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Effects of biopesticides on the management of *Myzus persicae* Sulzer and *Phenacoccus manihoti*

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Abstract

Aphids (*Myzus persicae* Sulzer) and mealybugs (*Phenacoccus manihoti*) are two economically important pests affecting agricultural crops in Guyana. The principal mode of control is the application of synthetic insecticides, which can be prejudicial on the environment and human health. Alternatively, these pests can be controlled using plant extracts with insecticidal and repellent properties. This article highlights the effects of three plant extracts obtained from locally cultivated crops in Guyana. Gas chromatography-mass spectrometry analysis was performed to identify the chemical compounds present in each extract with high insecticidal activity against aphids and mealy bugs revealing the presence of 8, 15, and 7 chemical compounds with "eucalyptol" common to all extracts. Laboratory bioassays were conducted under environmental conditions to determine the efficacy of methanol extracts obtained from *Zingiber officinale rhizome, Mentha viridis,* and *Jatropha curcas* leaves in controlling *M. persicae* Sulzer and *P. manihoti* using the leaf dip method. Results obtained indicated that the three plant extracts were significantly ($p < 0.05$) toxic to *M. persicae* Sulzer and *P. manihoti* after 48 h exposure.

Keywords: biopesticide; integrated pest management; Guyana.

Practical Application: These plant extracts are described and suggestions made for their possible incorporation in an integrated pest management strategy for the control of *M. persicae* Sulzer and *P. manihoti.*

1 INTRODUCTION

Agriculture remains the epitome of Guyana's fast developing economy and plays a vital role in food and job security. However, challenges such as pest and disease management continue to pose a threat to the industry, especially with the inappropriate and indiscriminate use of synthetic pesticides for its control. Two pests of economic importance and concern found affecting the preponderance of agricultural crops are aphids (*Myzus persicae* Sulzer) and mealybugs (*Phenacoccus manihoti*).

Aphids and mealybugs belong to the suborder Sternorrhyncha and are classified as sap-sucking insects. These insects are known vectors for transmitting many plant pathogens affecting crops (Hull, 2014). Once encountered in high populations, the potential damage is significant, which can result in weakened plants, stunted growth, abortion of flowers, development of secondary diseases such as sooty mold, and subsequent yield reduction.

Aphids and mealybugs are generally controlled using chemical pesticides. Unfortunately, despite the efficacy attributed to its use, the indiscriminate use of chemical pesticides has given rise to many well-known and negative effects, including resistance of pest species, toxic residues in stored products, nontarget toxicity, increasing costs of application, hazards from handling, and environmental pollution (Adeyemi, 2010; Lengai et al., 2020; Liu et al., 2022). Botanicals containing active insecticidal phytochemicals are a viable alternative to replace chemical pesticides and minimize these negative effects. Empirical evidence suggests that a number of local botanicals possess insecticidal properties. Thus, there is need to determine the efficacy of their extracts.

Botanical pesticides are extracts from plants that have developed natural, biochemical mechanisms to defend themselves from animal, insect, and fungal attacks. Secondary metabolites present in these plants apparently function as defense (toxic) mechanism, which inhibits reproduction and other processes in predators (Miresmailli & Isman, 2014). Thus, extracts from these plants have the potential to provide protection or even immunity from diseases caused by some pathogens (Opender et al., 2008).

Gas chromatography-mass spectrometry (GC-MS) is an important technique used to evaluate different phytoconstituents present in various plant extracts with their chemical structures. GC-MS consist of two different analytical techniques. This technique has superior separation potency which produces high accuracy and precision of chemical fingerprints (Thamer & Thamer, 2023). Moreover, quantitative data, coupled with mass spectral database, can be given by GC-MS that is of great value for achieving the correlation between bioactive compounds and their applications in agriculture (Doshi et al., 2020).

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This study aims to evaluate the effectiveness of methanolic plant extracts (*Mentha viridis, Zingiber officinale, Jatropha curcas*) in the management of aphids (*M. persicae* (Sulzer)) and mealybugs (*P. manihoti*) and identify some of the phytochemical compounds that may be responsible for their pesticide properties.

2 MATERIALS AND METHODS

2.1 Experimental outline

A complete randomized block design consisting of four treatments including a control (methanol) and three replicate per extract were used under laboratory conditions at room temperature at NAREI's Plant Pathology, Entomology, and Weed Science Department.

2.2 Collection and processing of plant material

Leaves of physic nuts (*J. curcas*), mint (*M. viridis*), and the rhizomes of ginger (*Z. officinale*) were collected from experimental plots at NAREI Mon Repos, East Coast Demerara. The leaves and rhizomes were washed thoroughly with distilled water and placed in a solar dryer for 3 days.

2.3 Preparation of plant powder

The dried specimens were pulverized using a high-speed electric stainless steel grinder. The powder obtained from the specimens was preserved individually in airtight Glad zip-lock bags and stored in bottles in the laboratory for use in extract preparation.

2.4 Preparation of plant extract

A sample of 40 g of powdered leaves was mixed with 200 mL of methanol as solvent and allowed to stand for 48 h. The solution was then filtered using a Whatman #42 filter paper to remove leaf particles. The filtered solution was then evaporated using the BUCHI Switzerland Rotary Evaporator at 68°C to remove the methanol to obtain a concentrated extract. The concentrated extract was kept in sterile amber bottles at -20°C in the laboratory refrigerator.

2.5 Screening of phytochemical constituents using the GC-MS analysis

Phytochemical screening of botanical extracts was conducted by the Pesticide and Toxic Chemical Control Board using the Thermo Scientific instrument: Trace GC Ultra-DSQ II MS. The instrument was equipped with a Thermo TR-5 capillary column (30 m × 0.25 mm I.D. × 0.25 µm film thickness).

Using standard parameters, a Splitless Injection with a surge was performed with helium as the carrier gas at a flow rate of 1 mL min^{-1} under constant flow mode at different temperature ranges. The parameters were maintained throughout the analysis of the three samples.

The identification of the peaks was based on computer matching of the mass spectra with the National Institute of Standards and Technology (NIST 08 and NIST 08s) library.

2.6 Insect culture and laboratory bioassay

Toxicity of extracts was determined using the leaf dip method (Paramasivam & Selvi, 2017). The solvent from the concentrated extract was evaporated and 5 mL of solvent added to the extract to determine its toxicity to aphids and mealybugs. Three replicates of three uninfected cucumber and cassava leaves (4 cm in diameter) were submerged in 6 mL extract solution for 10 s with gentle agitation (to ensure the entire leaf surface is covered equally) and placed to surface-dry on paper towels (abaxial surface facing skyward). This process was repeated using the three plant extracts. A small drop of water was placed on the surface of the agar, and the leaf was placed on it to ensure adhesiveness to the agar. Ten adult insects (mealybugs and aphids) were transferred with a paint brush to the leaves of cassava and cucumber plants, respectively. The containers were then covered with nylon mesh. Bioassay method was adapted from the insecticide resistance action committee susceptibility test methods series.

2.7 Data collection and analysis

Monitoring was conducted using a magnifying glass and microscope. The observations and data were recorded at morning hours (9 am) for 24 and 48 h, respectively. The average percentage mortality in each treatment was corrected using Abbott's formula (Abbott, 1925) (Equation 1).

$$\%\ \text{Mortality} = \frac{\text{No. of dead insect} \times 100}{\text{Total No. of insect}} \quad (1)$$

All data collected were subjected to ANOVA, and the significant means were separated at 5% level using least significant difference (LSD) pairwise comparison test and Microsoft Excel.

3 RESULTS AND DISCUSSION

The results from GC-MS analysis showed 8, 15, and 7 chemical compounds were identified in methanol extracts of *M. viridis* leaves, *Z. officinale* rhizomes, and *J. curcas* leaves, respectively. The phytochemicals found included terpenoids, alkaloids, and tannins, whose compounds are known to possess pesticidal properties. Similar results were obtained by Hameed et al. (2015), who showed that these plants possessed pesticidal properties (Tables 1, 2 and 3).

This study highlights the presence of many secondary metabolites *M. viridis, Z. officinale,* and *J. curcas*. The GC-MS analysis of these extracts showed various important compounds such as cubenol, naphthalene, α-caryophyllene, eugenol, eucalyptol zingiberene, camphene, citronellal, and α-farnesene that are used as insecticides, insect repellents, semiochemicals, and pheromones (attract insect predators) (BPDB, 2016). Similar results were obtained by Opender and Walia (2009), who mentioned that methanolic plant extracts that contain compounds such as eucalyptol and citronella are ecofriendly and have the potential to control insects such as aphids, white flies, and lepidopteran pests. Abeysekera et al. (2005) related that the volatile oil of ginger is mainly a mixture of monoterpenic and sesquiterpenic compounds, responsible for the characteristic *Zingiber* flavor

Table 1. Major phytochemical compounds found in the methanolic extracts of mint (*Mentha viridis*).

Phytochemical compound	Retention time (min)	Formula	Action
Limonene	8.78	$C_{10}H_{16}$	Botanical insecticide, repellent, adjuvant, veterinary substance, metabolite (soil, water). (Karr & Coats, 1988)
Eucalyptol	9.04	$C_{10}H_{18}O$	Insecticide and repellent (Slimane et al., 2014)
Borneol	11.93	$C_{10}H_{18}O$	Fumigant and contact toxicity (Li et al., 2017)
Eugenol	14.85	$C_{10}H_{12}O_2$	Insecticide, antifeedant (Yan et al., 2021)
α-Caryophyllene	16.78	$C_{15}H_{24}$	Insecticidal and toxic effect to insect (Liu et al., 2012)
Germacrene D	17.41	$C_{15}H_{24}$	Insecticidal (Al-Ghanim et al., 2023)
Naphthalene	18.54	$C_{10}H_8$	Insecticidal (Ojianwuna & Enwemiwe, 2022)
Cubenol	21.19	$C_{15}H_{26}$	Insecticidal (Çakır et al., 2016)

Table 2. Major phytochemical compounds found in the methanolic extracts of ginger (*Zingiber officinale*).

Phytochemical compound	Retention time (min)	Formula	Action
Camphene	7.22	$C_{10}H_{16}$	Insecticide, insect attractant, pheromone. (Benelli et al., 2018)
α-Pinene	6.63	$C_{10}H_{16}$	Fungicide, botanical insecticide (ppa) (Langsi et al., 2020)
Eucalyptol	8.94	$C_{10}H_{18}O$	Insecticide and repellent (Slimane et al., 2014)
Citronellal	11.35	$C_{10}H_{18}O$	Repellent, antifeedant (Papulwar et al., 2018)
(-)-Borneol	11.93	$C_{10}H_{18}O$	Fumigant and contact toxicity (Li et al., 2017)
β-Citronellol	12.70	$C_{11}H_{22}O$	Botanical insecticide, repellent (Tabari et al., 2017)
Citral	12.79	$C_{10}H_{16}O$	Repellent and antifeedant (Dancewicz et al., 2020)
Geraniol	13.12	$C_{10}H_{18}O$	Insecticidal and repellent (Chen & Viljoen, 2010)
(-)-β-Elemene	15.26	$C_{15}H_{24}$	Insecticide and larvicides (Govindarajan & Benelli, 2016)
α-Curcumene	17.20	$C_{15}H_{26}$	Antifungal, insecticide (Tanoh et al., 2020)
α-Cubebene	17.47	$C_{15}H_{24}$	Botanical insecticide (Ogunwande et al., 2017)
Zingiberene	17.63	$C_{15}H_{24}$	Insecticide, ovicidal, and larvicidal (Foko et al., 2018)
β-Sesquiphellandrene	18.62	$C_{15}H_{24}$	Insecticidal (Chen et al., 2017)
Elemol	19.52	$C_{15}H_{26}O$	Insecticidal and antitermite (Odimegwu et al.,·2013)
Copaene	17.48	$C_{15}H_{24}$	Antimicrobial and repellent (Lull et al., 2023)

Table 3. Major phytochemical compounds found in the methanolic extracts of physic nut (*Jatropha curcas*).

Phytochemical compound	Retention time (min)	Formula	Action
Eucalyptol	9.07	$C_{10}H_{18}O$	Insecticide and repellent (Slimane et al, 2014)
Ocimene	8.83	$C_{10}H_{16}$	Antifeedant (Kang et al., 2018)
Carvone	13.07	$C_{10}H_{14}$	Insecticidal (Porto et al., 2010)
Zingiberene	17.56	$C_{15}H_{24}$	Insecticide, ovicidal, and larvicidal (Foko et al., 2018)
α-Curcumene	17.25	$C_{15}H_{26}$	Antifungal, insecticide (Tanoh et al., 2020)
α-Farnesene	17.70	$C_{15}H_{24}$	Insecticidal (Al-Ghanim et al., 2023)
β-Sesquiphellandrene	18.40	$C_{15}H_{24}$	Insecticidal (Chen et al., 2017)

of which zingiberene is a major component. However, Chu et al. (2012) reported that compounds such as *ß*-pinene and borneol have insecticidal activities and also possess contact toxicity. Research done by Opender and Walia (2009) found that compounds such as citronella are responsible for the larvicidal and repellent activity of insect pest. While *Menta* sp. have compounds that ward off insect. Further work was conducted by Shahnaz and Mohammed (2015), who confirmed that *Zingiber* volatile oil showed antibacterial and antifungal activity.

The phytochemicals found in *M. viridis, Z. officinale,* and *J. curcas* have the potential to be a natural pesticide; thus, the second half of this investigation was to gain knowledge on the effects of these three extracts against aphids and mealybugs.

Figure 1 reveals that *Z. officinale, M. viridis,* and *J. curcas* extracts obtained a 100, 96.67, and 50% mortality of *M. persicae* (Sulzer) with 24 h exposure, respectively, while the control showed the least mortality at 20%. However, after 48 h exposure, *M. viridis* and *J. curcas* showed 100% and *Z. officinale* 96.67% mortality, while the control had 46% mortality. It can be assumed that the high mortality rate is due to the active compounds found in these plants' extract and the dosage used. Similar results were obtained by Aarthi et al. (2022), who mentioned that *M. viridis* tested on rice weevil and small borer of cereals caused up to 100% mortality. Similarly, Abdoul Habou et al. (2011) reported that *J. curcas* oil reduces the attack of cowpeas aphids by 50% after 96 h, thus increasing the yields when a comparison was done with untreated control.

Table 4 shows the percentage mortality of the *M. persicae* (Sulzer) noted after 24 and 48 h periods.

The results show that all plant extracts were significantly effective against *M. persicae* (Sulzer) in comparison with the control ($p < 0.05$) at 24 and 48 h exposure.

Figure 2 reveals that at 24 h exposure time *Z. officinale, J. curcas,* and *M. viridis* obtained a 100%, 100%, and 96.67% mortality of mealybugs, respectively. The least mortality rate was observed in the control with 13.3%.

After 48 h exposure time, *Z. officinale*, *M. viridis,* and *J. curcas* showed 100% mortality rate on *P. manihoti* respectively; however, the control treatment revealed the least percentage of morality at 33.3%. The increase in the percentage mortality of cassava mealybugs is supported by the presence of phytochemicals found in the plant extracts that have pesticidal properties.

Table 5 shows the percentage mortality of the *Phenacoccus manihoti* noted after 24 and 48 h period.

The results indicate that all plant extracts significantly increase the mortality of *P. manihoti* compared to the control treatment during 48 and 24 h exposure ($p < 0.05$).

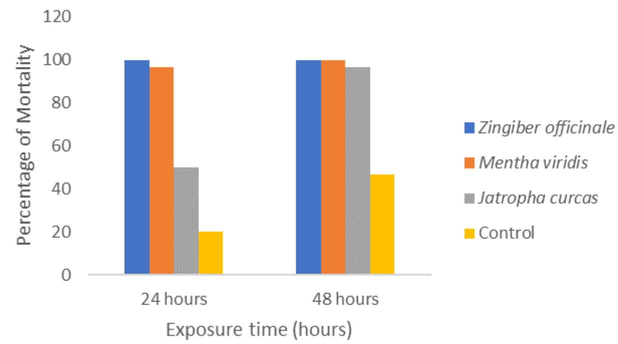

Figure 1. Percentage mortality of *Myzus persicae* (Sulzer) adults treated with various plant extracts and control group after 24 and 48 h.

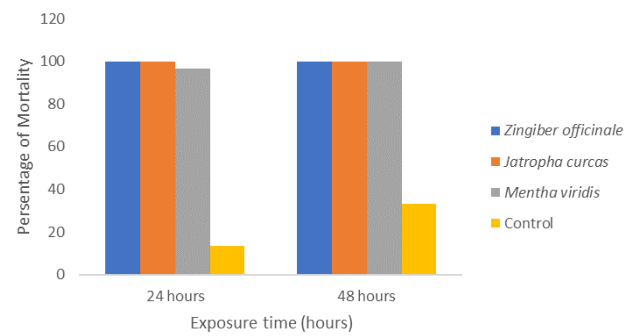

Figure 2. Percentage mortality of mealybug *(Phenacoccus manihoti)* adults treated with various plant extracts and control group after 24 and 48 h.

Table 4. Percentage mortality of the *M. persicae* (Sulzer) noted after 24 and 48 h periods.

Plant extract	**Mean percentage of aphid mortality**	
	24 h	48 h
Zingiber officinale (rhizomes)	100a	100a
Mentha viridis (leaves)	96.667a	100a
Physic nut (leaves)	50b	96.667a
Control (methanol)	20b	46.667b

*There are two groups a and b in which the means are not significantly different from one another, using LSD.

Table 5. The percentage mortality of the (*Phenacoccus manihoti*) noted after 24 and 48 h periods.

Plant extract	**Mean percentage of aphid mortality**	
	24 h	48 h
Zingiber officinale (rhizomes)	100a	100a
Mentha viridis (leaves)	96.667a	100a
Jatropha curcas (leaves)	50b	96.667a
Control (methanol)	20b	46.667b

*There are two groups a and b in which the means are not significantly different from one another, using LSD.

4 CONCLUSION

The results presented herein indicate that the methanol extract of *M. viridis, Z. officinale,* and *J. curcas* has the potential to be used as a botanical pesticide base on the compounds found. This showed significant results against *P. manihoti* and *M. persicae* (Sulzer). There was a statistically significant difference between the plant extracts and the control (methanol). Ginger was the most effective insecticide among all treatments. The use of these botanicals could be incorporated into an integrated pest management strategy, consequently reducing the need for conventional synthetic insecticides.

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