

A review of plant-derived biopesticides against the vine mealybug



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Background: *Planococcus ficus* Ben-Dov (vine mealybug) is an economically important pest that causes significant damage to grapevines. The insect has evolved different strategies of escaping synthetic insecticides. However, high diffusibility and cuticular penetration of plant-based insecticides have made these survival strategies ineffective, thereby predisposing the insects to early mortality.

Aim: This study reviewed literature on plant-based products that were screened for pest repellence and insecticidal properties with a view to exploiting their biogenic principles to minimise agricultural losses caused by vine mealybug infestation.

Setting: Related publications were sourced from Google Scholar, ScienceDirect and Web of Science databases using relevant keywords. Eligibility of the articles selected for review was determined based on their titles and abstracts, methods and materials, language (English) and year of publication (2012–2025).

Method: A total of 103 scientific articles published in English in peer-reviewed journals, three conference papers, one book chapter and seven websites were used for the review. Articles with restricted access and incomplete information were excluded.

Results: Evidence from the literature suggests that plant-based chemicals from species of *Azadirachta indica*, *Citrus aurantium*, *Eucalyptus camaldulensis*, *Calotropis procera*, *Cardamine hirsute*, *Terminalia chebula*, which exhibited a wide range of proven insecticidal properties, could be exploited to control mealybug infestation.

Conclusion: The development of new formulations from botanical ingredients with proven insecticidal properties will be beneficial to grapevine farmers amidst the quest to overcome pest resistance and expand the profit margins for small-scale and commercial farmers.

Contribution: Botanical pesticides are viable options for controlling the grapevine mealybug population to prevent depleting agricultural production.

Keywords: botanical insecticides; grapevine diseases; *Planococcus ficus*; pest management; synthetic insecticides.

Introduction

Planococcus ficus Ben-Dov (vine mealybug [VMB]), belonging to the family Pseudococcidae, is an economically important pest in global grape-growing regions, including South Africa, Australia and Argentina (Cocco et al. 2021). The significance of damage caused by the VMB to grapevines cannot be underestimated as the pest sucks and pierces the phloem tissue of grapevines, causing diversion of nutrients otherwise required for flowering and fruit production (Ahmed et al. 2023; Timm & Reineke 2014). Whilst feeding on grapevines, the pest excretes honeydew on the leaves that enhances the growth of sooty mould fungi on grape clusters, which compromises the fruit quality as the grape clusters become dehydrated (Cocco et al. 2021; Mansour et al. 2018). In addition, VMB has been identified as a vector for grapevine leaf-roll-associated virus 3 (GLRaV-3), which reduces photosynthesis by at least 65%, leading to reduced girth of stems and root growth (Almeida et al. 2013; Bertin et al. 2016).

Several conventional strategies of controlling VMB depend majorly on insecticidal chemicals, which kill the nymph and adult insects (Franco, Zada & Mendel 2009). Synthetic insecticides can either be applied directly to control VMB populations or used in conjunction with semi-chemicals such as sex pheromones for purposes including monitoring, mass trapping, mating disruption and kairomonal attraction to enhance the performance of natural parasitoids (Mansour et al. 2018). However, synthetic insecticides have adverse effects on human health, the environment

and other non-target organisms. These negative effects, along with the development of insect resistance, often resulting from the repeated or excessive use of insecticides from the same chemical family, have led to the search for safer and more sustainable alternative approaches (Pu & Chung 2024).

The adverse effects attributed to the application of synthetic insecticides sparked the rising demand for sustainable pest management options for VMB to minimise loss and optimise yield quality (Khan & Ahmad 2019; Pekár 2013). These approaches may include chemical and biological control and other integrated pest management (IPM) techniques involving prophylactic and cultural practices, specialised encyrtid parasitoids, coccinellid predators, and the application of semi-chemicals in various pheromone-mediated pest management practices. Despite their proven insecticidal potential, entomopathogens and natural products are not yet widely adopted (Baker, Green & Loker 2020).

The use of crude extracts and essential oils from plants as botanical insecticides is a promising alternative for managing grapevine diseases. Several studies have profiled the toxicity of plant extracts against different pests to evaluate the insecticidal properties of the plant species and propagate their potential use as botanical insecticides (Arokiyaraj, Bhattacharyya & Reddy 2022). This approach utilises secondary metabolites from plants such as phenolic acids, terpenoids, alkaloids, saponins, tannins and flavonoids. These plant-based biologically active chemicals have shown efficacy against VMB through repellence and other defence mechanisms, including inhibition of the insect's acetylcholinesterase and antifeedant activities (Peschiutta et al. 2018).

The effectiveness of botanical insecticides in controlling insect populations can vary depending on the physiological characteristics of the target pest, the type of plant materials used, the chemical properties of the plant materials and their modes of action (Grdiša et al. 2013; Ludwaba et al. 2024). Whilst the availability of effective commercial plant-based products remains limited amidst increasing global demand, some botanical insecticides, such as neem and pyrethrins, are already registered and commercially available in the agricultural market (Acheuk et al. 2022). This article aimed to review published literature on plant extracts evaluated for insecticidal and repellent properties against a wide range of pests, with a view to exploiting their biogenic principles in minimising agricultural losses caused by VMB infestation.

Methods

Google Scholar, ScienceDirect and Web of Science databases were used to identify related publications to the topic under review from 2012 to 2025. The following keywords and phrases were searched: 'botanicals against *Planococcus ficus*', 'chemical insecticides for vineyard management', 'bioinsecticides', 'plant-based insecticides', 'bioinsecticides and their mode of action', 'plant-derived insecticides

against *Planococcus ficus*', 'repellent activities of plant extracts', 'insecticidal plants', 'botanical insecticide'. A total of 103 scientific articles published in English in peer-reviewed journals, three conference papers, one book chapter and seven websites were used to gather data. Articles with restricted access and incomplete information were excluded. The articles eligible for this review were articles from 2012 to 2025, based on the title and abstract, and methods and materials to determine the plant parts used and the type of extraction method. The review is focusing on a global scale of plant extracts used against pests and the commercial products that have been developed using plant extracts.

Review findings

Toxic plants against a range of pests

Plant materials have demonstrated toxicity against a range of pests when applied to reduce losses and damage before and after harvest. Most targeted parts of the plant include leaves, roots, flower buds and stem bark (Isman 2020). The crude extracts, pure compounds and essential oils extracted from different plant parts largely constitute these plant-based chemicals, which exhibit different gradients of selective mortality and antifeedant effects on insects by disrupting their consciousness, larvicidal effects or inhibition by gustatory responses. A list of plants tested against a wide range of pests is presented in Table 1, whilst Table 2 shows selected plants tested for insecticidal activity against mealybug species.

Aromatic plants such as *Mentha* spp., *Lavendula* spp., *Cedrus* spp., *Pinus* spp., *Eucalyptus* spp., *A. indica*, and *Citronella* spp. and many more are depots of repellent and insecticidal chemicals. The repellency and insecticidal properties of extracts from these plants may be attributed to the characteristic permeation of insect exoskeleton, crevices and other materials that may act as shields to synthetic insecticides (Chandi & Kaur 2021). The insecticidal mechanisms of plant extracts, such as pyrethrum extracts, may include hyper-activating insect voltage-gated sodium channels, which could result in insect paralysis and death (Liu et al. 2021). In some cases, phytochemicals and essential oils from plants may act as chitin synthesis inhibitors by blocking the development of chitinous exoskeleton, making insects susceptible to early mortality because of indiscriminate interference with insect hormones during moulting (Chandi & Kaur 2021). The insect repellent activities of volatile compounds from plants have been demonstrated to involve receptor proteins at several binding sites that enable the transformation of chemical signals into electrical signals, which are then picked up by electroantennographic recordings during receptor-repellent interactions (Pulido et al. 2022). Pulido et al. (2022) further demonstrated in proteomic and electrophysiological experiments that repellent exposure disrupts ionic channel activity and modifies neuronal synapses and energy production processes in mosquitoes. Repellents may interfere with or mask the perception of host-attractant signals by exciting repulsion receptors (Liu et al. 2021).

TABLE 1: Toxic plants against a range of pests.

Plant	Family	Plant parts used	Extraction method	Solvent used	Pests	References
<i>Acacia modesta</i>	Fabaceae	Whole plant (stem, bark, root, leaves and seeds)	Maceration	Water	<i>Tribolium castaneum</i>	Nazeefullah, Dastagir & Ahmad 2014
<i>Glycyrrhiza glabra</i>	Fabaceae	Whole plants (rhizome, leaves and stem)	Maceration	Water	<i>Tribolium castaneum</i>	Nazeefullah et al. 2014
<i>Daphne mucronate</i>	Thymelaeaceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> , <i>Tribolium castaneum</i> , <i>Spodoptera exigua</i>	Guru-Pirasanna-Pandi et al. 2018
<i>Tagetes minuta</i>	Asteraceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> <i>Tribolium castaneum</i> <i>Spodoptera exigua</i>	Khan et al. 2017
<i>Calotropis procera</i>	Apocynaceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> <i>Tribolium castaneum</i> <i>Spodoptera exigua</i>	Khan et al. 2017
<i>Boenninghausenia albiflora</i>	Rutaceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> <i>Tribolium castaneum</i> <i>Spodoptera exigua</i>	Khan et al. 2017
<i>Eucalyptus sideroxylon</i>	Myrtaceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> <i>Tribolium castaneum</i> <i>Spodoptera exigua</i>	Khan et al. 2017
<i>Cinnamomum camphora</i>	Lauraceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> <i>Tribolium castaneum</i> <i>Spodoptera exigua</i>	Khan et al. 2017
<i>Isodon rugosus</i>	Lamiaceae	No specified	Maceration	Methanol	<i>Acyrtosiphon pisum</i> <i>Drasophila melanogaster</i> <i>Tribolium castaneum</i> <i>Spodoptera exigua</i>	Khan et al. 2017
<i>Cleistanthus collinus</i>	Phyllanthaceae	Leaves	Soxhlet apparatus	Acetone	<i>Tribolium castaneum</i>	Guru-Pirasanna-Pandi et al. 2018
<i>Peganum harmala</i>	Zygophyllaceae	Seed	Maceration	Acetone	<i>Tribolium castaneum</i> , <i>Aphis fabae</i> , <i>Aphis gossypii</i> , <i>Aphis nerii</i> and <i>Myzus persicae</i>	Salari et al. 2012
<i>Urtica dioica</i>	Urticaceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i> <i>Phenacoccus solenopsis</i>	Eldesouky, Tawfeek & Salem 2024
<i>Pluchea dioscoridis</i>	Asteraceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i> <i>Phenacoccus solenopsis</i>	Eldesouky et al. 2024
<i>Xanthium strumarium</i>	Asteraceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i> <i>Phenacoccus solenopsis</i>	Eldesouky et al. 2024
<i>Hyoscyamus albus</i>	Solanaceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i> , <i>Phenacoccus solenopsis</i>	Eldesouky et al. 2024
<i>Justicia adhatoda</i>	Acanthaceae	Leaves	Decoction	Distilled water	<i>Phenacoccus solenopsis</i>	Madasamy et al. 2023
<i>Ipomea carnea</i>	Convolvulaceae	Leaves	Decoction	Distilled water	<i>Phenacoccus solenopsis</i>	Madasamy et al. 2023
<i>Pongamia glabra</i>	Fabaceae	Leaves	Decoction	Distilled water	<i>Phenacoccus solenopsis</i>	Madasamy et al. 2023
<i>Annona squamosa</i>	Annonaceae	Leaves	Decoction	Distilled water	<i>Phenacoccus solenopsis</i>	Madasamy et al. 2023
<i>Tithonia diversifolia</i>	Asteraceae	Leaves	Maceration	Water	<i>Aphis fabae</i> , <i>Ootheca mutabilis</i> , <i>Ootheca bennigseni</i> , <i>Epicauta albobittata</i> , <i>Epicauta limbatipennis</i>	Mkenda et al. 2015
<i>Tephrosia vogelii</i>	Fabaceae	Leaves	Maceration	Water	<i>Aphis fabae</i> , <i>Ootheca mutabilis</i> , <i>Ootheca bennigseni</i> , <i>Epicauta albobittata</i> , <i>Epicauta limbatipennis</i>	Mkenda et al. 2015
<i>Vernonia amygdalina</i>	Asteraceae	Leaves	Maceration	Water	<i>Aphis fabae</i> , <i>Ootheca mutabilis</i> , <i>Ootheca bennigseni</i> , <i>Epicauta albobittata</i> , <i>Epicauta limbatipennis</i>	Mkenda et al. 2015
<i>Lippia javanica</i>	Verbenaceae	Leaves	Maceration	Water	<i>Aphis fabae</i> , <i>Ootheca mutabilis</i> , <i>Ootheca bennigseni</i> , <i>Epicauta albobittata</i> , <i>Epicauta limbatipennis</i>	Mkenda et al. 2015
<i>Nicotiana megalosiphon</i>	Solanaceae	Leaves	Maceration	Tap water	<i>Plutella xylostella</i> <i>Brevicoryne brassicae</i> <i>Myzus persicae</i>	Amoabeng et al. 2018
<i>Mentha satuireioides</i>	Lamiaceae	Leaves	Maceration	Tap water	<i>Plutella xylostella</i> <i>Brevicoryne brassicae</i> <i>Myzus persicae</i>	Amoabeng et al. 2018
<i>Azadirachta indica</i>	Meliaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Ocimum basilicum</i>	Lamiaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Nicotiana tabacum</i>	Solanaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Cymbopogon citratus</i>	Gramineae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Tephrosia vogelii</i>	Fabaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Aloe vera</i>	Asphodelaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Lantana camara</i>	Verbenaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Trichilia emetica</i>	Meliaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020

Table 2 continues on the next page →

TABLE 1 (Continues...) : Toxic plants against a range of pests.

Plant	Family	Plant parts used	Extraction method	Solvent used	Pests	References
<i>Vernonia amygdalina</i>	Asteraceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Lippia javanica</i>	Verbenaceae	Leaves	Maceration	Water	<i>Spodoptera frugiperda</i>	Phambala et al. 2020
<i>Syzygium cumini</i>	Myrtaceae	Peel and seed	Maceration	Ethanol	<i>Tribolium confusum</i>	Zaka et al. 2019
<i>Citrus reticulata</i>	Rutaceae	Peel and seed	Maceration	Ethanol	<i>Tribolium confusum</i>	Zaka et al. 2019
<i>Lantana camara</i>	Verbenaceae	Leaves	Maceration	Water	<i>Spodoptera exigua</i>	Asad et al. 2023
<i>Aloe vera</i>	Asphodelaceae	Leaves	Maceration	Water	<i>Spodoptera exigua</i>	Asad et al. 2023
<i>Azadirachta indica</i>	Meliaceae	Leaves	Maceration	Water	<i>Spodoptera exigua</i>	Asad et al. 2023
<i>Cymbopogon citratus</i>	Poaceae	Leaves	Maceration	Water	<i>Spodoptera exigua</i>	Asad et al. 2023
<i>Nicotiana tabacum</i>	Solanaceae	Leaves	Maceration	Water	<i>Spodoptera exigua</i>	Asad et al. 2023
<i>Ocimum basilicum</i>	Lamiaceae	Leaves	Maceration	Water	<i>Spodoptera exigua</i>	Asad et al. 2023
<i>Saponaria officinalis</i>	Caryophyllaceae	Roots	Maceration	Drinkable water	<i>Tetranychus urticae</i>	Pavela 2017
<i>Azadirachta indica</i>	Meliaceae	Seed kernel	Maceration	Water	<i>Mythimna separate</i>	Kumar et al. 2017
<i>Artemisia annua</i>	Asteraceae	Leaves	Maceration	Water	<i>Mythimna separate</i>	Kumar et al. 2017
<i>Anthemis cotula</i>	Asteraceae	Leaves	Maceration	Water	<i>Mythimna separate</i>	Kumar et al. 2017
<i>Datura stramonium</i>	Solanaceae	Leaves	Maceration	Water	<i>Mythimna separate</i>	Kumar et al. 2017
<i>Zingiber officinale</i>	Zingiberaceae	Rhizome	Maceration	Water	<i>Mythimna separate</i>	Kumar et al. 2017
<i>Juglans regia</i>	Juglandaceae	Leaves	Maceration	Water	<i>Mythimna separate</i>	Kumar et al. 2017
<i>Allium sativum</i>	Amaryllidaceae	Bulb	Maceration	Distilled water	<i>Plutella xylostella</i> , <i>Brevicoryne brassicae</i> , <i>Hellula undalis</i> , <i>Trichoplusia ni</i>	Baidoo & Mochiah 2016
<i>Capsicum frutescens</i>	Solanaceae	Fruit	Maceration	Distilled water	<i>Brevicoryne brassicae</i> , <i>Hellula undalis</i> , <i>Trichoplusia ni</i>	Baidoo & Mochiah 2016
<i>Thevetia peruviana</i>	Apocynaceae	Seeds	Maceration	Aqueous	<i>Sahlbergella singularis</i>	Mboussi et al. 2018
<i>Azadirachta indica</i>	Meliaceae	Seeds	Maceration	Aqueous	<i>Sahlbergella singularis</i>	Mboussi et al. 2018

Note: Please see the full reference list of Mange, T., Tanga, M., Jimoh, M.O., Fanadzo, M. & Nchu, F., 2026, 'A review of plant-derived biopesticides against the vine mealybug', *Journal of Medicinal Plants for Economic Development* 10(1), a306. <https://doi.org/10.4102/jomped.v10i1.306>.

Repellent plant extracts against mealybugs and other pest species

Compared to studies on insect mortality, relatively few investigations have focused on the repellency of plant extracts (Peschiutta et al. 2018). The repellent activity of botanical extracts largely depends on the methods of extraction and type of solvent used (Jaleel et al. 2020). Several plant species, their extraction methods, and solvent types have been tested against various plant species (Table 3). In a study by Singh (2012), methanolic leaf extracts of *A. indica*, *Eucalyptus globulus* and *Ocimum basilicum* showed 97.0%, 93.0% and 88.0% repellency, respectively, against cotton mealybug (*Phenacoccus solenopsis*) after 24 h. The repellent effect was attributed to active compounds in these plants. For example, the bioactive alkaloid azadirachtin and other tetranortriterpenoids found in *A. indica* are responsible for its strong repellency (Guchhait et al. 2025). Similarly, Sombra et al. (2022) reported that compounds such as alkaloids, phenols and esters may act at multiple sites within insect physiology, exhibiting biocidal, repellent, antifeedant and developmental disruption activities.

Several plants, including *Azadirachta indica*, *Eucalyptus globulus*, *Prunus persica* and *Polyalthia longifolia*, have been reported to exhibit significant repellency against mealybugs (Peschiutta et al. 2018). In another study, Baliyarsingh, Mishra and Rath (2021) reported high repellency of leaf extracts of *Andrographis paniculata* against *Tribolium castaneum* (red flour beetle). In addition, Roonjho et al. (2013) tested the toxicity and repellency of different solvent extracts (petroleum ether, ethanol and acetone) of *Prunus persica*, *Sonchus oleraceus*, *Silybum marianum*, *Polyalthia longifolia* and *Eucalyptus globulus* against cotton mealybug. Findings from the study indicated that the ethanol

extract of *P. persica* exerted 72.5% repellency against the cotton pest, whilst other plant extracts exhibited lower repellency compared to *P. persica*.

Registered botanical insecticides and their mode of action

The main categories of botanical products include pyrethrum, rotenone, neem and their essential oils (Sarwar 2023). Among these, pyrethrum and neem are derived from plants that are widely used to produce some of the most commercially available botanical pesticides (Table 4). For example, rotenone is a flavonoid compound found in the roots of several plant species and is known for its insecticidal properties (Shivkumara et al. 2019). Nicotine, ryania and sabadilla are other plant-based insecticides with documented insecticidal potency; however, their mechanisms of action are not well understood (Campos et al. 2019; Peschiutta et al. 2019).

The potency of plant-derived insecticides is determined by different mechanisms which involve targeting biological systems, such as endocrine, nervous and respiratory systems, as well as homeostasis, including water regulation. In the nervous system, botanical insecticides target acetylcholinesterase, tyramine and octopamine receptors, sodium and g-aminobutyric acid-gated chloride channels (Regnault-Roger, Vincent & Arnason 2012). Unlike conventional insecticides, which typically rely on a single active ingredient, botanical insecticides leverage the synergistic effects of heterogenous chemicals in plants, which influence both behavioural and physiological processes, providing a multifaceted mode of action. Their ability to interfere with insect physiology makes them a promising alternative that aligns with IPM (La Pergola et al. 2017).

TABLE 2: Selected plants tested for insecticidal activity against mealybug species.

Scientific name	Botanical family	Solvent used	Mealybug species	Activity	References
<i>Azadirachta indica</i>	Meliaceae	Water, Ethanol, Acetone	<i>Drosicha mangiferae</i>	Mortality	Majeed et al. 2018
<i>Citrus aurantium</i>	Rutaceae	Water, Ethanol, Acetone	<i>Drosicha mangiferae</i>	Mortality	Majeed et al. 2018
<i>Citrus sinensis</i>	Rutaceae	Water, Ethanol, Acetone	<i>Drosicha mangiferae</i>	Mortality	Majeed et al. 2018
<i>Eucalyptus camaldulensis</i>	Myrtaceae	Water, Ethanol, Acetone	<i>Drosicha mangiferae</i>	Mortality	Majeed et al. 2018
<i>Azadirachta indica</i>	Meliaceae	n-Hexane, Acetone, Water	<i>Phenacoccus solenopsis</i>	Mortality	Badshah et al. 2015
<i>Azadirachta indica</i>	Meliaceae	Water	<i>Phenacoccus solenopsis</i>	Mortality	Mamoon-Ur-Rashid et al. 2016
<i>Azadirachta indica</i>	Meliaceae	Distilled water	<i>Phenacoccus solenopsis</i>	Mortality	Umar Sardar et al. 2018
<i>Calotropis procera</i>	Asclepiadaceae	Distilled water	<i>Phenacoccus solenopsis</i>	Mortality	Umar Sardar et al. 2018
<i>Cardamine hirsute</i>	Cardamine	Distilled water	<i>Phenacoccus solenopsis</i>	Mortality	Umar Sardar et al. 2018
<i>Trachyspermum ammi</i>	Apiaceae	Distilled water	<i>Phenacoccus solenopsis</i>	Mortality	Umar Sardar et al. 2018
<i>Terminalia chebula</i>	Terminalia	Distilled water	<i>Phenacoccus solenopsis</i>	Mortality	Umar Sardar et al. 2018
<i>Allium sativum</i>	Amaryllidaceae	Distilled water	<i>Phenacoccus solenopsis</i>	Mortality	Umar Sardar et al. 2018
<i>Azadirachta indica</i>	Meliaceae	Distilled water	<i>Drosicha mangiferae</i>	Mortality	Rizwan et al. 2022
<i>Eucalyptus camaldulensis</i>	Myrtaceae	Distilled water	<i>Drosicha mangiferae</i>	Mortality	Rizwan et al. 2022
<i>Datura stramonium</i>	Solanaceae	Distilled water	<i>Drosicha mangiferae</i>	Mortality	Rizwan et al. 2022
<i>Chenopodium album</i>	Amaranthaceae	Distilled water	<i>Drosicha mangiferae</i>	Mortality	Rizwan et al. 2022
<i>Cymbopogon citratus</i>	Poaceae	Distilled water	<i>Drosicha mangiferae</i>	Mortality	Rizwan et al. 2022
<i>Azadirachta indica</i>	Meliaceae	Distilled water	<i>Rastrococcus invadens</i>	Mortality	Fawrou Seye et al. 2022
<i>Azadirachta indica</i>	Meliaceae	Ethanol	<i>Phenacoccus solenopsis</i>	Mortality	Arif et al. 2015
<i>Nicotiana tabacum</i>	Solanaceae	Ethanol	<i>Phenacoccus solenopsis</i>	Mortality	Arif et al. 2015
<i>Azadirachta indica</i>	Meliaceae	Methanol	<i>Dysmicoccus brevipes</i>	Mortality	Talib et al. 2023
<i>Phaleria macrocarpa</i>	Thymelaeaceae	Methanol	<i>Dysmicoccus brevipes</i>	Mortality	Talib et al. 2023
<i>Andrographis paniculata</i>	Acanthaceae	Methanol, Ethanol	<i>Phenacoccus solenopsis</i>	Mortality	Bala, Ganesa Raja & Author 2019
<i>Eucalyptus globulus</i>	Myrtaceae	Methanol, Ethanol	<i>Phenacoccus solenopsis</i>	Mortality	Roonjho et al. 2013
<i>Calotropis gigantea</i>	Apocynaceae	Distilled water	<i>Maconellicoccus hirsutus</i>	Mortality	Devi, Jeyarajan Nelson & Kannan 2018
<i>Ocimum sanctum</i>	Lamiaceae	Distilled water	<i>Phenacoccus solenopsis</i> <i>Paracoccus marginatus</i>	Mortality	Thammayya et al. 2024
<i>Andrographis paniculata</i>	Acanthaceae	Distilled water	<i>Phenacoccus solenopsis</i> <i>Paracoccus marginatus</i>	Mortality	Thammayya et al. 2024
<i>Annona squamosa</i>	Annonaceae	Distilled water	<i>Phenacoccus solenopsis</i> <i>Paracoccus marginatus</i>	Mortality	Thammayya et al. 2024
<i>Adathoda vasica</i>	Acanthaceae	Ethanol, Water	<i>Maconellicoccus hirsutus</i>	Mortality	Mohamed et al. 2021
<i>Trigonella foenum–Graecum</i>	Fabaceae	Ethanol Water	<i>Maconellicoccus hirsutus</i>	Mortality	Mohamed et al. 2021
<i>Eucalyptus Camaldulensis</i>	Myrtaceae	Ethanol	<i>Planococcus citri</i>	Mortality	Bajwa et al. 2020
<i>Azadirachta indica</i>	Meliaceae	Ethanol	<i>Planococcus citri</i>	Mortality	Bajwa et al. 2020
<i>Zingiber officinale</i>	Zingiberaceae	Ethanol	<i>Planococcus citri</i>	Mortality	Bajwa et al. 2020
<i>Allium sativum</i>	Amaryllidaceae	Ethanol	<i>Planococcus citri</i>	Mortality	Bajwa et al. 2020
<i>Tectona grandis</i>	Lamiaceae	Ethanol, methanol	<i>Phenacoccus manihoti</i>		Pumnuan, Insung & Montri 2021
<i>Allium sativum</i>	Amaryllidaceae	Methanol	<i>Pseudococcus viburni</i> Signoret	Mortality	Ramzi et al. 2022
<i>Gliricidia sp.</i>	Fabaceae	Ethanol	<i>Planococcus citrii</i>	Mortality	Tintumol et al. 2022
<i>Ocimum sanctum</i>	Lamiaceae	Ethanol	<i>Planococcus citrii</i>	Mortality	Tintumol et al. 2022
<i>Capsicum frutescence</i>	Solanaceae	Ethanol	<i>Planococcus citrii</i>	Mortality	Tintumol et al. 2022
<i>Elaeagnus latifolia</i>	Elaeagnaceae	Water, Ethanol, Hexane	<i>Phenacoccus manihoti</i>	Mortality	Pumnuan et al. 2019
<i>Capsicum frutescens</i>	Solanaceae	Ethanol	<i>Ferrisia virgata</i>	Mortality	Roddee, Nonkheang & Klangjoho 2020
<i>Allium sativum</i>	Amaryllidaceae	Ethanol	<i>Ferrisia virgata</i>	Mortality	Roddee et al. 2020
<i>Piper nigrum</i>	Piperaceae	Ethanol	<i>Ferrisia virgata</i>	Mortality	Roddee et al. 2020
<i>Azadirachta indica</i>	Meliaceae	Ethanol	<i>Ferrisia virgata</i>	Mortality	Roddee et al. 2020
<i>Ageratum conyzoides</i>	Asteraceae	Ethanol	<i>Rastrococcus invadens</i>	Mortality	Mano et al. 2023
<i>Hyptis suaveolens</i>	Lamiaceae	Ethanol	<i>Rastrococcus invadens</i>	Mortality	Mano et al. 2023

Note: Please see the full reference list of Mange, T., Tanga, M., Jimoh, M.O., Fanadzo, M. & Nchu, F., 2026, 'A review of plant-derived biopesticides against the vine mealybug', *Journal of Medicinal Plants for Economic Development* 10(1), a306. <https://doi.org/10.4102/jomped.v10i1.306>.

Dalmatian pyrethrum

Pyrethrum, derived from the *Dalmatian pyrethrum* plant (*Tanacetum cinerariifolium* L.) contains six active ingredients known as pyrethrins, which are insecticidal esters. These are categorised into two groups, namely Pyrethrins I and Pyrethrins II. They are fast-acting and cause immediate 'knockdown' paralysis in insects (Sarwar 2023). Their neurotoxic mechanism of action involves blocking voltage-gated sodium channels in the insect nervous system, ultimately leading to paralysis and death upon contact, whether applied as a spray or powder (Chen et al. 2018;

Sarwar 2023). The insecticidal activity of the pyrethrins results from the synergistic action of the six ingredients. Pyrethrins are effective against a wide range of insect pests from various taxonomical orders. However, their moderate toxicity to mammals and non-target insect species limits their widespread application (Jeran et al. 2021).

Neem

Neem is the common name for *Azadirachta indica* Juss (Meliaceae), a tree native to the Indo-Pak subcontinent (Badshah et al. 2015). The tree contains several potent bioactive

TABLE 3: Repellent plants against mealybugs and other pests.

Scientific name	Family	Plant part	Extraction method	Solvent used	Pest species	Reference
<i>Psidium guajava</i>	Myrtaceae	Leaves	Maceration	Ethanol	<i>Sitophilus oryzae</i>	Akhtar et al. 2013
<i>Citrus reticulata</i>	Rutaceae	Fruit peel	Maceration	Ethanol	<i>Sitophilus oryzae</i>	Akhtar et al. 2013
<i>Citrus limon</i>	Rutaceae	Fruit peel	Maceration	Ethanol	<i>Sitophilus oryzae</i>	Akhtar et al. 2013
<i>Citrus sinensis</i>	Rutaceae	Fruit peel	Maceration	Ethanol	<i>Sitophilus oryzae</i>	Akhtar et al. 2013
<i>Azadirachta indica</i>	Meliaceae	Leaves	Maceration	Ethanol	<i>Sitophilus oryzae</i>	Akhtar et al. 2013
<i>Azadirachta indica</i>	Meliaceae	Seeds	Maceration	Water	<i>Sugarcane mealybug</i>	Miah et al. 2018
<i>Azadirachta indica</i>	Meliaceae	Seeds	Maceration	Acetone	<i>Bactrocera dorsalis</i> <i>Bactrocera correcta</i>	Jaleel et al. 2020
<i>Piper nigrum</i>	Piperaceae	Seeds	Maceration	Acetone	<i>Bactrocera dorsalis</i> <i>Bactrocera correcta</i>	Jaleel et al. 2020
<i>Seriphidium brevifolium</i>	Asteraceae	Seeds	Maceration	Acetone	<i>Bactrocera dorsalis</i> <i>Bactrocera correcta</i>	Jaleel et al. 2020
<i>Peganum harmala</i>	Meliaceae	Seeds	Maceration	Acetone	<i>Myzus persicae</i>	Salari et al. 2012
<i>Toona sureni</i>	Meliaceae	Seeds	Maceration	Methanol	<i>Tribolium castaneum</i>	Parvin et al. 2012
<i>Adathoda vassica</i>	Acanthaceae	Leaves	Soxhlet method	Ethyl acetate	<i>Spodoptera frugiperda</i>	Henagamage et al. 2023
<i>Dathura metel</i>	Solanaceae	Leaves	Soxhlet method	Ethyl acetate	<i>Spodoptera frugiperda</i>	Henagamage et al. 2023
<i>Tagetes erecta</i>	Asteraceae	Leaves	Soxhlet method	Ethyl acetate	<i>Spodoptera frugiperda</i>	Henagamage et al. 2023
<i>Urtica dioica</i>	Urticaceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i> <i>Phenacoccus solenopsis</i>	Eldesouky et al. 2024
<i>Hyoscyamus albus</i>	Solanaceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i> <i>Phenacoccus solenopsis</i>	Eldesouky et al. 2024
<i>Pluchea dioscoridis</i>	Asteraceae	Aerial parts	Maceration	Methanol	<i>Aphis gossypii</i>	Eldesouky et al. 2024
<i>Xanthium strumarium</i>	Asteraceae	Aerial parts	Maceration	Methanol	<i>Phenacoccus solenopsis</i>	Eldesouky et al. 2024
<i>Andrographis paniculata</i>	Acanthaceae	Leaves	Soxhlet	Methanol & Ethanol	<i>Phenacoccus solenopsis</i>	Bala et al. 2019
<i>Eucalyptus globulus</i>	Myrtaceae	Leaves	Soxhlet		<i>Phenacoccus solenopsis</i>	Roonjho et al. 2013
<i>Toddalia asiatica</i>	Rutaceae	Leaf and fruit	Maceration	Hexane, Diethyl ether, Methanol	<i>Callosobruchus maculatus</i> , <i>Sitophilus oryzae</i> , <i>Tribolium castaneum</i>	Nattudurai et al. 2015
<i>Eucalyptus globulus</i>	Myrtaceae	Leaves	Maceration	Acetone, Ethanol Petroleum ether	<i>Phenococcus solenopsis</i>	Roonjho et al. 2013
<i>Prunus persica</i>	Rosaceae	Leaves	Maceration	Acetone, Ethanol Petroleum ether	<i>Phenococcus solenopsis</i>	Roonjho et al. 2013
<i>Polyalthia longifolia</i>	Annonaceae	Leaves	Maceration	Acetone, Ethanol Petroleum ether	<i>Phenococcus solenopsis</i>	Roonjho et al. 2013
<i>Sonchus oleraceus</i>	Asteraceae	Leaves	Maceration	Acetone, Ethanol Petroleum ether	<i>Phenococcus solenopsis</i>	Roonjho et al. 2013
<i>Silybum marianum</i>	Asteraceae	Leaves	Maceration	Acetone, Ethanol Petroleum ether	<i>Phenococcus solenopsis</i>	Roonjho et al. 2013
<i>Nigella sativa</i>	Ranunculaceae	Seeds	Maceration	Acetone	<i>Tribolium castaneum</i>	Sagheer et al. 2014
<i>Syzygium aromaticum</i>	Myrtaceae	Flower buds	Maceration	Acetone	<i>Tribolium castaneum</i>	Sagheer et al. 2014
<i>Trachyspermum ammi</i>	Apiaceae	Seeds	Maceration	Acetone	<i>Tribolium castaneum</i>	Sagheer et al. 2014
<i>Caesalpinia bonducella</i>	Fabaceae	Leaves	Soxhlet	Methanol, Ethanol, Water	<i>Phenacoccus solenopsis</i>	Bala et al. 2019
<i>Ocimum sanctum</i>	Lamiaceae	Leaves	Soxhlet	Methanol, Ethanol, Water	<i>Phenacoccus solenopsis</i>	Bala et al. 2019
<i>Solanum torvum</i>	Solanaceae	Leaves	Soxhlet	Hexane, Ethyl acetate, Methanol	<i>Callosobruchus maculatus</i>	Murugesan et al. 2021
<i>Azadirachta indica</i>	Meliaceae	Not specified	Maceration	Acetone	<i>Tribolium castaneum</i>	Khan et al. 2013
<i>Eucalyptus globules</i>	Myrtaceae	Not specified	Maceration	Acetone	<i>Tribolium castaneum</i>	Khan et al. 2013
<i>Citrus limon</i>	Rutaceae	Not specified	Maceration	Acetone	<i>Tribolium castaneum</i>	Khan et al. 2013
<i>Allium sativum</i>	Amaryllidaceae	Not specified	Maceration	Acetone	<i>Tribolium castaneum</i>	Khan et al. 2013

Note: Please see the full reference list of Mange, T., Tanga, M., Jimoh, M.O., Fanadzo, M. & Nchu, F., 2026, 'A review of plant-derived biopesticides against the vine mealybug', *Journal of Medicinal Plants for Economic Development* 10(1), a306. <https://doi.org/10.4102/jomped.v10i1.306>.

compounds, including azadirachtin, nimbin, meliantriol, desacetylnimbin, nimbidin, salannin and desacetylsalannin. Over 100 chemical compounds have been identified from neem, with azadirachtin being the most effective among them. According to Jababu, Kopta and Pokluda (2016); Sarwar (2023), Azadirachtin has two significant effects on insects. At the physiological level, it blocks the prothoracic gland from synthesising and discharging moulting hormones (ecdysteroids), which results in incomplete ecdysis in immature insects. In adult female insects, a similar mechanism results in sterility.

Neem exhibits multiple insecticidal properties, acting as an insect growth regulator, antifeedant and sterilant. It also affects insect vigour, longevity and fecundity. Neem has demonstrated

effectiveness in controlling a wide range of agricultural insect pests. For example, a study reported by Majeed et al. (2018) found that the neem extract was the most toxic against adult citrus mealybugs, whereas Ali et al. (2017) tested several plant extracts against sucking insect pests and found neem seed extract to be more effective compared to extracts from other plants.

Essential oils

Essential oils are volatile hydrophobic compounds extracted from plants. These oils are highly concentrated heterogeneous mixtures of 20–60 compounds, though some contain over 300 different constituents (De Sousa et al. 2023). Typically, two or

TABLE 4: Registered products of commercial use from plant-based pesticides.

Trade name	Registration number	Active ingredient	Description	References or source
NeemAzal	Reg. No. L7840 Act No. 36 of 1947	Azadirachtin	An azadirachtin-based botanical insecticide with antifeedant, repellent and insect growth-regulating properties for controlling codling moth on apples and pears.	https://avima.co.za/
Bioneem	Reg. no. L6958 Act 36 of 1947	Azadirachtin	A growth regulator, anti-feedant, and insect repellent that disrupts the normal metabolic activity of insects.	Biogrow (https://biogrow.co.za/insecticide/)
Bio-neem	ACT / WET 36 / 1947 REG. No: L7039	Azadirachtin	Suitable for controlling leaf miners on potatoes and the snout beetle on apples and grapes	Rovensa (https://biogrow.co.za/insecticide/)
Biogrow Pyrol	Reg. no. L7062 Act 36 of 1947	Pyrethrin and canola oil	A broad-spectrum contact insecticide	(https://biogrow.co.za/insecticide/)
Biogrow Vegol	Reg. no. L7061 Act No. 36 of 1947	Canola	Contact insecticide with ovicidal activity	www.greenhouston.co.za
Eco-neem	Not Applicable	Azadirachtin	Works in multiple ways, with the two main actions being suppression of insect appetite and restricting growth	www.ecoorganicgarden.com.au
Kannar KangroShield 100	Reg. No L7630 Act 36 of 1947	Canola Oil, garlic extract, Pyrethrin extract, and piperonyl butoxide	An organic broad-spectrum insecticide concentrated with contact and repellent action; used as a full cover spray for the control of insects	https://talborne.co.za/pest-and-disease-control/
Kannar Kangar 931	Reg. L931 Act 36 of 1947	Canola Oil Garlic extract from <i>Allium sativa</i>	An organic broad-spectrum insecticide concentrate with contact and repellent action; used as a full cover spray for the control of insects	Talborne Organic 2022
Kannar Pygar 932	Reg. No. L7146 Act 36 of 1947	Canola oil, garlic extract, and pyrethrin	An organic broad-spectrum insecticide concentrate with contact and repellent action; used as a full cover spray for the control of insects.	Talborne Organic 2022
Bonide captain Jack's neem oil concentrate	EPA Reg. No. 70051-2-4	Clarified Hydrophobic Extract of Neem oil	Neem Oil (3-in-1), insecticide, fungicide, miticide for organic gardening.	https://bonide.com

Note: Please see the full reference list of Mange, T., Tanga, M., Jimoh, M.O., Fanadzo, M. & Nchu, F., 2026, 'A review of plant-derived biopesticides against the vine mealybug', *Journal of Medicinal Plants for Economic Development* 10(1), a306. <https://doi.org/10.4102/jomped.v10i1.306>.

three compounds are generally available in significant proportions (20% – 70%) and these are primarily responsible for the biological activity (De Sousa et al. 2023). High variability and diverse complexity of aromatic mixtures of essential oils complicate the understanding of their mechanisms of action. This shifts attention to the study of individual compounds (Verdeguer, Sánchez-Moreiras & Araniti 2020). The toxicity and ability of the lipophilic essential oil to penetrate the waxy cuticle of mealybugs and disrupt their physiological activities and morphological features make them more suitable than synthetic insecticides, which often encounter barriers when in contact with waxy cuticle (Avila et al. 2023; Karamaouna et al. 2013).

Plant-based insecticides versus synthetic insecticides

Over the years, chemical insecticides have been used by farmers in controlling pest infestations to minimise pre- and post-harvest losses. These chemicals control pests but leave behind adverse effects on humans like food poisoning, environmental pollution, ozone layer depletion, pest resistance, mutations and extended toxicity on non-target organisms. In most cases, these chemicals cause severe injuries to critical human organs such as the liver, heart, kidneys, lungs and blood capillaries (Murugesan et al. 2021). For instance, pyrethroids, a prominent group of synthetic insecticides, have been classified as endocrine disruptors because of their antiprogesterone properties, oestrogenic activity and neurodevelopmental toxicity (Elser, Hing & Stevens 2022).

The persistence of chemical insecticides in the environment is of great concern to environmental biologists as pest management becomes a costly enterprise for organic farmers. The choice of plant-based biopesticides as alternatives to synthetic insecticides created a compelling need to screen the insecticidal properties of several plant materials (Seiber et al. 2014). Thus, it became necessary to invent efficient means of minimising the contamination of synthetic insecticides

through microbial degradation, chemical oxidation and photooxidation (Gajendiran & Abraham 2018). These approaches, coupled with the need to ensure human safety and safeguard the environment from chemical hazards, promoted the development and propagation of plant-based, eco-friendly chemicals that could be used as insecticides based on the pest management properties of novel compounds in the plants (Purkait et al. 2019).

The use of plant-based chemicals in pest management is supported by prominent epidemiological reports, including their biodegradability, reduced risk of toxicity to humans and non-target organisms, and low resistance development by pests (Adetuyi et al. 2024; Cantrell, Dayan & Duke 2012). High diffusibility and cuticular penetration of phytochemical insecticides are enhanced by the polarity of solvents used for extraction and various antifeedant mechanisms, such as distortion of typical neurological function capable of perceiving chemical phagostimulants, interference of ribonucleic acid synthesis pathways or by stimulating specialised receptors for feeding inhibition (Jimoh et al. 2023; Seiber et al. 2014).

The relationship between exposure time and concentration of plant-based insecticides

The exposure time and concentration of plant-based insecticides play a significant role in determining their efficacy. According to Peschiutta et al. (2018), exposure time plays a critical role in determining the effectiveness of botanical compounds. However, findings by Rajagopal et al. (2022) suggest that whilst the concentration of extracts significantly contributes to adult insect mortality, treatment duration may not always have a notable effect (Rajagopal et al. 2022).

In contrast, several studies have reported that the efficacy of plant extracts generally increases with both higher

concentrations and longer exposure periods (Badshah et al. 2015; Ramzi et al. 2022; Umair Sardar et al. 2018). For instance, Badshah et al. (2015) found that after a 1-week exposure at 3% concentration, mortality rates were recorded at 100%, 97%, 88% and 67% for neem seed n-hexane extract, neem seed acetone extract, neem oil and neem seed water extract, respectively. At a lower concentration of 1%, the respective mortality rates decreased to 68%, 62%, 56% and 29%. Similarly, Umair Sardar et al. (2018) observed that a 1% neem water extract resulted in a 21.66% mortality rate after 24 h, which increased to 33.33% after 48 h (Umair Sardar et al. 2018). These findings illustrate that both time and concentration can synergistically influence insect mortality. However, it is not always the case that an increase in the concentration of plant extracts increases the mortality rate.

The repellency and mortality rate increased proportionately with the concentration and time (Miah et al. 2018). According to Singh, (2012), after 24 h of mealybug release, the methanolic extracts (*A. indica* leaf, *E. globules* leaf and *O. basilicum* leaf extract) obtained the highest repellency of 97.0%, 93.0% and 88.0%, respectively. However, Erdemir and Erler (2017) reported that all the essential oils tested had a repellent activity in varying degrees, though the repellent activity was concentration- and time-dependent.

Implications and recommendations

Challenges of botanical pesticides

Despite a significant increase in academic publications recommending botanical insecticides as environment-friendly alternatives to synthetic pesticides, only a limited number of commercial products based on plant-derived pesticides are available. The preparation of these botanical formulations at the domestic level often requires basic technical skills, which may not be widely accessible (Ngegba et al. 2022; Tripathi 2021). One major limitation to the commercialisation of botanical pesticides is the availability of plant materials in large and sustainable quantities. The cultivation of source plants is constrained by land-use competition with food crops, especially in regions experiencing increasing food production demands (Seiber et al. 2014).

Suggestions for future research

The study is only focusing on a single insect species (VMB). Hence, future research could explore the long-term effects of these plant-based chemicals with extended exposure time on other insect species especially close-relatives of the VMB. Additionally, it is imperative to investigate the mechanism of action of the insecticidal properties of plant extracts to provide valuable insights for their application in IPM strategies. Finally, it is crucial for researchers to continue to innovate with the view of promoting the formulation of eco-friendly anti-insect chemicals.

Conclusion

Botanical pesticides are viable options for controlling the grapevine mealybug population to prevent depleting

agricultural production. Evidence from the literature suggests that plant-based chemicals with a wide range of proven insecticidal properties could be exploited to control mealybug infestation. The benefits of botanical pesticides cannot be underestimated because of their high diffusibility and cuticular penetration, biodegradability, reduced risk of toxicity to humans and non-target organisms, and low resistance development by pests, which place phytochemical insecticides above synthetic chemicals. The development of new formulations from botanical ingredients with proven insecticidal properties will be beneficial to grapevine farmers amidst the quest to overcome pest resistance, reduce pre- and post-harvest losses, and expand the profit margins in agricultural industries.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

The following authors were responsible for handling different aspects of the study: conceptualisation, Felix Nchu and Morris Fanadzo; methodology, Tokozani Mange, Felix Nchu and Morris Fanadzo; validation, Muhali O. Jimoh, Mbappe Tanga, Morris Fanadzo and Felix Nchu; formal analysis, Muhali O. Jimoh; investigation, Tokozani Mange; resources, Felix Nchu and Morris Fanadzo; data curation, Muhali O. Jimoh and Mbappe Tanga; writing – original draft, Tokozani Mange and Muhali O. Jimoh; writing – review and editing, Muhali O. Jimoh, Felix Nchu and Morris Fanadzo; supervision, Felix Nchu and Morris Fanadzo. All authors have read and agreed to the published version of the article.

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Data availability

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