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Utilization of Active Compounds in Plants as Botanical Pesticides for the Control of Mealybug (*Pseudococcus lilacinus*)

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ABSTRACT

This study aims to evaluate the effectiveness of active compounds contained in several plant species as botanical pesticides to control mealybug pests (Pseudococcus lilacinus). Mealybugs are major agricultural pests that damage plants by sucking cell sap, leading to growth inhibition and yield loss. The excessive use of synthetic pesticides poses health and environmental risks and promotes pest resistance. Therefore, botanical alternatives are needed for safer and sustainable pest control. The research used plant extracts containing bioactive compounds such as alkaloids, flavonoids, saponins, tannins, and terpenoids, which act as contact poisons, antifeedants, and growth inhibitors. Laboratory tests were conducted to evaluate mortality rates of mealybugs under different extract concentrations. The results showed that certain plant extracts significantly increased mealybug mortality, indicating their potential as effective botanical pesticides. This finding supports the use of plant-based pesticides as an eco-friendly alternative to synthetic chemicals.

Keywords: botanical pesticide, *Pseudococcus lilacinus*, plant extract, pest control, eco-friendly

1. INTRODUCTION

Cocoa (*Theobroma Cacao* L.) is a strategically important plantation commodity that contributes significantly to the Indonesian economy, ranking as the third-largest foreign exchange earner in the plantation sector.[1] Despite its economic importance, cocoa cultivation faces substantial challenges, primarily due to pest infestations. One of the most detrimental pests is the mealybug (*Pseudococcus calceolariae* or *Pseudococcus lilacinus*), which often aggregates in colonies of thousands on the host plant. Mealybugs damage cocoa plants by sucking the sap from all plant parts. Infestations on young shoots result in stunted, yellowed, and shriveled leaves that appear scorched, often leading to defoliation. Furthermore, the pest secretes honeydew, which subsequently promotes the growth of sooty mold fungus, turning the affected plant areas black.[2] On cocoa plants, mealybugs cluster on the stem nodes and the surface of cocoa pods. This infestation prevents the development of young pods or causes them to rot; while mature or nearly ripe pods can still be harvested, the resulting bean quality is poor.[3]

The conventional method for controlling mealybugs currently practiced by many farmers involves the application of synthetic chemical pesticides. The preference for chemical pesticides is often attributed to their easy availability, rapid action, and effectiveness in preventing crop losses.[4] However, the excessive and continuous use of these chemical agents poses significant risks to human health, potentially causing damage to the kidneys and liver, birth defects, and severe environmental pollution. To minimize reliance on synthetic chemical pesticides, there is an urgent need to explore and implement environmentally friendly control alternatives, such as botanical pesticides (biopesticides), which utilize active compounds derived from plants.[5] Botanical pesticides represent a key component of Integrated Pest Management (IPM) due to their eco-friendly nature. These biopesticides are extracts, often made from various plant parts (roots, leaves, stems, and fruits), processed into specific concentrations without altering their chemical composition.[6] Their mechanism of action is multifaceted, including acting as a repellent (deterring pests), an antifeedant (reducing pest feeding), disrupting the development of eggs, larvae, and pupae, inhibiting the reproductive system, and exhibiting neurotoxic effects.[7] The efficacy of botanical pesticides is primarily attributed to secondary metabolites, which are compounds naturally produced by higher-level plants as a defense mechanism against environmental stress and organisms like pests.[8]

Previous research has explored the insecticidal properties of various commonly available plants. Plants such as Ageratum conyzoides L. (billygoat-weed), Nicotiana tabacum (tobacco), Allium sativum (garlic), Cymbopogon nardus (citronella grass), Datura metel (devil’s trumpet), Syzygium aromaticum (clove), Zingiber officinale Rosc (ginger), and Alpinia officinarum (galangal) are known to contain bioactive compounds with potential for use as botanical pesticides against numerous pests, including mealybugs.[9] The application of crude extracts and essential oils from several plants like Cassia spectabilis, Gliricidia sepium, Cinnamomum burmannii, Allium sativum, Reutealis trisperma, and Cymbopogon nardus at a concentration of 5% has been reported to achieve mealybug mortality rates comparable to the synthetic insecticide deltamethrin.[1] Other studies have also demonstrated the effectiveness of extracts from Carica papaya and Piper betle in suppressing mealybug populations. Despite these advancements, a significant research gap exists, as most studies focus on single plant extracts or do not comprehensively evaluate the synergistic potential of combining multiple extracts at varying concentrations to determine the most optimal dosage against the cocoa mealybug, Pseudococcus lilacinus. Therefore, the novelty of this study lies in a comprehensive approach: evaluating the potential of eight different plant extracts Ageratum conyzoides, tobacco, garlic, citronella grass, Datura metel, clove, ginger, and galangal for the effective control of Pseudococcus lilacinus on cocoa pods.

This research aims to answer two fundamental questions: (1) Can the extracts from the specified eight plants be used as effective botanical pesticides against the cocoa mealybug (Pseudococcus lilacinus)? And (2) What is the most effective concentration of each plant extract for maximizing mealybug mortality? The methodology will employ a detailed laboratory screening and a dose-response bioassay. Extracts of the plant materials will be prepared using different solvents (alcohol, coconut water, and molasses) through maceration to isolate key bioactive compounds, such as alkaloids, flavonoids, and essential oils. The resulting extracts will be tested at various concentrations, such as 5%, 10%, and 15%, using a direct contact or spraying method on mealybug-infested cocoa pods. Efficacy will be measured by pest mortality rate and reduction in plant damage after treatment. It is hypothesized that the secondary metabolites in one or more of the tested botanical extracts will exhibit significant insecticidal activity, and an optimal, effective, and environmentally safer concentration will be identified, providing a sustainable alternative to chemical control in cocoa farming.

2. EXPERIMENTAL

2. Experimental

2.1. Chemicals, Equipment, and Instrumentation

The main materials used in this study included Ageratum conyzoides L. (babadotan leaves), Nicotiana tabacum (tobacco leaves), Allium sativum (garlic), Cymbopogon nardus (lemongrass), Datura metel (devil's trumpet leaves), Syzygium aromaticum (clove), Zingiber officinale Rosc. (ginger), and Alpinia officinarum (galangal). Supporting materials such as ethanol (C_2H_5OH, 96%, technical grade), coconut water, molasses (2% w/v), sugar (sucrose), distilled water (aquades), and a universal pH indicator were also used. The tools and instruments employed in this research consisted of a blender, knife, analytical balance (±0.01 g accuracy), measuring cylinder, plastic funnel, sieve, jerrycan, beaker, glass stir rod, and pH meter. In addition, personal protective equipment such as a mask, gloves, and laboratory coat were used to ensure safety during the experimental process.

2.2. Research Procedure

The preparation of the botanical pesticide began with the cleaning and cutting of all plant materials, which were then blended into a fine mixture to increase surface area and facilitate fermentation. The blended materials were transferred into a jerrycan and mixed thoroughly with 2 liters of 96% ethanol. The mixture was left to ferment under anaerobic conditions for three days to allow the release and extraction of essential oils and other bioactive compounds. After this initial fermentation, the mixture was filtered to obtain a clear liquid extract. The filtrate was then diluted using coconut water and supplemented with 2% molasses to promote beneficial microbial growth during the second fermentation stage. The resulting solution was fermented again for fourteen days under closed conditions to enhance the formation of active compounds such as alkaloids, terpenoids, and phenolic substances. Upon completion of fermentation, the botanical pesticide was ready for application and exhibited a light brown color with a pleasant, natural aroma.

The prepared botanical pesticide was applied to cocoa (Theobroma cacao) plants affected by mealybugs (Pseudococcus lilacinus). The pesticide was sprayed evenly on the leaves and stems twice a week to ensure optimal protection, as the bioactive compounds are easily degraded in the environment. Regular application was necessary to maintain the pesticide's effectiveness in controlling pest populations and protecting the plants.

2.3. Experimental Design

This research was conducted at the Chemistry Laboratory, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan (UNIMED), located on Jalan Willem Iskandar, Pasar V, Medan, North Sumatra, Indonesia. The experimental design consisted of preparing and applying the botanical pesticide to cocoa plants, followed by observation of its effects on pest population reduction, plant health, and crop quality in comparison with untreated control plants.

2.4. Target Indicators

The expected outcomes of this study included a significant decrease in the population of mealybugs on cocoa plants, improved plant health, and a reduction in crop damage. Treated plants were expected to show at

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least a 70% reduction in pest population and a 50% decrease in visible damage compared to control plants. In addition, the pesticide was expected to remain effective for approximately one to two weeks after application without inducing resistance in the target pest. Overall, the use of the botanical pesticide was anticipated to enhance plant vigor and yield quality, demonstrating its potential as an environmentally friendly alternative for pest management in cocoa cultivation.

3. RESULTS AND DISCUSSION

3.1. Efficacy (%)

The results presented in Table 4.1 indicate that the organic insecticide treatments with concentrations ranging from 10% to 50% were effective in controlling mealybug infestations. The highest efficacy percentages were observed at concentrations of 40% and 50%, both achieving 100% efficacy. The mortality of the insects occurred due to the pesticide solution applied to the plants being absorbed into the insect's body, leading to protein precipitation and accumulation in the insect's stomach. This process resulted in digestive system failure and ultimately caused insect death.[10]

The higher the concentration of the organic insecticide, the greater the percentage of insect mortality observed. This effect is attributed to the presence of several bioactive compounds such as alkaloids, tannins, and annonaceous acetogenins, which possess cytotoxic properties.[11] According to Sumantri et al. (2014), acetogenin compounds found in plants such as clove (Syzygium aromaticum) and devil's trumpet (Datura metel) can induce coagulation within the insect's digestive tract, leading to digestive malfunction and death.

This mechanism explains the mortality of mealybugs (Pseudococcus lilacinus) following the application of extracts derived from Ageratum conyzoides L. (babadotan leaves), Nicotiana tabacum (tobacco leaves), Allium sativum (garlic peels), Cymbopogon nardus (lemongrass), Datura metel (devil's trumpet leaves), Syzygium aromaticum (clove), Zingiber officinale Rosc. (ginger), and Alpinia officinarum (galangal). These plant-based ingredients acted synergistically to enhance the overall insecticidal efficacy of the organic formulation.

Table 4.1. Percentage of mealybug mortality under various organic insecticide concentrations

Treatment	**Average (%)**
Control	50.57 a
Concentration 5%	60.57 a
Concentration 10%	66.00 bc
Concentration 15%	70.00 ab
Concentration 20%	85.44 de
Concentration 25%	89.60 cde
Concentration 30%	93.32 cd
Concentration 35%	98.87 cd
Concentration 40%	100.00 e
Concentration 45%	100.00 e
Concentration 50%	100.00 e

LSD (5%) = 13.00

Note: Values followed by the same letters are not significantly different at the 5% LSD test.

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3.2. Mortality Rate

The results presented in Table 4.2 show that there was no significant difference in the average mortality rate of mealybugs among the various concentrations of the organic insecticide treatments. The fastest mortality was observed at the 50% concentration, with an average death rate of 3.50 days. Conversely, the slowest mortality rate was recorded at the 5% concentration, with mealybug death occurring after an average of 5.40 days.

The gradual decrease in mortality time along with increasing concentration indicates that higher concentrations of the organic pesticide accelerate the toxic response in insects. This may be attributed to the higher availability of active compounds such as alkaloids, terpenoids, and phenolic compounds, which interfere with the insect's nervous and digestive systems. The mode of action likely involves the inhibition of enzymatic activity and the disruption of cellular respiration, leading to faster physiological breakdown and death.

Table 3.2. Average mortality rate of mealybugs under different organic insecticide concentrations

Treatment	Average (Days)
Control	5.37
Concentration 5%	5.40
Concentration 10%	5.25
Concentration 15%	5.23
Concentration 20%	5.20
Concentration 25%	5.10
Concentration 30%	5.07
Concentration 35%	4.73
Concentration 40%	4.50
Concentration 45%	4.37
Concentration 50%	3.50

LSD (5%) = 1.08

3.3. Lethal Time 50% (LT_{50})

The results presented in Table 4.3 show that the application of organic insecticides had a significant effect on the LT_{50} values of mealybugs. The highest LT_{50} value was observed in the control treatment, reaching 250.00 hours, while the lowest LT_{50} value was recorded at the 50% concentration with an LT_{50} of 86.00 hours. These findings indicate that the higher the concentration of the organic insecticide, the faster it induces mortality in mealybug populations. The rapid lethal effect at higher concentrations is attributed to the increased presence of bioactive compounds with toxic properties, such as acetogenins, tannins, and flavonoids.

Tannins function as antinutritional and enzyme-inhibiting compounds that reduce the hydrolysis of starch and blood sugar levels in insects.[11] They can also interact with proteins to form toxic protein–tannin complexes, which inhibit α-amylase activity in the insect digestive system, leading to impaired nutrient absorption and developmental inhibition.[12] Meanwhile, flavonoids act as natural insecticidal agents by targeting the insect nervous system, disrupting mitochondrial respiration, and inhibiting electron transfer, which ultimately disturbs cellular energy production.[13] Furthermore, flavonoids alter protein structures and reduce the permeability of digestive cell walls, resulting in decreased nutrient transport efficiency and contributing to insect mortality.[4]

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Table 3.3. Lethal Time 50% (LT_{50}) of mealybugs under various concentrations of organic insecticide

Treatment	Average (Hours)
Control	250.00 d
Concentration 5%	230.00 cb
Concentration 10%	220.00 bc
Concentration 15%	200.00 cd
Concentration 20%	182.00 b
Concentration 25%	158.00 b
Concentration 30%	158.00 b
Concentration 35%	148.00 b
Concentration 40%	118.00 a
Concentration 45%	100.00 a
Concentration 50%	86.00 a

LSD (5%) = 36.32

Observation data further demonstrated that mealybug infestations on cocoa pods were completely eliminated at the 50% concentration level. According to Herminanto et al. (2010), increasing the dosage of botanical pesticide extracts enhances their toxic potency, leading to higher pest mortality. The findings of this study are consistent with those reported by Triyono and Sumarmi (2020), who noted that finished botanical pesticides typically exhibit a light brown color and a distinctive herbal aroma. The pesticide produced in this study displayed similar characteristics-a brown color and a strong yet non-dizzying aromatic scent indicating a successful fermentation process and the presence of active compounds.

The use of botanical insecticides offers several advantages for farmers due to their simple preparation process and the availability of raw materials that do not require synthetic chemicals. Employing plant-based extracts such as *Ageratum conyzoides* and other aromatic plants for pest control in cocoa cultivation is highly recommended, as it minimizes the risk of chemical contamination and preserves the quality of the cocoa fruits.

4. CONCLUSION

The study concludes that extracts from several plant species such as *Ageratum conyzoides*, tobacco, garlic, lemongrass, *Datura*, clove, ginger, and galangal are effective as botanical pesticides against mealybug

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(*Pseudococcus lilacinus*) on cacao (*Theobroma cacao L.*). Higher extract concentrations increased pest mortality, with 40–50% achieving 100% efficacy. This effect is attributed to bioactive compounds such as alkaloids, tannins, and flavonoids, which damage the digestive and nervous systems of insects. The use of plant-based pesticides is environmentally friendly, easy to produce, and beneficial in maintaining cacao quality free from chemical residues.

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