Online Journal of Biological Sciences

Review

Botanic Products as a Sustainable Alternative in the Control of Rice and Grape Pests in South America

[1]Ricardo Diego Duarte Galhardo de Albuquerque, [2]Frank Romel Leon-Vargas, [3]Carmen Cerdeña del Aguila, [2]Victor Garcia-Perez and [4]Yessenia Vanessa Sherrezade Ramos-Rivas

[1]*Laboratório de Tecnologia de Produtos Naturais, Universidade Federal Fluminense, Street Mario Vianna, Niterói, RJ, Brazil*
[2]*Departamento de Ingenieria Química, Facultad de Ingenieria Química de la Universidad Nacional de la Amazonia Peruana, Street San Marcos, Iquitos, Loreto, Peru*
[3]*Departamento de Ciencias Básicas, Facultad de Ingenieria Química de la Universidad Nacional de la Amazonia Peruana, Street San Marcos, Iquitos, Loreto, Peru*
[4]*Departamento de Ciencias Clínicas, Facultad de Medicina de la Universidad Nacional de la Amazonia Peruana, Peru*

Article history
Received: 18-07-2024
Revised: 03-09-2024
Accepted: 16-09-2024

Corresponding Author:
Ricardo Diego Duarte Galhardo de Albuquerque
Laboratório de Tecnologia de Produtos Naturais, Universidade Federal Fluminense, Street Mario Vianna, Niterói, RJ, Brazil
Email: richardcabofrio@gmail.com

Abstract: Pests present a major threat to agricultural crops, leading to diminished yields, economic losses, and potential food insecurity. In South America, rice and grape cultivation have become increasingly significant due to their economic value, contribution to food security, and role in exports. However, these crops are vulnerable to pests such as *Oebalus poecilus*, *Hydrellia wirthi*, and *Pseudococcus viburni*. The reliance on synthetic pesticides raises concerns due to their residual environmental effects and potential risks to human health. Consequently, Integrated Pest Management (IPM) strategies, including natural botanical products, are crucial for sustainable pest control. Hence, this review aims to compile and evaluate the use of botanical products for pest management, providing safer and more environmentally friendly alternatives to conventional pesticides for rice and grape crops in South America. This review utilized five scientific databases and employed search terms such as "essential oil," "extract," "activity" and relevant scientific names to identify pertinent articles. A total of 10 relevant documents were identified. Notably, *Calotropis gigantea* leaf extract exhibited high insecticidal activity against *O. poecilus* in rice cultivation. Neem oil was effective against both *O. poecilus* and *H. wirthi*. For the control of *P. viburni*, both *Artemisia annua* essential oil and methanolic extract demonstrated significant insecticidal properties. Additionally, garlic oil and proteins from *Phycela australis* also showed insecticidal activity against *P. viburni*. Plant-derived resources present viable and sustainable alternatives to conventional pesticides. Their use benefits South America's agricultural sectors by enhancing food security, supporting domestic and export markets, and offering environmentally friendly pest control solutions.

Keywords: Biopesticides, Sustainability, Natural Products, *Oebalus poecilus*, *Hydrellia wirthi*, *Pseudococcus viburni*

Introduction

Agricultural losses attributable to pests represent a significant challenge impacting global food production and security. Pests-encompassing insects, pathogens, weeds, and other detrimental organisms can cause extensive damage to crops, resulting in decreased yields and compromised quality. This threat jeopardizes global food supplies, farmer livelihoods, and the overall stability of agricultural systems (Savary *et al*., 2019). Addressing these pest-induced losses is of paramount importance. With the global population projected to reach 9.7 billion by 2050, the demand for food is expected to rise substantially. To meet this increasing demand, it is essential to optimize agricultural productivity while minimizing pest-related losses. Neglecting this issue could exacerbate hunger and malnutrition, impede socio-economic development, and lead to adverse environmental impacts (Arora, 2019; Shukla *et al*., 2019).

Pests are capable of affecting crops at all stages of their development, from germination to post-harvest storage.

Insects such as locusts, aphids, and beetles damage plant tissues by feeding on sap or chewing leaves, which impairs photosynthesis and leads to stunted growth. The consequences of pest-related agricultural losses extend beyond individual farms and have significant global implications (Mehta *et al*., 2018). Economically, these losses amount to billions of dollars annually, impacting both smallholder farmers and large agribusinesses. This situation contributes to higher food prices, diminished incomes, and reduced investment in agricultural development. Socio-politically, it exacerbates poverty, inequality, and food insecurity, particularly in developing countries that are heavily dependent on agriculture (Mesterházy *et al*., 2020).

In South America, the cultivation of rice and grapes has become increasingly crucial within the agricultural sector. These crops have gained prominence due to their economic value, contributions to food security, and their role in the export industry (Anderson Seminario *et al*., 2021; Salvagni *et al*., 2020). The cultivation of rice and grapes has not only created significant livelihood opportunities for farmers but has also positioned South American countries as key players in global agricultural markets.

Rice cultivation in South America has experienced notable growth and significance in recent years. As a staple food for millions, rice production is essential for food security. The favorable climate and geographical diversity in countries such as Brazil, Peru, and Colombia offer suitable conditions for rice cultivation across various regions. Consequently, several South American countries have increased rice production, reducing dependency on imports and enhancing self-sufficiency (Garg *et al*., 2020; Anderson Seminario *et al*., 2021; Castro-Llanos *et al*., 2019).

Similarly, grape cultivation in South America has seen substantial growth. While Argentina, Chile, and Southern Brazil have long been known for vine production, other regions, including Peru, Bolivia, and Northeastern Brazil, have also expanded their grape cultivation capacities (Pantaleón Santa María *et al*., 2021; Oliva Oller *et al*., 2022; Bonanno and Cavalcanti, 2012). For instance, Peru's unique climate, especially in its coastal regions, provides ideal conditions for producing high-quality grapes with distinctive flavors (Valencia Sandoval and Duana Avila, 2019). The rapid expansion of grape production in these regions is driven by increased domestic consumption, rising demand for wine, and the growing popularity of table grapes in international markets. These developments have not only generated foreign exchange earnings but also enhanced the global reputation of South American countries as reliable suppliers of agricultural products (Chavez Anaya *et al*., 2019; Estacio *et al*., 2022; Medeiros *et al*., 2022).

Rice and grape cultivations in South American countries are vulnerable to various pests, including insects, diseases, and weeds. In the context of rice plantations, insect pests such as rice stem borers, rice bugs, and armyworms pose significant threats, leading to substantial damage, reduced yields, and economic losses for farmers. Notably, *Oebalus poecilus* (Pentatomidae) and *Hydrellia wirthi* are prominent pests affecting rice cultivation in the region. *Oebilus poecilus*, commonly known as the rice stink bug, damages rice grains, leading to decreased yields and economic losses (Weber *et al*., 2020; Tumanyan *et al*., 2022). *Hydrellia wirthi*, an aquatic fly, is also a significant pest, causing damage to rice stems and leaves, which results in diminished photosynthetic efficiency and reduced grain production (Arteaga Briceño, 2020; Nieto-Cañarte *et al*., 2024).

Grape cultivation in South America is similarly affected by a range of pests that impact both table grape and wine grape production. Insect pests such as the grape moth, mealybugs, and leafhoppers can damage grapevines, compromising grape quality and yield. Additionally, diseases such as powdery mildew, downy mildew, and botrytis can lead to decreased grape production, adversely affecting both the table grape and wine industries. Weed competition also poses a challenge, as it can disrupt grapevine growth and quality, highlighting the need for effective weed management strategies (Lessio and Alma, 2021). Among the pests, the genus *Pseudococcus*, specifically *Pseudococcus viburni*, is of particular concern in South American grape cultivation. These scale insects infest grapevines and directly damage grape berries by feeding on plant sap, which results in reduced grape quality, decreased yield, and economic losses for growers (Mathulwe *et al*., 2021).

To mitigate the impact of pests on rice and grape cultivation, Integrated Pest Management (IPM) practices are essential. IPM involves a combination of cultural, biological, and chemical control strategies aimed at reducing pest damage while minimizing environmental impacts. Culturally, techniques such as crop rotation, effective irrigation management, and sanitation can help prevent pest infestations. Biological control methods, including the use of beneficial insects and microorganisms, contribute to natural pest regulation. Although chemical control with pesticides may be necessary, it should be applied judiciously to minimize ecological and health risks (Fahad *et al*., 2021; Mondani *et al*., 2020).

Given these concerns, the use of natural products for sustainable pest control is increasingly important. Natural products offer environmentally friendly alternatives to synthetic pesticides, reducing risks to ecosystems and non-target organisms. Incorporating natural products into IPM strategies helps decrease dependence on chemical pesticides, promoting long-term agricultural sustainability (Souto *et al*., 2021). Botanicals, as natural products, provide multiple modes of action that can mitigate pesticide resistance and align with consumer preferences for safer, more sustainable food production. Despite potential challenges, such as the need for more frequent applications and variable efficacy, ongoing research and advancements continue to enhance their formulation and effectiveness (Koul, 2023).

Additionally, optimizing the use of botanical products for specific pest control is necessary to identify the most effective solutions and determine the need for further research. This review article aims to compile and evaluate the application of botanical products, including extracts and essential oils, for controlling *Oebalus poecilus*, *Hydrellia wirthi*, and *Pseudococcus* viburni, which are key pests affecting rice and grape production in South American countries.

Methodology

The study employed specific search terms such as "essential oil", "extract", "activity", "*Oebilus poecilus*", "*Hydrelia wirthi*" and "*Pseudococcus* viburni" to identify relevant articles. Several research databases were utilized, including Science Direct (16 documents), Web of Science (3 documents), Scopus (39 documents), and Google Scholar (235 documents). Duplicate articles or those only citing studies on the topic were eliminated. Following meticulous selection, the documents relating directly to the central theme were included and discussed in the succeeding review sections. Table (1) summarizes the information on the selected articles.

Table 1: Botanical products with insecticidal activity against *Oebilus poecilus*, *Hydrelia wirthi*, and *Pseudococcus viburni*

Affected Pest	Active Plant Species	Active Product	Biological activity	Reference
Oebalus poecilus	*Calotropsis gigantea*	Hot water leaf extract	100% mortality on adult insects using 6% conc., in 48 h ($p = 0.0001$)	Deolall *et al.* (2022)
	Momordica charantia		100% mortality on adult insects using 24% conc., in 48 h ($p = 0.0001$)	
	Cordia curassavica			
	Azadirachta indica	Neemactin, Agroneem, Neem-x, Nuvacron, Crude extract	Neemactin and Agroneem: 35-40% mortality on adult insects using 12.5 mL/L conc., in 24 h ($p<0.05$); NEEMACTIN, NEEM-X, NUVACRON and Crude extract: 5-25% reduction of damage leaves by antifeedant effect ($F_{2,27} = 5.36$; $p < 0.01$)	Sutherland *et al.* (2002)
		Dalneem and Nim-I-Go (neem oils)	Dalneem oil: 45% mortality on adult insects using 4% conc., in 24 h; Dalneem oil and nim-I-Go oil: 12.7-33.8 FDI using 1% conc. (antifeedant effect) ($p < 0.01$)	Pinheiro and Quintella, (2010)
Hydrellia wirthi		Hot water seed extract	66.6% mortality on adult insects using 2 L/200 L ($p<0.05$)	Jordán-Sánchez Aaron (2020)
Pseudococcus viburni	*Artemisia annua*	Leaf Essential oil	LC_{50} equal to 0.693% on third instar nymphae, in 24 h (mortality); ED_{50} equal to 0.4% (antifeedant effect) ($X^2 = 2.6535$; df = 3)	Ramzi *et al.* (2017)
		Leaf methanolic extract	LC_{50} equal to 0.287% on third instar nymphae, in 24 h (mortality) ($X^2 = 1.223$; df = 3).	Ramzi *et al.* (2018)
	Allium sativum	Garlic oil and methanolic extract	LC_{50} equal to 0.31% (oil) and 0.42% (methanolic extract) on third instar nymphae, in 24 h (mortality) ($X^2 = 3.145$; df = 3); ED_{50} equal to 0.31% (oil) and 0.22% (methanolic extract) (antifeedant effect) ($X^2 = 2.136$; df = 3)	Ramzi *et al.* (2022)
	Phycella australis	Crude protein extract from bulbs	LC_{50} equal to 0.6% on first instar nymphae, in 72 h (mortality) ($p<0.05$)	Alarcón *et al.* (2018)
	Glycine max	Golden Natural Oil (93% soy oil)	Incidence Reduction (73.33-33.33%; $p = 0.007$) and Infestation Reduction (68.7 to 35 nymphae and 5-1.3 adults; $p = 0.036$ and 0.002, respectively), using a 4 L/ha dosis	Aguilar-Villanueva (2022)
	Quillaja saponaria	QL Agri 35 (35% extract)	Effective insecticidal concentration: 200-300 cc/100 L	Agrícola y Granadero (SAG) (2020)

DOI: 10.3844/ojbsci.2025.323.332

Results

Oebalus Poecilus

Deolall *et al*. (2022) investigated the insecticidal effects of hot water leaf extracts from three plant species: *Momordica charantia*, *Calotropis gigantea*, and *Cordia curassavica*. They tested three different concentrations (6, 12, and 24%) on adult insects to assess mortality and repellency. The mortality assays, conducted in Petri dishes with milk grains, showed that the 6% *Calotropis gigantea* extract achieved 100% mortality within 48 h, whereas the 24% *Momordica charantia* and *Cordia curassavica* extracts reached the same level of mortality within the same time frame. No repellent effects were observed for any of the extracts (Deolall *et al*., 2022).

In a separate study, Sutherland *et al*. (2002) evaluated several neem (*Azadirachta indica*)-based products, including crude neem extract, for controlling *Oebalus poecilus*. Neem products, such as NEEMACTIN and AGRONEEM, achieved mortality rates of 35-40% with azadirachtin equivalent doses of 0.15% and 12.5 mL/L dilution over a 24-hour period. Additionally, these neem products, along with NEEM-X, NUVACRON, and crude neem extract, exhibited antifeedant effects, reducing foliar damage by 5-25% compared to the control group. No significant effects on oviposition activity were noted. Field trials revealed significant differences in *Oebalus poecilus* populations 24 and 96 h post-application ($F_{5,15}$ = 3.38, P = 0.03 and $F_{5,15}$ = 7.44, P = 0.001). At 24 h, only monocrotophos (positive control) differed significantly from all other treatments and the control. At 96 h, both monocrotophos and AGRONEEM showed slightly lower pest populations compared to other treatments (Sutherland *et al*., 2002).

Furthermore, Pinheiro and Quintella (2010) examined the insecticidal and antifeedant effects of neem products on adult insects using an ingestion model. Their study found that only the higher concentration (4%) of the neem oil product Dalneem resulted in a 45% mortality rate. In contrast, the 1% concentration of Dalneem and Nim-I-Go induced antifeedant effects, reducing feeding compared to the control group. The Feeding Deterrence Index (FDI) values were 26.8 (males) and 33.8 (females) for Dalneem, 12.7 (males), and 20.7 (females) for Nim-I-Go (Pinheiro and Quintella, 2010).

Hydrellia Wirthi

Neem seed extract, obtained through hot water maceration over an 8-day period (2 lbs./gallon), resulted in 66.6% mortality of *Hydrellia wirthi* adult insects in a field trial. The treatment was applied at a dose of 2 per 200 L of water per hectare, with six applications over a 10-day period. This treatment also increased the number of grains per rice cob compared to the control (from 108-125 grains), leading to an enhancement in total yield from 4021.09 -4871.90 kg/ha (Jordán-Sánchez Aaron, 2020).

Pseudococcus Viburni

The essential oil extracted from *Artemisia annua* leaves demonstrated significant mortality in third instar *Pseudococcus viburni* nymphs, with an LC_{50} value of 0.693% achieved within 24 h when applied directly to *Camelia sinensis* leaves. Additionally, deterrence assays indicated an ED_{50} value of 0.4%. Physiological evaluations revealed that while alanine aminotransferase activity showed no significant differences between treated and control nymphs, aspartate aminotransferase and γ-glutamyl transferase activities were elevated in the treated group. Conversely, activities of aldolase, lactate dehydrogenase, and acid phosphatase were significantly reduced compared to the control (Ramzi *et al*., 2017). In the same year, the same research group assessed the impact of a methanolic extract of *Artemisia annua*. This extract had an LC_{50} of 0.287% within 24 h. The activities of alanine aminotransferase, aspartate aminotransferase, and γ-glutamyl transferase were significantly lower in the treated nymphs, with the exception of 24-h γ-glutamyl transferase and 48-h alanine aminotransferase. Increased activities of lactate dehydrogenase and both acid and alkaline phosphatases were observed, while enzymes involved in the antioxidant system, including catalase, peroxidase, superoxide dismutase, ascorbate peroxidase, and glucose-6-phosphate dehydrogenase, were elevated in treated nymphs compared to controls (Ramzi *et al*., 2018). Subsequently, a similar study evaluated the effects of garlic (*Allium sativum*) oil and methanolic extract. The LC50 values were 0.31 and 0.42%, respectively, within 24 h and the deterrence rates were 0.31 and 0.22%, respectively. Both treatments significantly increased the activities of aspartate aminotransferase, alanine aminotransferase, and γ-glutamyl transferase. However, lactate dehydrogenase activity was lower in nymphs treated with both Methanolic Extract (ME) and Essential Oil (EO), while acid and alkaline phosphatase activities were significantly higher in nymphs treated with ME and EO, respectively. Additionally, both treatments notably decreased protein and glycogen content in the nymphs (Ramzi *et al*., 2022).

The study of Alarcón *et al*. (2018) evaluated the insecticidal activity of crude protein extracts obtained from bulbs of three different Chilean species of the family Amaryllidaceae (*Phycella australis*, *Rhodophiala pratensis* and *Rhodolirium speciosum*) on *Pseudococcus viburni*. The extracts were supplied in diet artificially to first instar nymphs for three days and the most activity insecticide was obtained with the extract from *Pseudococcus australis*, reaching 76.25% mortality after 72 h and presenting an LC_{50} equal to 0.6% (*w/v*) (Alarcón *et al*., 2018). Furthermore, the work of Aguilar-Villanueva (2022) demonstrated the effect of the phytoproduct golden natural oil (93% based soy oil), using a dosis equal to 4 L/ha (diluted to a total volume of

800 L +0.2 L sulfurous acid/ha), on *Pseudococcus* spp., which reduced the incidence from 73.33-33.33% and the severity of infestation from 68.7-35 nymphae and from 5-1.3 adults in each *Vaccinum corymbosum* plants (Aguilar-Villanueva, 2022). Another phytoproduct named QL Agri 35 (based on 35% *Quillaja saponaria* extract containing 28.1% of bidesmosidic glycosides of quillaic acid) is commercially used to control *Pseudococcus viburni*, with an effective concentration of 200-300 cc/100 L (Agrícola y Granadero (SAG) 2020).

Discussion

The review identified ten studies that examine the potential of botanical products as biological control agents for key agricultural pests affecting rice and grape crops in South America, including *Oebalus poecilus* and *Hydrellia wirthi* (rice pests) and *Pseudococcus viburni* (grape pest) (Fig. 1). Among these, the study by Deolall *et al*. (2022) highlighted the superior insecticidal activity of *Calotropis gigantea* leaf extract against *Oebalus poecilus* (Fig. 2). The authors attribute this effectiveness to the high saponin content in *Calotropis gigantea*, as saponins are known to act as both insecticides and antifeedants across various insect life stages, playing a crucial role in the natural defense mechanisms of certain plants (Qasim *et al*., 2020). Saponins can disrupt insect physiology through multiple mechanisms, including their surfactant properties, which destabilize cellular membranes, as well as their interactions with cholesterol, which interfere with the synthesis of ecdysteroids and function as hormone disruptors (Roopashree and Naik, 2019). Additionally, *Calotropis gigantea* contains other bioactive compounds such as flavonoids, alkaloids, tannins, phytoesterols, and terpenoids, which may also contribute to its insecticidal activity (Chandrawat and Sharma, 2018).

In studies focusing on *Oebalus poecilus* and *Hydrellia wirthi*, neem oil has been demonstrated to be an effective insecticide and, in some cases, an antifeedant. This application reduces pest infestation and enhances rice grain yield (Sutherland *et al*., 2002; Pinheiro and Quintela, 2010; Jordán-Sánchez Aaron, 2020).

Fig. 1: South American pests in rice and grape plantations. From left to right: *Oebalus poecilus* (Author: Andrew J. Crawford), *Hydrellia wirthi* (Author: Michael Seymour), and *Pseudococcus viburni* (Author: Raymond California Department of Food and Agriculture)

Fig. 2: Some plants with remarkable activity against rice and grape pests in South America. From left to right: *Calotropis gigantea* (Author: J.S. Gamble-ENVIS, Flora of Madras Presidency), *Azadirachta indica* (Author: Kevin Sooryan), and *Artemisia annua* (Author: Stefan Lefnaer)

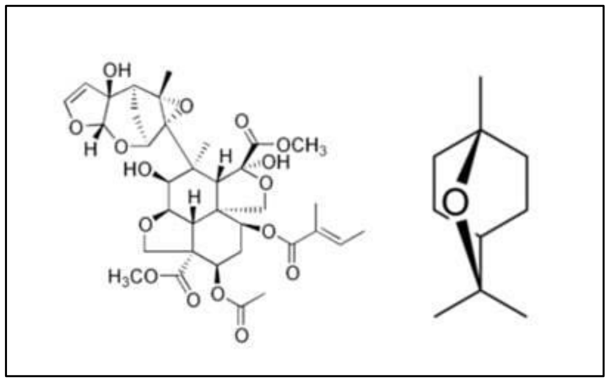

Fig. 3: Respective structures of azadirachtin and 1,8-cineole, main active substances from botanical products used in the control of South American rice and grape plantations

The efficacy of neem (*Azadirachta indica*) (Fig. 2) is largely attributed to its limonoid content, particularly azadirachtin (Fig. 3). Azadirachtin disrupts the molting process by interfering with the release and synthesis of molting hormones, leading to sterility in adult females and incomplete ecdysis in immature insects (Isman, 2006). Additionally, other compounds in *Azadirachta indica*, such as quercetin and sallanic acid, contribute to its insecticidal properties. Quercetin is known to generate Reactive Oxygen Species (ROS) through oxidation, which reduces the nutritional quality of food in the insect gut lumen. It also inhibits transhydrogenase activity, affecting insect growth and leading to mortality (Pessoa *et al*., 2018). Sallanic acid, on the other hand, interferes with sensory inputs and functions as a feeding inhibitor (Koul, 2008).

Regarding the control of *Pseudococcus viburni*, *Artemisia annua* (Fig. 2) exhibits significant insecticidal activity through its essential oil and methanolic extract. Key compounds in this essential oil include camphor, germacrene D, artemisia ketone, and 1,8-cineole (Fig. 3) (Bilia *et al*., 2014). Camphor and 1,8-cineole are noted for their insecticidal properties and synergistic effects, they bind to [^3H]-TBOB, the picrotoxin binding site on insect GABA receptors, thereby inducing toxic effects on the insect nervous system. Additionally, 1,8-cineole demonstrates superior topical penetration compared to camphor (Tak and Isman, 2015). *Artemisia annua* extracts are well-documented for their insecticidal, deterrent, and antifeedant effects (Knudsmark Jessing *et al*., 2014). Garlic oil also shows substantial efficacy against *Pseudococcus viburni*. Its primary components, allyl disulfide, and diallyl trisulfide, contribute to its toxicity by forming reactive products that interact with crucial proteins involved in insect metabolism, structure, and reproduction (Kimbaris *et al*., 2009; Wu *et al*., 2020). Furthermore, the insecticidal properties of proteins from *Phycela australis* have been documented by Zapata *et al*. (2016). These proteins exhibit toxic, anti-reproductive, and antifeedant effects on aphids, likely due to a mannose-binding lectin from the bulbs that disrupts nutrient absorption and reproductive functions (Zapata *et al*., 2016). Neem-based phytoproducts, as discussed by Aguilar-Villanueva (2022); and Agrícola y Granadero (SAG) (2020), also demonstrate effectiveness against *Pseudococcus viburni*, operating through similar mechanisms.

Overall, the studies reviewed suggest that plant-derived products represent a viable and sustainable alternative to conventional pesticides for managing key agricultural pests affecting rice and grape crops in South America. These botanical agents not only mitigate soil contamination from synthetic pesticides but also protect beneficial flora and fauna, thereby maintaining ecosystem balance, and potentially reducing long-term environmental remediation costs (Pathak *et al*., 2022). Moreover, increasing resistance to synthetic pesticides requires higher dosages and more frequent applications, making botanical alternatives a viable option to reduce health risks. This shift could lead to a healthier and more productive workforce and potentially lower public health expenditures. Furthermore, natural pesticides typically operate through multiple modes of action, reducing the likelihood of pests developing resistance and ensuring long-term applicability and economic sustainability (Khursheed *et al*., 2022). Since plant-based biological controls are sourced from organic producers cultivating standardized species, the risk of deforestation and environmental contamination is considered negligible (Gamage *et al*., 2023). Regarding the implied economic aspects of the use of organic pesticides, the global pesticide market was valued at over $55 billion in 2020 (Group, 2021). Additionally, the organic food market has experienced robust growth, with global sales reaching nearly $57.5 billion in 2021, so producers can tap into this expanding market by utilizing natural insecticides, positioning their products as sustainably cultivated, and potentially commanding premium prices (Waltover, 2023). Furthermore, South American native species such as *Momordica charantia* and *Quillaja saponaria* offer valuable local resources for the development of sustainable biocontrol agents. Utilizing these species could enhance local economies and involve various stakeholders, including farmers, distributors, chemists, and biologists.

However, despite the effectiveness demonstrated in the studies included in this review, advances must still be sought in order to improve technical aspects such as the solubility and aqueous dispersion of more nonpolar components such as essential oils, as well as the stability of active compounds, many of which are extremely susceptible to the action of hydrolysis and UV rays. In this sense, the use of technologies such as the development of nanoemulsions may be an affordable solution for the current moment, since they have the advantages of improving the dispersion of active substances in an aqueous medium, as well as providing greater protection against factors related to the degradation mechanisms previously mentioned (Echeverría *et al*., 2019). Furthermore, the chemical standardization of such oils and extracts is also a concern that must be taken seriously into account, since the variation in the collection site of the plant material may be decisive for the change in the chemical profile and, consequently, in its capacity for biological activity (Mehta *et al*., 2018).

Other concerns include safety and ethical aspects so assessing the long-term effects on ecosystems is crucial. While biopesticides are often touted for being environmentally friendly, their impact on non-target species, soil health, and biodiversity must be carefully evaluated. Also important is ensuring that plant-based biopesticides do not pose risks to human health. This involves thorough testing to avoid potential allergic reactions, toxicity, or other adverse effects. Transparency in adherence to regulatory standards is essential, as this ensures that consumers make informed choices and ensures that biopesticides meet safety and efficacy standards. Furthermore, understanding and respecting local knowledge and practices related to plant use is vital. Biopesticides should not undermine traditional agricultural practices or exploit local resources without fair compensation or acknowledgment.

Additionally, it is essential to investigate other aspects such as optimization of raw material yields, as well as develop formulations that enhance the efficacy of these resources, verify synergistic effects and facilitate large-scale application. Addressing these issues will require the collaboration of researchers across multiple disciplines, including chemistry, pharmacology, biology and toxicology.

Conclusion

The review evaluated the potential of botanical products as biological control agents for agricultural pests affecting rice and grape crops in South America. *Calotropis gigantea* leaf extract demonstrated significant insecticidal activity against *Oebalus poecilus* in rice cultivation. Neem oil was also effective in managing both *Oebalus poecilus* and *Hydrellia wirthi*. For the grape pest

Pseudococcus viburni, *Artemisia annua* essential oil and methanolic extract exhibited insecticidal properties, while garlic oil and proteins from *Phycela australis* demonstrated insecticidal activity through various mechanisms. The studies underscore the potential of plant-derived resources as viable and sustainable alternatives to conventional pesticides. These botanical products can enhance food security, support environmental balance, and contribute to national and export markets. However, further collaboration among researchers across disciplines is needed to address specific challenges and evaluate the practical application of these products.

Acknowledgment

The authors thank to Universidad Nacional de la Amazonía Peruana for finnancial support.

Funding Information

The funding for publication was provided by the Universidad Nacional de la Amazonía Peruana.

Author's Contributions

Ricardo Diego Duarte Galhardo de Albuquerque: Designed and wrote the manuscript.

Frank Romel Leon-Vargas: Contributed to a selection of articles and reviewed the chemical aspects.

Carmen Cerdeña del Aguila: Contributed to the selection of articles and final structuration.

Victor Garcia-Perez: Reviewed the biological aspects.

Yessenia Vanessa Sherrezade Ramos-Rivas: Made the overall revision and approved the final manuscript.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

References

Agrícola y Granadero. (SAG), S. (2020). *QL Agri 35*. SAG-Agricultural and Livestock Service. https://www.sag.gob.cl/content/ql-agri-35

Aguilar-Villanueva, G., Alva-Alayo, C. A., Rosas-Ventura, C., Alverca-Meza, C. A., Cabrera-Cruzado, C., Alfaro-Flores, I., Trujillo-Neciosup, M., & Aguilar-Urbina, E. W. (2022). Tuberculosis multisistémica inusual en paciente inmunodeprimido por VIH: reporte de caso. *Horizonte Médico (Lima)*, *22*(2), e1741. https://doi.org/10.24265/horizmed.2022.v22n2.11

Alarcón, P., Díaz, C., Vergara, J., Vásquez, V., & Torres, C. (2018). Analysis of Conceptual Metaphors on the Social Image of Teachers in Pedagogical Students. *Onomázein*, *30*(40), 1–27. https://doi.org/10.7764/onomazein.40.01

Anderson Seminario, M. D. las M., Gómez Oscorima, R. M., Diez Matallana, R. A., & Linares Salas, A. J. (2021). Peruivity and Sudamric in Arroz Production (Oryza Sativa) and Papa (Solanum Tuberosum). *Anales Científicos*, *82*(1), 11–21. https://doi.org/10.21704/ac.v82i1.1737

Arora, N. K. (2019). Impact of Climate Change on Agriculture Production and its Sustainable Solutions. *Environmental Sustainability*, *2*(2), 95–96. https://doi.org/10.1007/s42398-019-00078-w

Arteaga Briceño, K. R. (2020). *Efecto de Tres Ingredientes Activos Para el Control de Hydrellia Wirthi en Arroz (Oryza sativa L.), Valle Santa*. Universidad San Pedro.

Bilia, A. R., Santomauro, F., Sacco, C., Bergonzi, M. C., & Donato, R. (2014). Essential Oil of Artemisia Annua L.: An Extraordinary Component with Numerous Antimicrobial Properties. *Evidence-Based Complementary and Alternative Medicine*, *2014*(1), 1–7. https://doi.org/10.1155/2014/159819

Bonanno, A., & Cavalcanti, J. S. B. (2012). Globalization, Food Quality and Labor: The Case of Grape Production in North-Eastern Brazil. *The International Journal of Sociology of Agriculture and Food*, *19*(1), 37-55.

Castro-Llanos, F., Hyman, G., Rubiano, J., Ramirez-Villegas, J., & Achicanoy, H. (2019). Climate Change Favors Rice Production at Higher Elevations in Colombia. *Mitigation and Adaptation Strategies for Global Change*, *24*, 1401-1430. https://doi.org/10.1007/s11027-019-09852-x

Chandrawat, P., & Sharma, R. A. (2018). Screening for Bioactive Compounds in Different Plant Parts of Calotropis Gigantea L. *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 1592–1594.

Chavez Anaya, T. M., Cuadros Rivera, M. M., Lopez Maque, A., Montoya Zea, M. F., Requena Esquieros, N., & Talavera Aliga, Y. (2019). Análisis psicométrico de la escala de estresores academicos (ECEA), en estudiantes de la Universidad Catolica de Santa Maria. *Avances En Psicología*, *27*(1), 73–82. https://doi.org/10.33539/avpsicol.2019v27n1.1467

Deolall, M. D., Singh, D., Srikishen, A., & Da Silva, P. N. B. (2022). Investigating Insecticidal and Repellent Activity of Momordica Charantia, Calotropis Gigantea and Cordia Curassavica Against Oebalus Poecilus. *GSC Biological and Pharmaceutical Sciences*, *20*(2), 80–86. https://doi.org/10.30574/gscbps.2022.20.2.0305

Echeverría, J., & Galhardo de Albuquerque, R. D. D. (2019). Nanoemulsions of Essential Oils: New Tool for Control of Vector-Borne Diseases and In Vitro Effects on Some Parasitic Agents. *Medicines*, *6*(2), 42. https://doi.org/10.3390/medicines6020042

Estacio, M., Gómez, A., Gómez, Z. C., Granda, H. K., Guerrero, M., Gutierrez, J., Herrada, L., Nina, M., Ohara, Z. J., Olaya, U. M., Olivos, M., Pulache, K., Quispe, M., Castañeda, B., & Ibáñez, L. (2022). Comparative Study of the Anti-Inflammatory Effect of the Plant Major. Llantén and Diclofenac. *Horizonte Médico (Lima)*, *2*(1/2). https://doi.org/10.24265/horizmed.2002.v2n1.07

Fahad, S., Saud, S., Akhter, A., Bajwa, A. A., Hassan, S., Battaglia, M., Adnan, M., Wahid, F., Datta, R., Babur, E., Danish, S., Zarei, T., & Irshad, I. (2021). Bio-Based Integrated Pest Management in Rice: An Agro-Ecosystems Friendly Approach for Agricultural Sustainability. *Journal of the Saudi Society of Agricultural Sciences*, *20*(2), 94–102. https://doi.org/10.1016/j.jssas.2020.12.004

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P., & Merah, O. (2023). Role of Organic Farming for Achieving Sustainability in Agriculture. *Farming System*, *1*(1), 100005. https://doi.org/10.1016/j.farsys.2023.100005

Garg, V., Zia, G., Chauhan, M., & Dutt, R. (2020). Facts About Standardization of Herbal Medicines. In *Promising Drug Molecules of Natural Origin* (1st ed.). Apple Academic Press. ISBN-10: 9781003010395. https://doi.org/10.1201/9781003010395-2

Group, F. (2021). *Global Pesticides Industry Reports, Global* (Global Pesticides). Fridonia Group.

Isman, M. B. (2006). Botanical Insecticides, Deterrents and Repellents in Modern Agriculture and an Increasingly Regulated World. *Annual Review of Entomology*, *51*(1), 45–66. https://doi.org/10.1146/annurev.ento.51.110104.151146

Jordán-Sánchez Aaron, A. (2020). *Uso De Repelentes Orgánicos Para El Control Del Minador (Hydrellia sp.) En El Cultivo De Arroz (Oryza sativa L.)*. Universidad Agraria Del Ecuador.

Khursheed, A., Rather, M. A., Jain, V., Wani, A. R., Rasool, S., Nazir, R., Malik, N. A., & Majid, S. A. (2022). Plant Based Natural Products as Potential Ecofriendly and Safer Biopesticides: A Comprehensive Overview of Their Advantages Over Conventional Pesticides, Limitations and Regulatory Aspects. *Microbial Pathogenesis*, *173*, 105854. https://doi.org/10.1016/j.micpath.2022.105854

Kimbaris, A. C., Kioulos, E., Koliopoulos, G., Polissiou, M. G., & Michaelakis, A. (2009). Coactivity of Sulfide Ingredients: A New Perspective of the Larvicidal Activity of Garlic Essential Oil Against Mosquitoes. *Pest Management Science*, *65*(3), 249–254. https://doi.org/10.1002/ps.1678

Knudsmark Jessing, K., Duke, S. O., & Cedergreeen, N. (2014). Potential Ecological Roles of Artemisinin Produced by Artemisia Annua L. *Journal of Chemical Ecology*, *40*(2), 100–117. https://doi.org/10.1007/s10886-014-0384-6

Koul, O. (2008). Phytochemicals and Insect Control: An Antifeedant Approach. *Critical Reviews in Plant Sciences*, *27*(1), 1–24. https://doi.org/10.1080/07352680802053908

Koul, O. (2023). Biopesticides: Commercial Opportunities and Challenges. In *Development and Commercialization of Biopesticides Costs and Benefits* (1st ed., pp. 1–23). Academic Press. ISBN-10: 978-0-323-95290-3. https://doi.org/10.1016/b978-0-323-95290-3.00009-1

Lessio, F., & Alma, A. (2021). Models Applied to Grapevine Pests: A Review. *Insects*, *12*(2), 169. https://doi.org/10.3390/insects12020169

Mehta, S., Garg, A., Garg, S., Kumar, M., & Shukla, A. (2018). Concise Report on Standardization of Herbal Drugs and its Products. *Advance Pharmaceutical Journal*, *3*(3), 83–89. https://doi.org/10.31024/apj.2018.3.3.3

Mathulwe, L. L., Malan, A. P., & Stokwe, N. F. (2021). A Review of the Biology and Control of the Obscure Mealybug, Pseudococcus viburni (Hemiptera: Pseudococcidae), with Special Reference to Biological Control Using Entomopathogenic Fungi and Nematodes. *African Entomology*, *29*(1), 1–16. https://doi.org/10.4001/003.029.0001

Medeiros, M.L., Carvalho Pinto Vieira, A., & Silva, H. V. (2022). Turismo & pandemia: o repensar do turismo nos Vales da Uva Goethe (SC). *Diálogo com a Economia Criativa*, *7*(19).

Mesterházy, Á., Oláh, J., & Popp, J. (2020). Losses in the Grain Supply Chain: Causes and Solutions. *Sustainability*, *12*(6), 2342. https://doi.org/10.3390/su12062342

Mondani, L., Palumbo, R., Tsitsigiannis, D., Perdikis, D., Mazzoni, E., & Battilani, P. (2020). Pest Management and Ochratoxin a Contamination in Grapes: A Review. *Toxins*, *12*(5), 303. https://doi.org/10.3390/toxins12050303

Nieto-Cañarte, C. A., Lozano-Mendoza, P. H., Corella-Romero, P. M., Sánchez-Loor, M. N., Sánchez-Loor, N. C., & Muñoz-Rodríguez, K. I. (2024). Estudio de Vulnerabilidad Climática en el Cantón Mocache, Los Ríos, Ecuador. *Green World Journal*, *7*(2), 168. https://doi.org/10.53313/gwj72168

Oliva Oller, P., Notaro, M., Langer, E., & Gary, C. (2022). Structure and management of traditional agroforestry vineyards in the high valleys of southern Bolivia. *Agroforestry Systems*, *96*(2), 375-386. https://doi.org/10.1007/s10457-021-00725-4

Pantaleón Santa María, A. L., Medina Cardozo, I. I., & Montes Ninaquispe, J. C. (2021). Comportation of Production and Arroz'S Importation in the Perth 2016-2020. *Tzhoecoen*, *13*(2), 76–83. https://doi.org/10.26495/tzh.v13i2.2001

Pathak, V. M., Verma, V. K., Rawat, B. S., Kaur, B., Babu, N., Sharma, A., Dewali, S., Yadav, M., Kumari, R., Singh, S., Mohapatra, A., Pandey, V., Rana, N., & Cunill, J. M. (2022). Current Status of Pesticide Effects on Environment, Human Health and it's Eco-Friendly Management as Bioremediation: A Comprehensive Review. *Frontiers in Microbiology*, *13*, 962619. https://doi.org/10.3389/fmicb.2022.962619

Pessoa, L. Z. da S., Duarte, J. L., Ferreira, R. M. dos A., Oliveira, A. E. M. de F. M., Cruz, R. A. S., Faustino, S. M. M., Carvalho, J. C. T., Fernandes, C. P., Souto, R. N. P., & Araújo, R. S. (2018). Nanosuspension of Quercetin: Preparation, Characterization and Effects Against Aedes Aegypti Larvae. *Revista Brasileira de Farmacognosia*, *28*(5), 618–625. https://doi.org/10.1016/j.bjp.2018.07.003

Pinheiro, P. V., & Quintela, E. D. (2010). Neem Oil Antifeedant and Insecticidal Effects on Oebalus Poecilus (Hemiptera: Pentatomidae) Males and Females. *Pesquisa Agropecuária Tropical*, *40*(4), 513–520. https://doi.org/10.1590/s1983-40632010000400018

Qasim, M., Islam, W., Ashraf, H. J., Ali, I., & Wang, L. (2020). Saponins in Insect Pest Control. In J.-M. Merillon & K. G. Ramawat (Eds.), *Co-Evolution of Secondary Metabolites* (pp. 897–924). Springer International Publishing. ISBN-10: 978-3-319-96397-6. https://doi.org/10.1007/978-3-319-96397-6_39

Ramzi, S., Seraji, A., Azadi Gonbad, R., & Roofigari Haghighat, S. (2022). Effects of the Extract and the Essential Oil of Allium Sativum on Tea Mealy Bug, Pseudococcus Viburni Sigornet (Hemiptera: Pseudococcidae). *Biocatalysis and Agricultural Biotechnology*, *42*, 102359. https://doi.org/10.1016/j.bcab.2022.102359

Ramzi, S., Seraji, A., Azadi Gonbad, R., Mirhaghparast, K., & Mojib-Haghghadam, Z. (2018). Effects of Artemisia Annua Methanolic Extracton the Enzymatic Components of Intermediary Metabolism and the Antioxidant System of Pseudococcus Viburni Signoret. *Journal of Plant Protection Research*, *58*(3), 289–296. https://doi.org/10.24425/jppr.2018.124637

Ramzi, S., Seraji, A., Azadi Gonbad, R., Mirhaghparast, S. K., Mojib Haghghadam, Z., & Haghighat, S. (2017). Toxicity of Artemisia Annua (Asteraceae) Essential Oil on the Tea Mealy Bug, Pseudococcus Viburni Sigornet (Hemiptera: Pseudococcidae). *Archives of Phytopathology and Plant Protection*, *50*(19–20), 941–956. https://doi.org/10.1080/03235408.2017.1352223

Roopashree, K., & Naik, D. (2019). Saponins: Properties, Applications and as Insecticides: A Review. *Bioscience Trends*, *8*(1), 1–14.

Salvagni, J., Nodari, C. H., & Valduga, V. (2020). Cooperation, innovation and tourism in the grape and wine region, Brazil. *Cuadernos de Desarrollo Rural*, *17*. https://doi.org/10.11144/Javeriana.cdr17.citg

Savary, S., Willocquet, L., Pethybridge, S. J., Esker, P., McRoberts, N., & Nelson, A. (2019). The Global Burden of Pathogens and Pests on Major Food Crops. *Nature Ecology and Evolution*, *3*(3), 430–439. https://doi.org/10.1038/s41559-018-0793-y

Shukla, N., Akansha Singh, E. A. N., Kabadwa, B. C., Sharma, R., & Kumar, J. (2019). Present Status and Future Prospects of Bio-Agents in Agriculture. *International Journal of Current Microbiology and Applied Sciences*, *8*(4), 2138–2153. https://doi.org/10.20546/ijcmas.2019.804.251

Souto, A. L., Sylvestre, M., Tölke, E. D., Tavares, J. F., Barbosa-Filho, J. M., & Cebrián-Torrejón, G. (2021). Plant-Derived Pesticides as an Alternative to Pest Management and Sustainable Agricultural Production: Prospects, Applications and Challenges. *Molecules*, *26*(16), 4835. https://doi.org/10.3390/molecules26164835

Sutherland, J., Baharally, V., & Permaul, D. (2002). Use of Botanical Insecticide, Neem, to Control the Small Rice Stinkbug Oebalus Poecilus (Dallas, 1851) (Hemiptera: Pentatomidae) in Guyana. *Entomotropica*, *17*(1), 97–101.

Tak, J.-H., & Isman, M. B. (2015). Enhanced Cuticular Penetration as the Mechanism for Synergy of Insecticidal Constituents of Rosemary Essential Oil in Trichoplusia ni. *Scientific Reports*, *5*(1), 12690. https://doi.org/10.1038/srep12690

Tumanyan, N. G., Tkachenko, M. A., Kumeiko, T. B., & Chizhikova, S. S. (2022). Rice Grain Dark Spots and Their Impact on Quality Associated Traits. *SABRAO Journal of Breeding and Genetics*, *54*(4), 803–813. https://doi.org/10.54910/sabrao2022.54.4.11

Valencia Sandoval, K., & Duana Avila, D. (2019). The Competitiveness of Grape Trade in the International Market and in the United States. *Revista Cimexus*, *14*(1), 56–77. https://doi.org/10.33110/cimexus140103

Wu, M.-Y., Ying, Y.-Y., Zhang, S.-S., Li, X.-G., Yan, W.-H., Yao, Y.-C., Shah, S., Wu, G., & Yang, F.-L. (2020). Effects of Diallyl Trisulfide, An Active Substance from Garlic Essential Oil, on Energy Metabolism in Male Moth Sitotroga Cerealella (Olivier). *Insects*, *11*(5), 270. https://doi.org/10.3390/insects11050270

Weber, N. C., Redaelli, L. R., Santos, E. M. dos, & Werner, F. M. (2020). Quantitative and Qualitative Damages of Oebalus Poecilus on Irrigated Rice in Southern Brazil. *Revista Ceres*, *67*(2), 126–132. https://doi.org/10.1590/0034-737x202067020005

Waltover, S. (2023). *Organic Food Sales Growth Outpaces Rest of Grocery Industry*. Business News Daily. https://www.businessnewsdaily.com/2404-organic-industry-healthy-growth.html

Zapata, N., Van Damme, E. J. M., Vargas, M., Devotto, L., & Smagghe, G. (2016). Insecticidal Activity of a Protein Extracted from Bulbs of Phycella Australis Ravenna Against the Aphids Acyrthosiphon Pisum Harris and Myzus Persicae Sulzer. *Chilean Journal of Agricultural Research*, *76*(2), 188–194. https://doi.org/10.4067/s0718-58392016000200008