because it can grow wild in various habitats, so that efforts to sanitize the putri malu population can also be used as a plant insecticide material.

Until now, research on the efficacy of plant insecticides derived from weed plants has rarely been studied for its benefits in pest control in agriculture. In addition, the content of vegetable insecticides also needs to be proven through more in-depth testing. Based on this background, this study was prepared to examine the use of extracts of Babandotan (*Ageratum conyzoides*) and Putri Malu (*Mimosa pudica*) leaves with various levels of concentration against *S. frugiperda* pest insects and to examine the content of active ingredients in these plant extracts.

2. MATERIALS AND METHODS

2.1. Time and Location of the Researcher

The research was carried out at the Pest Laboratory of UPT Proteksi TPH Surabaya, UPT Herbal Laboratory Materia Medica Batu City, and Integrated Research and Testing Laboratory (LPPT) UGM Yogyakarta which took place from June to November 2024.

2.2. Materials and Equipment

The plant leaves of babandotan (*Ageratum conyzoides*) and putri malu (*Mimosa pudica*) were taken from the yard of UPT Proteksi TPH Surabaya. The chemicals consisted of aquades and 70% ethanol. Test larvae of *S. frugiperda* instar 3, baby corn cobs for larval feed and 10% honey solution for imago feed *S. frugiperda*. The tools used in the study included analytical balances, blenders, ovens, a set of GC-MS, a set of rotary vacuum evaporators, and measuring cups, scissors, tissues, filter paper, test tubes, test tube racks, cups, stirring rods, chemical beakers, Erlenmeyer flask, cotton, aluminum foil, micro pipettes, sample bottles, split funnels, drip pipettes, clamps, round base flasks, spatulas.

2.3. Research design

The study employed a Completely Randomized Design with a single factor: the type of plant used as a botanical insecticide at varying solution concentrations. The treatments consisted of T0 (control, without botanical insecticide application), *Ageratum conyzoides* at 0.2% (A1), 0.5% (A2), and 1% (A3), and *Mimosa pudica* at 0.2% (M1), 0.5% (M2), and 1% (M3). Each treatment was replicated five times, resulting in a total of 35 experimental units. Each replicate used 10 test larvae. Observation parameters included symptoms, larval mortality, and the development of *Spodoptera frugiperda* larvae until emergence as imago after treatment application.

2.4. Implementation of research research

2.5.1. Extracts of Babandotan (ACE) and Putri Malu (MPE)

The samples used were the old, dark green leaves of babandotan and putri malu plants. The old leaves have a greater ability to synthesize bioactive compounds. The formation of bioactive compounds is greatly influenced by the age of plant organs (Harborne & Williams, 2000). The leaves of babandotan and putri malu were washed thoroughly with running water, then chopped to facilitate the grinding process. The chopped leaves were dried in an oven at 40°C. This drying lasts until the moisture content of ±10% (Mengkido *et al.*, 2019). The dried simplicia is then blended until smooth, then sifted with a 20-mesh sieve. The sifted simplicia were extracted using 70% ethanol in a ratio of 1:10. Then let it sit for 3 x 24 h and stir every day for 10 min. The extract was then evaporated using rotary evaporation until a thick paste extract was obtained (Fadlian *et al.*, 2016). The extracts of *Ageratum conyzoides* (ACE) and *Mimosa pudica* (MPE) and were stored in a refrigerator at 4°C until used for research (Giovanny *et al.*, 2019).

2.5.2. Screening of chemical compounds using GC-MS

The ACE and MPE extracts in viscous form were screened for qualitative phytochemical tests carried out at the Materia Medica Herbal Laboratory in Batu City to determine the content of secondary metabolites in each extract. The phytochemical test employed deposition and staining method (Harborne, 1996). The screening parameters of phytochemical tests included the qualitative tests of flavonoids, alkaloids, saponins, tannins, and terpenoids.

The chemical compound content of the ACE and MPE was analyzed using GC-MS (*Gas Chromatography-Mass Spectrometry*) at the LPPT UGM Yogyakarta. GC-MS analysis was performed using a gas chromatograph Trace 1310 equipped with a column of HP-5 ms UI (30 m x 0.25 mm x 0.25 µm) and connected to an ISQ LT mass spectrometer. At the time of sample injection, the split ratio was set to 1:50. Helium gas was used as a carrier gas with a fixed flow rate of 1.0 mL/min towards the column. The oven temperature starts at 60°C and was maintained for 2 min, then the temperature was increased at a rate of 10°C/min until it reaches 280°C and was kept for 8 min. The conditions of the mass detector included the ionization energy of 70 eV, the temperature of the ionization source 200°C, the temperature of the transfer path 250°C, the mass scanning range of 40–500 m/z, the injection volume of 1 µL, the injector temperature of 230°C, and the solvent delay time of 4 min. The peak area of each phytoconstituent was calculated to determine its relative percentage. Mass spectral data were analyzed using Xcalibur 1.1 software, and the NIST library was used to identify such phytoconstituents (Surahmaida *et al.*, 2019).

2.5.3. Extract Application

The application of the extract was carried out through the feed dipping method, namely by dipping 50 g of baby corncobs into the extract solution according to the predetermined treatments (0.2%, 0.5%, and 1%) for 30 s and drying for 10 min (Mukti *et al.,* 2024). The baby corn was then placed in a plastic jar container sizing of 16 x 16 x 5 cm and *S. frugiperda* larvae were introduced, then the jar was covered with gauze. Each plastic jar was filled with 10 larvae that have been fasted for 24 h. Observations were made every 24, 48, 72, 96 and 120 h after application (HAA) and the feed (baby corncobs) was replaced daily (Vargas-Méndez *et al.*, 2019).

2.5. Research parameters

Observation parameters of insects treated with ACE and MPE at various concentrations included larval symptoms, larval mortality, number of pupae formed, and number of imago formed. The phytochemical compounds contained in the extracts included the type of compounds detected during qualitative phytochemical tests by staining and deposition method, as well as detected using GC-MS analysis.

2.6. Data Analysis

The data obtained was statistically analyzed using multiple fingerprint analysis in accordance with the Completely Randomized Design. If there is a difference in the mean values among treatments, a DMRT was carried out at a significant difference level of 5% using the RStudio program.

3. RESULTS AND DISCUSSION

3.1. hemical Compounds of Babandotan and Putri Malu Extracts

Based on the results of phytochemical screening tests (Table 1), babandotan leaf extract is positive for secondary metabolite compounds, including flavonoids, tannins or phenols, and triterpenoids. This is in accordance with previous research that explains that babandotan leaves contain flavonoids, terpenoids and tannins (Bosi *et al.*, 2013; Munira *et al.*, 2020).

Table 1. Results of phytochemical screening of *Ageratum conyzoides* and *Mimosa pudica* using Staining and Deposition method

Test Parameters	Method	Types of Extracts	
		Ageratum conyzoides	*Mimosa pudica*
Flavonoids	Staining and Deposition (Harborne, 1996)	(+) Positive	(+) Positive
Alkaloids	Staining and Deposition (Harborne, 1996)	(-) Negative	(+) Positive
Tannin/Phenol	Staining and Deposition (Harborne, 1996)	(+) Positive	(+) Positive
Steroids	Staining and Deposition (Harborne, 1996)	(-) Negative	(-) Negative
Triterpenoids	Staining and Deposition (Harborne, 1996)	(+) Positive	(+) Positive
Saponins	Staining and Deposition (Harborne, 1996)	(-) Negative	(-) Negative

In the testing parameters of alkaloids, steroids and saponins show negative values which means that they are not contained in babandotan leaf extract. Meanwhile, putri malu positive leaf extract contains flavonoid compounds, alkaloids, tannins/phenols, and triterpenoids. This is in accordance with the research of Pohan & Yang (2024), which states that white white ethanol extract contains flavonoids, polyphenols, terpenoids and alkaloids. In the testing of saponins and steroids, the leaf extract of the embarrassed princess showed a negative reaction.

Flavonoid compounds, tannins, and triterpenoids contained in babandotan leaf extract and putri malu leaf extract play a role in reducing the larval population *of S. frugiperda* by interfering with various physiological processes that are important for the survival of *S. frugiperda* larvae. Hernani & Raharjo (2005), mentioned that flavonoid compounds are compounds that are toxic to insects. Flavonoids can inhibit the growth of larvae and act as respiratory inhibitors, namely by entering the respiratory tract of insects and then attacking the nerves and respiratory system resulting in difficulty breathing and death (Robinson, 1995). The tannin compounds contained in babandotan leaf extract and putri malu leaf extract work by binding and deactivating important proteins in the larva's body, inhibiting the digestive process and nutrient absorption. This causes *S. frugiperda* larvae to starve and experience metabolic stress resulting in death. According to the results of research by Barbehenn & Peter Constabel (2011), tannins have a bitter taste so that they can cause eating inhibition mechanisms in test animals. Tannin compounds can suppress feed consumption, growth rate and survivability of test animals. Just like tannin compounds, triterpenoids are also toxic to the digestive system of *S. frugiperda* larvae. Triterpenoids also act as *antifeedants* and block food taste receptors in larvae. Wu *et al.* (2020), stated that triterpenoid compounds are one of the compounds that are antifeedant because of their bitter taste so that insects refuse to eat.

Examination of alkaloid compounds in babandotan extract was not detected, while putri malu extract was positive for alkaloid compounds in the Dragendrof, Mayer and Bouchardat reagents. Alkaloid compounds have the ability to control the larval population of *S. frugiperda* because they are nerve toxins and inhibitors of insect growth. According to the results of Yallac *et al.*'s (2022), research, alkaloid compounds are used as biopesticides because they can attack the neurosecretory cells of the insect brain (which are toxic to nerves), inhibit the formation of pupae and growth hormone, thus interrupting or stopping the larval cycle. Guswenrivo *et al.* (2013), mention compounds in the alkaloid group that are toxic, *repellent* and have food inhibiting activity against insects, warehouse pests or *antifeedants.*

3.2. GC-MS Analysis for Babandotan Extract

Advanced chemical compound content testing was carried out by Gas Chromatography-Mass Spectrometry (GC-MS) analysis method. This was done to compare the results of the phytochemical screening test qualitatively with the results of the GC-MS quantitative analysis. Based on the results of testing babandotan leaf extract (Figure 1), there are phytoconstituents that are known to have insecticidal activity and can affect the life of *S. frugiperda* pest insects. These phytoconstituents include 2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimethyl- (25.55%); Hexadecanoic acid, methyl ester (5.68%); and 6-Octadecenoic acid (5.08%).

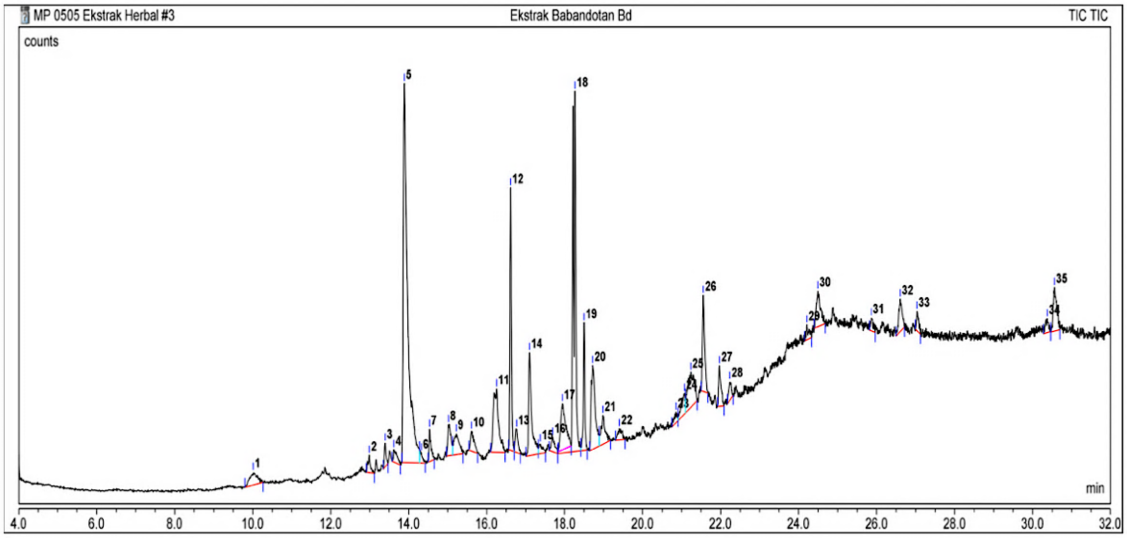

Figure 1. GC-MS chromatogram for Babandotan extract

The most compound components in babandotan leaf ethanol extract are located at peak 5 with a retention area value of 25.55% with the possibility of 1 insecticidal compound, namely 2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimethyl. According to the National Institute of Standards and Technology (NIST) Chemistry WebBook website, the compound 2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimethyl- has a synonym name, namely Precocene II with the chemical structure $C_{13}H_{16}O_3$. Precocene II is a compound that acts as an anti-juvenile hormone that causes *S. frugiperda* larvae to not develop into pupae until imago. This is in accordance with the statement of Adebayo *et al.* (2010), that Precocene II is a compound produced by plants of the family Asteraceae and has an important effect on the development of insects that can specifically cause damage to allatal corporeal cells thereby preventing the synthesis of juvenile hormones. This hormone plays a role in the broad physiological development of insects from metamorphosis to reproduction.

The compounds detected at peak 12 with a retention area value of 5.68% are Hexadecanoic acid, methyl ester. The results of Abdullah (2019) research explained that Hexadecanoic acid, methyl ester compounds are insecticidal and larvisidal which can cause mortality in the larval and imago phases of *Spodoptera littoralis* and *Aphis gossypii* pests. This shows that the compound Hexadecanoic acid, methyl ester has the potential to reduce the larval population of *S. frugiperda* because it is larvasidal.

The compound 6-Octadecenoic acid detected at peak 20 with a retention area value of 5.08% also plays a role in disrupting the sensing system of *S. frugiperda* larvae, preventing the larvae from detecting food sources or locations where they usually breed. The results of a study by Bishr & Salama (2018), on the essential oil content of the *Balanites aegyptiaca* plant (desert date plant) used as an imago insecticide *Tribolium castaneum* showed that the content of 6-Octadecenoic acid compound of 2.38% had a rejection effect on *the imago of T. castaneum* and reduced its population density.

3.2.2. GC-MS Analysis for Putri Malu Extract

The results of testing the leaves of putri malu by the GC-MS Analysis method (Figure 2) showed that phytoconstituents are insecticidal and affect the survival of *S. frugiperda* pests, including 3-O-Methyl-d-glucose; Desulphosinigrin; 3,5,6,7,8,3',4'-Heptamethoxyflavone and D-Amygdalin. The main compound 3-O-Methyl-d-glucose is at peaks 6 to 13 with the largest retention area value of 65.86% at peak 9. The compound 3-Methylglucose is a derivative of glucose (National Center for Biotechnology Information, 2025). This compound when consumed in high quantities can affect the development of *S. frugiperda* larvae. Francikowski *et al.* (2021) stated that high glucose consumption in insects can lead to delays in the achievement of the pupa stage, reduced nutrient absorption, metabolic changes that lead to fat accumulation in larvae, and weight loss in imago. The phytoconstituents detected to be repellents are Desulphosinigrin compounds at peak 5 with a retention area value of 0.65%. Desulphosinigrin has the potential to be a natural insecticide raw material because it plays a role in inhibiting odor binding protein or Odorant Binding Protein 1 (OBP1) (Biessmann *et al.*, 2010). OBP1 is a family of proteins found in the chemosensory organs of vertebrates and insects. These proteins play an important role in supporting the sense of smell and can be used in biotechnology applications such as the manufacture of biosensors (Cali *et al.*, 2020).

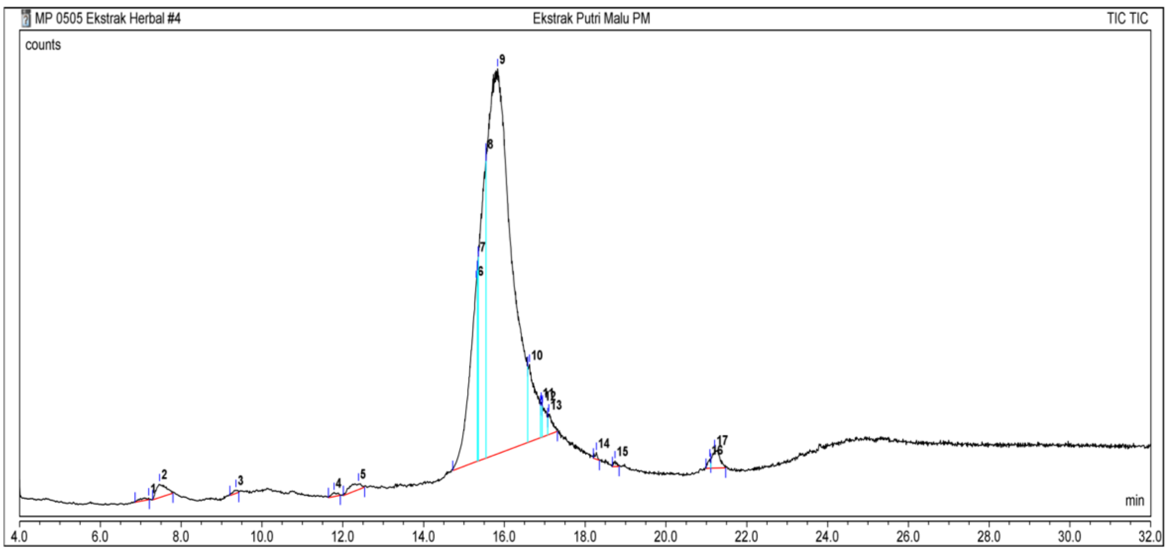

Figure 2. GC-MS chromatogram for Putri Malu extract

The D-Amygdalin compound detected at peak 15 with a retention area value of 0.12% has the potential to control the *S. frugiperda* population because it is toxic to insect pests. According to the statement of Jaszczak *et al.* (2017), that the cyanogenic glycoside compound group is naturally toxic to insects and most herbivorous animals. *Cyanogenic glycosides* are thought to have an important role in plant defenses against herbivores due to their bitter taste and the release of toxic hydrogen cyanide when tissues are disturbed (Zagrobelny *et al.*, 2004). Compounds 3,5,6,7,8,3',4'-Heptamethoxyflavone were detected at peak 17 with a retention area value of 1.01% which is one of the compounds in the Flavonoid group. According to the research of Morimoto & Komai (2006), the compound 3,3',4',5,6,7,8-heptamethoxy- shows antifeedant activity against the larvae of the pest *Spodoptera litura*. From the results of the study, the application of putri malu leaf extract appears to affect the eating behavior of *S. frugiperda*, namely the decrease in the consumption of baby corn feed.

3.3. Symptoms in Larvae After Application

Babandotan leaf extract and putri malu leaf extract have an influence on the larvae's feeding activity until morphologically and physiologically changes occur. The physiological changes that occur in all treatments are almost the same, namely changes in the color of the skin and body shape of the larvae when death occurs. At the beginning of death, the larvae's skin color changes from yellowish-green to blackish-brown and eventually turns pitch black and secretes fluid (Figure 3). The body shape of the larvae becomes wrinkled and stiff. This is in accordance with research by Anggraini & Rustam (2023), which explains the change in the skin of the larvae at the beginning of brown death, then changes in color to black and the larvae's body shape becomes wrinkled.

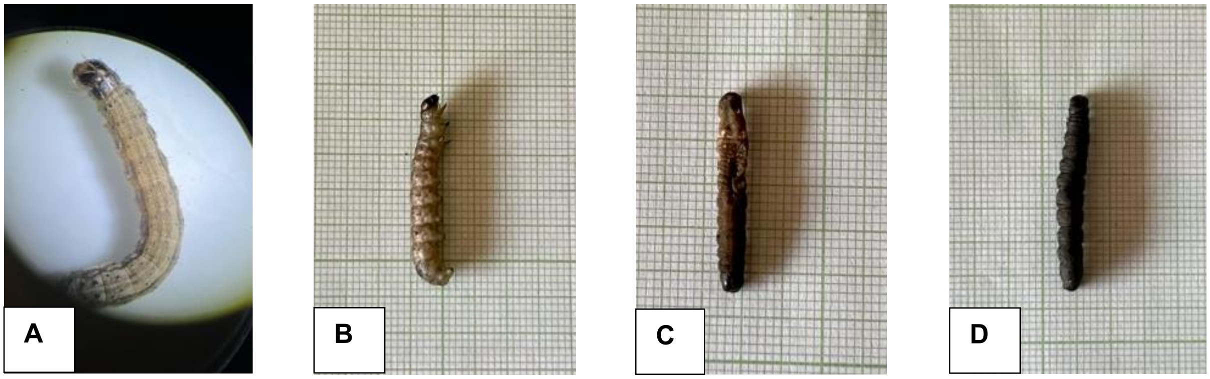

Figure 3. Morphological changes in S. frugiperda larvae as a result of extract treatment, (A) 0 hours after application, (B) 24 hours after application, (C) 48 hours after application, and (D) 72 hours after application

In addition to symptoms in the color and shape of the larvae's body, the larvae's movement activity also slows down. The movement of larvae in the treatment of babandotan leaf extract and putri malu leaf extract when touched using the tip of a brush tended to be slower, than the larvae in the control treatment. This slow movement can affect eating activities so that nutrients become unfulfilled and die slowly. According to Rustam & Rajani (2021), the initial symptoms of *S. frugiperda* larval death are characterized by changes in behavior, namely the larvae become less active, appetite decreases, look weak or passive movement due to paralysis due to reactions from chemical compounds found in babandotan leaf extract and putri malu leaf extract.

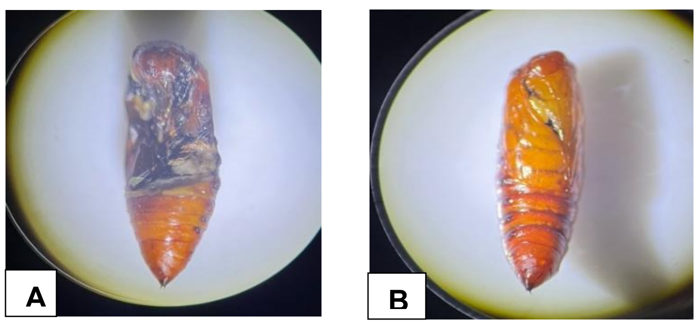

Figure 4. Effect of extracts on pupa shape: A) Abnormal Pupa, and B) Normal Pupa

Morphological changes occur in the process of forming the pupa phase. *S. frugiperda* larvae that survive will form pupae, but there are some larvae that fail to become pupae so that the shape of the pupa becomes abnormal. Visual differences can be clearly seen between normal and abnormal pupae (Figure 4). The abnormal pupa appears deflated and wrinkled in the middle of the pupa layer, so the abnormal pupa fails to become an imago. Normal pupae appear dark brown with normal size so that they succeed in becoming an imago. The application of plant pesticides affects the feeding behavior of larvae, so that the weight of the pupa obtained will be low, abnormal pupa growth, and can even cause death due to nutritional deficiencies (Mukti *et al.*, 2024).

Based on the observation results, the application of babandotan leaf extract and putri malu leaf extract affected the appearance of imago *S. frugiperda*. The normal pupa that forms develops into a normal and abnormal imago (Figure 5). Abnormal imagomas have physical characteristics including curved wing shape and shorter size than the abdomen as seen in Figure 5. In addition, the body shape of the abnormal imago is smaller than the normal imago. Aprianti *et al.* (2022) explained that abnormal imago experiences physical defects such as imperfect formation of the wing where the wings appear shorter than the length of the body so that the imago cannot fly. In addition, there is an imago failure against its appearance from the pupa. The image does not manage to come out of the pupa which eventually the imago dies inside the pupa. Dead pupae appear blackish and hard.

Figure 5. Effect of the extract on the form of imago; A) normal image, B) abnormal image

3.4. Larval mortality after extract application

The results of the analysis of the effect of the combination of plant extract treatment and the concentration of extract solution on the mortality of *S. frugiperda* larvae showed a significant effect on the mortality of *S. frugiperda* at 24, 48, 72, 96, and 120 JSA presented in Table 2. Based on the results of the study, it was shown that the administration of Babandotan 1% or Putri Malu 1% could control the larval population of *S. Frugiperda* by 76% and 80%, respectively. This happens because babandotan leaf extract and putri malu leaf extract contain secondary metabolite compounds with the same role in reducing the larval population *of S. frugiperda.* Based on the results of phytochemical screening, babandotan leaf extract contains flavonoid compounds, tannins, and triterpenoids, while putri malu leaf extract contains flavonoid compounds, alkaloids, tannins, and triterpenoids.

Table 2. Effect of ACE and MPE concentration on the average mortality of *S. frugiperda* larvae

Treatment	Mortality (%) in Hours After Application (HAA)				
	24	48	72	96	120
Control	4.0 c	4.0 d	8.0 d	10.0 p	12.0 c
Babandotan 0.2%	8.0 bc	12.0 c	32.0 c	36.0 c	54.0 b
Babandotan 0.5%	8.0 bc	16.0 bc	36.0 c	44.0 c	62.0 b
Babandotan 1%	24.0 a	36.0 a	54.0 ab	58.0 ab	76.0 a
Putri Malu 0.2%	10.0 bc	22.0 b	38.0 bc	46.0 bc	58.0 b
Putri Malu 0.5%	16.0 ab	18.0 bc	46.0 abc	46.0 bc	62.0 b
Putri Malu 1%	22.0 a	36.0 a	56.0 a	60.0 a	80.0 a
DMRT 5%	7.74	6.57	16.46	12.86	7.59

Remarks: The mean accompanied by the same letter in in the same column showed no significant difference in the 5% DMRT.

Putri malu leaf extract contains alkaloid secondary metabolite compounds that are not contained in babandotan leaf extract. Alkaloid compounds are used as biopesticides because they are able to attack the neurosecretory cells of the insect brain (Fadlian *et al.*, 2016; Pohan & Yang, 2024). In addition, contact toxins that work to damage the cell walls of the larvae's body (alkaloids, tannins, and flavonoids) can easily enter the larva's body. Alkaloid compounds will directly attack the digestive system, then flavonoids will attack the digestive nervous system, so that there will be contractions in the larvae body to cause death (Kurniawan *et al.*, 2021).

Giving plant pesticide extracts at higher concentrations also resulted in a higher percentage of mortality compared to lower concentrations. According to the results of Kurniawan *et al.* (2021), toxic compounds that enter the larvae will undergo biotransformation which produces compounds that are polar and easily soluble in water, so that the higher the concentration of extract solutions that enter the larva's body, the higher the larval death.

3.5. Number of Pupae Formed

Results Analysis of the effect of the combination of extract type treatment and extract solution concentration on the formation of *S. frugiperda* pupa is presented in Table 3. The administration of a combination of extract type treatment and concentration has a real effect on the total pupa formed, and has no real effect on the normal and abnormal pupae formed. Based on the results of the study, the administration of 1% Babandotan or 1% Putri Malu extract can reduce the number of pupae formed until the pupa population remains by 20–24%. The effect of the compounds contained in the extract greatly affects the development of *S. frugiperda* larvae into pupae. The high concentration also affects the pupa population that is formed. Based on the results of the study, the higher the concentration, the lower the pupa formed.

Table 3. Effect of ACE and MPE concentration on the pupa formed

Treatment	Total Pupa (head)	Normal Pupa (%)	Abnormal Pupa (%)
Control	88.00 a	96.00	4.00
Babandotan 0.2%	46.00 b	88.00	12.00
Babandotan 0.5%	38.00 c	90.00	10.00
Babandotan 1%	24.00 d	83.30	16.70
Putri Malu 0.2%	42.00 bc	95.00	5.00
Putri Malu 0.5%	38.00 c	89.30	10.70
Putri Malu 1%	20.00 d	80.00	20.00
DMRT 5%	7.59	Not significant	Not significant

Remarks: The mean number accompanied by the same letter in the same column showed no significant difference in the 5% DMRT.

Babandotan leaf extract produces compounds 2H-1-Benzopyran, 6,7-dimethoxy-2,2-dimethyl or Precocene II with a retention area value of 25.55% which acts as an anti-juvenile hormone in the metamorphosis process of *S. frugiperda*. The putri malu leaf extract contains the compound 3-O-Methyl-d-glucose which is the main compound contained in the putri malu leaf extract and has a retention area value of 65.86%. High glucose content can also interfere with the development of *S. frugiperda* metamorphosis. According to Francikowski *et al.* (2021), High glucose consumption in insects can cause delays in the achievement of the pupa stage, reduced absorption of nutrients, metabolic changes leading to fat accumulation in larvae, and weight loss in imago.

3.6. Number of Imago

The results of the variance analysis showed that there was a real influence of the combination of extract type treatment and concentration on the formation of imago *S. frugiperda* (Table 4). The treatment of Babandotan 1% and Putri Malu 1% resulted in the lowest total imago count of 20 and 16 heads, respectively. The lowest number of normal imago was achieved by the treatment of Babandotan 1% and Putri Malu 1%, which was 26.67%. The highest abnormal imago formation was achieved by the treatment of Babandotan 1% and Putri Malu 1%, which was 73.33%. The treatment of Putri Malu and Babandotan at the highest concentrations produced compounds that interfered the development of insects, especially at the stage of imago formation. The high concentration also determines the content of secondary metabolite compounds contained in each extract. Thus, the higher the concentration used, the more the amount of active ingredients consumed by insects so that there is a disturbance in the growth process.

Table 4. Effect of ACE and MPE concentration on the imago formed

Treatment	Total Imago (head)	Normal Image (%)	Abnormal Image (%)
Control	84.00 a	97.78 a	2.22 d
Babandotan 0.2%	38.00 b	85.00 ab	15.00 cd
Babandotan 0.5%	34.00 b	60.00 bc	40.00 bc
Babandotan 1%	20.00 c	26.67 d	73.33 a
Putri Malu 0.2%	40.00 b	65.33 bc	34.67 bc
Putri Malu 0.5%	34.00 b	48.33 cd	51.67 ab
Putri Malu 1%	16.00 c	26.67 d	73.33 a
DMRT 5%	9.03	27.52	27.52

Remarks: The mean number accompanied by the same letter in the same column showed no significant difference in the 5% DMRT test.

According to the results of phytochemical screening and GC-MS analysis, babandotan leaf extract and putri malu leaf extract contain hormones that inhibit the development of *S. frugiperda* larvae. The alkaloid compounds contained in the leaf extract of putri malu can inhibit skin turnover in each phase of the larvae. As already mentioned Yallac *et al.* (2022), explained that alkaloid compounds are used as biopesticides because they can attack insect brain neurosecretory cells (toxic to nerves), inhibit the formation of pupae and growth hormone, thus interrupting or stopping the larval cycle. This alkaloid compound has the same role as the Precocene II compound found in bamandotan leaf extract, so there is no real difference between the types of extracts.

4. CONCLUSION

Based on the discussion above, it can be concluded that Babandotan and Putri Malu extracts at the highest concentration (1%) significantly increase the mortality rate *S. frugiperda* larvae, decrease the number of pupae and the number of imago formed. Babandotan and Putri Malu extracts contain flavonoids, tannins, and triterpenoids that can be used to control the *S. frugiperda* population.

REFERENCES

Abdullah, R.R. (2019). Insecticidal activity of secondary metabolites of locally isolated fungal strains against some cotton insect pests. *Journal of Plant Protection and Pathology*, ***10***(12), 647–653. https://doi.org/10.21608/jppp.2019.79456

Adebayo, A., Zeng, G.-Z., Zhang, Y., Ji, C., Akindahunsi, A., & Hua, N. (2010). Toxicological evaluation of precocene II isolated from *Ageratum conyzoides* L. (Asteraceae) in Sprague Dawley rats. *African Journal of Biotechnology*, ***9***(20), 2938-2944.

Anggraini, D., & Rustam, R. (2023). Efektivitas berbagai konsentrasi ekstrak daun sirih hutan (*Piper aduncum* L.) dalam mengendalikan ulat grayak jagung. *Jurnal Agroteknologi*, ***13***(2), 77-84. http://dx.doi.org/10.24014/ja.v13i2.17600

Aprianti, F., Hidayat, Y., & Dono, D. (2022). Pengaruh ukuran partikel sulfur terhadap mortalitas, pertumbuhan dan perkembangan ulat grayak jagung *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae). *Agrikultura*, ***32***, 257-265. https://doi.org/10.24198/agrikultura.v32i3.35270

Badan Pangan Nasional Republik Indonesia. (2023). *SK Pedoman Klasifikasi Pangan Segar* (No. 0, pp. 1–23).

Balfas, R., & Willis, M. (2009). Pengaruh ekstrak tanaman obat terhadap mortalitas dan kelangsungan hidup *Spodoptera litura* F. (Lepidoptera: Noctuidae). *Buletin Penelitian Tanaman Rempah dan Obat*, ***20***(2), 148–156.

Barbehenn, R.V., & Constabel, C.P. (2011). Tannins in plant–herbivore interactions. *Phytochemistry*, 72(13), 1551-1565. https://doi.org/10.1016/j.phytochem.2011.01.040

Biessmann, H., Andronopoulou, E., Biessmann, M.R., Douris, V., Dimitratos, S.D., Eliopoulos, E., Guerin, P.M., Iatrou, K., Justice, R.W., Kröber, T., Marinotti, O., Tsitoura, P., Woods, D.F., & Walter, M.F. (2010). The *Anopheles gambiae* odorant binding protein 1 (AgamOBP1) mediates indole recognition in the antennae of female mosquitoes. *PloS One*, ***5***(3), e9471. https://doi.org/10.1371/journal.pone.0009471

Bishr, M., & Salama, O. (2018). Inter and intra GC-MS differential analysis of the essential oils of three *Mentha* species growing in Egypt. *Future Journal of Pharmaceutical Sciences*, ***4***(1), 53-56. https://doi.org/10.1016/j.fjps.2017.08.003

Bosi, C.F., Rosa, D.W., Grougnet, R., Lemonakis, N., Halabalaki, M., Skaltsounis, A.L., & Biavatti, M.W. (2013). Pyrrolizidine alkaloids in medicinal tea of *Ageratum conyzoides*. *Revista Brasileira de Farmacognosia*, ***23***(3), 425–432. https://doi.org/https://doi.org/10.1590/S0102-695X2013005000028

Cali, K., Tuccori, E., & Persaud, K.C. (2020). Chapter Eighteen - Gravimetric biosensors. *Methods in Enzymology*, 642, 435–468. https://doi.org/10.1016/bs.mie.2020.05.010

Fadlian, Hamzah, B., & Abram, P.H. (2016). Uji efektivitas ekstrak tanaman putri malu (*Mimosa pudica* Linn) sebagai bahan pengawet alami tomat. *Jurnal Akademika Kimia*, ***5***(4), 153–158.

Francikowski, J., Potrzebska, M., Szulińska, E., Tarnawska, M., Radai, Z., Łozowski, B., Baran, B., & Krzyżowski, M. (2021). The effects of high-monosaccharide diets on development and biochemical composition of white-eyed mutant strain of house cricket (*Acheta domesticus*). *Scientific Reports*, ***11***(1), 21147. https://doi.org/10.1038/s41598-021-00393-5

Giovanny, L., Lestari, F. A., Marfira, N., Ambarsari, L., & Warnasih, S. (2019). Potency of ethanol extracts of palm seeds (*Phoenix dactylifera* L.) as antidiabetic with inhibition kinetics parameter. *Current Biochemistry*, ***6***(2), 55–67. https://doi.org/10.29244/cb.6.2.1

Guswenrivo, I., Tarmadi, D., & Yusuf, S. (2013). Aktivitas insektisida ekstrak buah bintaro (*Cerbera manghas*) terhadap kutu beras *Sitophilus oryzae* (Coleoptera: Curculionidae). *Jurnal Ilmu Dan Teknologi Kayu Tropis*, ***11***(1), 64–90.

Harborne, J.B. (1996). *Phytochemical methods: a guide to modern techniques of plant analysis*. Chapman and Hall.

Harborne, J.B., & Williams, C.A. (2000). Advances in flavonoid research since 1992. *Phytochemistry*, ***55***(6), 481–504. https://doi.org/10.1016/S0031-9422(00)00235-1

Hernani, & Raharjo. (2005). *Tanaman Berkhasiat Antioksidan*. Penebar Swadaya, Jakarta.

Jaszczak, E., Polkowska, Ż., Narkowicz, S., & Namieśnik, J. (2017). Cyanides in the environment-analysis-problems and challenges. *Environmental Science and Pollution Research International*, ***24***(19), 15929–15948. https://doi.org/10.1007/s11356-017-9081-7

Kamboj, A., & Saluja, A.S. (2008). *Ageratum conyzoides* L.: A review on its phytochemical and pharmacological profile. *International Journal of Green Pharmacy*, ***2***(2), 59-68.

Kurniawan, A., Muhfahroyin, M., & Sutanto, A. (2021). Efektivitas variasi konsentrasi ekstrak daging buah bintaro sebagai insektisida lepidoptera pada bawang daun sebagai sumber belajar pencemaran lingkungan. *BIOLOVA*, ***2***(1), 54–63. https://doi.org/10.24127/biolova.v2i1.323

Mengkido, M., Lambui, O., & Harso, W. (2019). Uji daya hambat ekstrak daun bandotan (*Ageratum conyzoides* L.) terhadap pertumbuhan bakteri *Staphylococcus aureus*. *Biocelebes,* ***13***(2), 121–130.

Mithöfer, A., & Boland, W. (2012). Plant defense against herbivores: Chemical aspects. *Annual Review of Plant Biology*, ***63***(1), 431–450. https://doi.org/10.1146/annurev-arplant-042110-103854

Morimoto, M., & Komai, K. (2006). Insect antifeedant activity of natural products and the structure-activity relationship of their derivatives. In *Natural Products for Pest Management* (Vol. 927). American Chemical Society, Washington, DC 20036: 182–193. https://doi.org/10.1021/bk-2006-0927.ch014

Mukti, A.N.K., Rahmadhini, N., & Triwahyu, E. (2024). Pengaruh pestisida nabati daun kemangi untuk pengendalian hama *Spodoptera frugiperda* (*Lepidoptera* : *Noctuidae*) pada tanaman jagung. *Biofarm*, ***20***(1), 44–49.

Munira, M., Rodisa, F., & Nasir, M. (2020). Uji antibakteri kombinasi ekstrak daun Biduri (*Calotropis gigantea* L.) dan daun Bandotan (*Ageratum conyzoides* L.). *Jurnal SAGO Gizi Dan Kesehatan*, ***1***, 165-171. https://doi.org/10.30867/gikes.v1i2.410

National Center for Biotechnology Information. (2025). *PubChem Compound Summary for CID 8973, 3-O-Methylglucose*. https://pubchem.ncbi.nlm.nih.gov/compound/3-O-Methylglucose

Nonci, N., Kalgutny, Hary, S., Mirsam, H., Muis, A., Azrai, M., & Aqil, M. (2019). *Pengenalan Fall Armyworm* (*Spodoptera frugiperda* J.E. Smith) *Hama Baru Pada Tanaman Jagung Di Indonesia*. Balai Penelitian Tanaman Serealia, Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian, Jakarta.

Pohan, D.J., & Yang, J.J. (2024). Effect of putri malu (*Mimosa pudica* Linn) leaf extract as an inhibitor of vibrio cholerae growth. *Journal of Complementary and Alternative Medical Research*, ***25***(2), 1–9. https://doi.org/10.9734/JOCAMR/2024/v25i2514

Robinson, T. (1995). *Kandungan Senyawa Organik Tumbuhan Tinggi* (Translated by Kosasih Padmawinata). ITB Press, Bandung.

Rohimatun, Aisyah, M.D.N., Ahyar, & Wahyudi, S. (2021). Babadotan (*Ageratum conyzoides* L.) sebagai insektisida nabati. *Wartabalittro*, ***38***(76), 14–19. https://www.researchgate.net/publication/352838361

Rustam, R., & Rajani. (2021). Uji beberapa konsentrasi ekstrak akar tuba (*Derris elliptica* Benth) untuk mengendalikan hama ulat grayak (*Spodoptera frugiperda* J.E. Smith) di laboratorium. *Jurnal Agrotek*, ***5***(1), 24–33. https://doi.org/10.33096/agrotek.v5i1.156

Surahmaida, S., Sudarwati, T.P.L., & Junairiah, J. (2019). Analisis GCMS terhadap senyawa fitokimia ekstrak metanol *Ganoderma lucidum*. *Jurnal Kimia Riset*, ***3***(2), 147–155. https://doi.org/10.20473/jkr.v3i2.12060

Syarifah, R.N.K. (2020). Pemanfaatan gulma mimosa invisa sebagai pengendali organisme pengganggu tanaman. *Biofarm : Jurnal Ilmiah Pertanian*, ***16***(2), 59-67. https://doi.org/10.31941/biofarm.v16i2.1207

Tarigan, W.Y.B., Siregar, S.D., & Hartono. (2024). Hubungan faktor pendidikan, pelatihan, pengetahuan, ekonomi dan penggunaan APD dalam penggunaan pestisida di Desa Cinta Rakyat Tahun 2023. *Jurnal Kesehatan Tambusai*, ***5***(3), 8259–8265.

Vargas-Méndez, L.Y., Sanabria-Flórez, P.L., Saavedra-Reyes, L.M., Merchan-Arenas, D.R., & Kouznetsov, V.V. (2019). Bioactivity of semisynthetic eugenol derivatives against *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae infesting maize in Colombia. *Saudi Journal of Biological Sciences*, ***26***(7), 1613–1620. https://doi.org/10.1016/j.sjbs.2018.09.010

Wu, Z., Wei, W., Cheng, K., Zheng, L., Ma, C., & Wang, Y. (2020). Insecticidal activity of triterpenoids and volatile oil from the stems of *Tetraena mongolica*. *Pesticide Biochemistry and Physiology*, ***166***, 104551. https://doi.org/https://doi.org/10.1016/j.pestbp.2020.02.017

Yallac, F.I., Novi, C., & Abdilah, N.A. (2022). Efikasi biopeptisida ekstrak *Etlingera elatior* (Jack) R.M.SM. terhadap mortalitas larva *Spodoptera litura*. *Jurnal Medika & Sains*, ***2***(2), 103-112.

Zagrobelny, M., Bak, S., Rasmussen, A.V., Jørgensen, B., Naumann, C.M., & Lindberg Møller, B. (2004). Cyanogenic glucosides and plant-insect interactions. *Phytochemistry, **65***(3), 293–306. https://doi.org/10.1016/j.phytochem.2003.10.016