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REVIEW ARTICLE

Green Insecticides: A Comprehensive Review

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ABSTRACT

The article discusses the need for more environmentally friendly pest control strategies as well as the detrimental impacts of synthetic pesticides on human health, biodiversity and the environment. It draws attention to the advantages of botanical pesticides, which are made from plants and have been in use for thousands of years prior to the development of synthetic pesticides. Bioactive substances found in botanical pesticides, including fatty acids, alkaloids, terpenoids, phenols, and quercetin, can kill insects and mites by suffocating them or rupturing their membranes. Numerous plant species, including flora found in nature and herbal treatments, have pesticidal properties and can be utilised to control pests. In organic farming, the use of botanical pesticides is growing in popularity. The paper contends that bio-pesticides are less dangerous to mammals, have positive impacts on environmental preservation, and don't put the target pests at risk of developing resistance, thus, they may be used as an alternative to traditional tools for integrated pest control.

Keywords: *Bio-pesticides, Synthetic pesticides, Insecticides, Agrochemicals, Mechanism of action, Pest control, Environmental impact, Human health.*

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INTRODUCTION

Pesticides, a crucial component of modern agriculture, play a vital role in protecting crops from pests and ensuring food security. However, the use of pesticides comes with a complex set of benefits and drawbacks that extend beyond the fields they're applied to. Pesticides encompass a variety of substances designed to combat pests, including insects, weeds, fungi, and pathogens. They prevent the loss of crops to pests, ensuring higher yields and maintaining the quality of harvested produce. Without pesticides, global food production would face significant challenges, potentially leading to food shortages and escalating prices. While pesticides provide benefits, their widespread use has raised environmental concerns. Runoff from fields can contaminate water sources, affecting aquatic ecosystems and potentially harming aquatic life. Non-target organisms, such as pollinators like bees and other beneficial insects, can also be unintentionally affected by pesticide use, disrupting ecosystems and biodiversity. The impact of pesticide residues on human health is another critical aspect. Pesticide residues can find their way into the food chain, and prolonged exposure, even at low levels, may pose health risks. Certain pesticides have been associated with various health issues, including cancer, neurological disorders, and developmental problems, leading to ongoing debates about acceptable levels of exposure and regulatory measures.

In the 1950s and 1960s, the height of the Green Revolution, crop output was increased to increase food supply in low-income countries by heavily using inputs like inorganic fertilisers, synthetic insecticides, and genetically engineered organisms [1, 2]. Without proactive and preventative efforts by using agrochemicals, more than 70% of agricultural production would suffer huge losses while over 67,000 species show visible advantages on agricultural crops [2, 3]. In order to defend their crops against insect assaults and damage, farmers frequently choose to use synthetic pesticides as quick-fix pest control options [4]. However, the effectiveness of synthetic pesticides and their widespread misuse create several bottlenecks, particularly those that result in insect resistance and health problems [5]. Unwanted repercussions of their uncontrolled use of these synthetic pesticides include environmental degradation,

damage to non-target creatures, contamination of food and feed, insect comeback, genetic variety in plants, and adverse effects on biodiversity [6, 7].

Synthetic pesticides have hazardous impacts on human health that range from the bioaccumulation of pollutants in food chains to their widespread use in land and aquatic ecosystem [8]. The two most used synthetic pesticides, dichlorodiphenyltrichloroethane and toxaphene, have the potential to have long-lasting impacts on the soil as well as to wash into groundwater and aquatic biota[9]. Human disorders that linger after exposure or ingestion have negative impacts on the immune system, the neurodevelopmental and endocrine systems, metabolic diseases, cancer, and infertility[10, 11], and these are the principal health dangers linked to the ongoing use of synthetic pesticides[12]. The quality of synthetic pesticides is frequently harmed in a number of rural communities by dilution, poor mixing, and selling after their expiration date[13]. According to the World Health Organisation, pesticides directly cause 200,000 deaths worldwide each year[14]. Notably, several synthetic pesticides continue to exist in the environment, damaging the soil and water supplies and thinning the ozone layer[15, 16]. It is noteworthy that around USD 31 billion, or 2-4 percent of the global pesticide industry, was spent on synthetic pesticide usage in Africa[17]. However, it has been claimed that the danger of human death is greater in Africa due to the improper application of pesticides[18]. According to the United Nations Environmental Programme, between 2005 and 2020, the cost of diseases caused by pesticides in Sub-Saharan Africa might exceed USD 90 billion[19]. Alternative methods of pest management are now necessary due to the negative effects associated with the incorrect and excessive use of chemical pesticides[20]. Consequently, there is a stronger emphasis on the creation and study of botanical pesticides.

Before the invention of synthetic pesticides, botanical pesticides were widely used in both subsistence and commercial farming for thousands of years. Ingredients in botanical pesticides are chemically derived from plants that operate as attractants, attractants, antifeedants, and growth inhibitors[20, 21, 22]. These substances become plant pesticides when they are extracted using the proper solvents and/or combined with the required pesticide adjuvants. The use of plant-based products gradually decreased until recently, when the excessive use of synthetic pesticides began posing an immediate threat to environmental safety and human health due to their strength and effectiveness against damaging crop diseases[23, 24]. Due to their safety record for crop consumption, botanicals are becoming more and more popular in organic farming, and customers are prepared to pay more for organic products[25].

Examining the known and untapped plant species with pesticidal characteristics has produced a number of conclusions[26, 27]. Numerous plants, including wild plants and herbal remedies, include hundreds of botanical pesticidal chemicals. Many plants of Rutaceae, Compositae, Meliaceae, Leguminosae, Araceae, Platycodoniaceae, Solanaceae, Chenopodiaceae, Zingiberaceae, Labiatae, Loniceraceae, Umbelliferae, Polygonaceae, and Euphorbiaceae possess pesticidal attributes and numerous compounds of plant secondary metabolites, including alkaloids, terpenoids, and flavonoids that show pesticidal activities. It's interesting to note that a number of commercially available plant-based pesticides are mostly derived from the following plants: pyrethrum (Tanacetumcinerariifolium), tobacco (Nicotianatabacum L.), neem (Azadirachtaindica A. Juss), sabadilla (Schoenocaulonofficinale Grey), and ryania (Ryaniaspeciosa)[28]. The bulk of insecticides made from plants are used to manage insect pests[29, 30], in addition to reducing plant parasites including nematodes, fungus, bacteria, and viruses [31, 32]. Since they have good effects on environmental preservation, are less harmful to mammals, and pose no threat of causing target pests to develop resistance, botanical pesticides may be helpful as alternatives to conventional instruments for integrated pest control[33, 34, 35].

Chemical Insecticides

Chemical agent intended to eradicate or slow the development of pests that harm or obstruct the growth of crops, bushes, trees, and other human-desired vegetation. However, almost all chemical pesticides are toxins that represent a long-term threat to the environment and to people due to their persistence in plants or human body tissue. The majority of pesticides are non-specific and may damage beneficial or harmless life species.

Advantages and disadvantages of herbal insecticides

Advantages: The active ingredient's quick decomposition may be advantageous because it lowers the possibility of residues in food. Some of these items might be utilised right before harvesting. Even if they do not ultimately result in insect death, several of these products have a very immediate action by preventing insects from feeding. These compounds stomach-like actions and quick decomposition may make them more selective against insect pests and less aggressive towards their natural adversaries. Most

of these substances are not hazardous to plants. As opposed to synthetic pesticides, resistance to these chemicals does not emerge as quickly.
Disadvantages: Most of these products are not truly pesticides since many are merely insect deterrents and their effect is slow. They are rapidly degraded by UV light so that their residual action is short. Not all plant pesticides are less toxic to other animals than synthetic ones. They are not necessarily available season-long. Most of them have no established residue tolerances. No legal registrations are establishing their use. Not all recommendations followed by growers have been scientifically verified.

Mechanism of Action of Herbal Insecticides

Plants produce various bioactive compounds to protect themselves from herbivores and pathogens. These compounds can be extracted from the plant and used as a source of natural insecticides. Some of the most common bioactive compounds found in plant extracts include fatty acids, alkaloids, terpenoids, phenols and quercetin.
Fatty acid salt kills small insects and mites through suffocation i.e. by blocking the spiracles or disruption of waxes present in cuticles and membranes in the integument and hence leads to desiccation[36].
Alkaloids, a group of naturally occurring nitrogenous compounds present in plants with a wide range of biological activities, are a common source of insecticides. For example, nicotine, a well-known alkaloid, is toxic to insects due to its ability to disrupt their nervous system. This property has been exploited for use in agriculture, with nicotine sulfate being used as an insecticide for controlling aphids and other pests in crops[37]. Some alkaloids, such as nicotine, harmine, and piperine, have been reported to have insecticidal activity against several insect pests. Harmine, an indole alkaloid, inhibits acetylcholinesterase activity and causes neurotoxicity in insects[38].
Terpenoids, a large class of compounds produced by plants, are also commonly used as insecticides. For example, the terpenoidazadirachtin, found in neem oil, is a potent insecticide that interferes with insect growth and development [39, 40]. Neem oil has been widely used in agriculture for controlling pests such as aphids, caterpillars, and whiteflies[40].
Limonene, a monoterpene, is a potent insecticide that disrupts the insect's nervous system[41].
Phenols, a class of compounds found in many plant species, are also used as insecticides and antimicrobials. For example, eucalyptol, a phenol found in eucalyptus oil, is toxic to a range of insect pests and has been used as an insecticide for controlling mites and other pests in crops[42].
Thymol, a phenolic compound present in thyme, has shown insecticidal activity against several insect pests, including beetles and mites. It acts by disrupting the insect's cell membranes[43].
Quercetin (flavonoid) has been found as a compound of interest in producing bioinsecticides. Its plant metabolism has been associated with a defense mechanism. The plant alters its palatability and nutritional value, decreases digestibility, or even acts as a toxin[44].
Bacillus thuringiensis (Bt) is a gram-positive bacterium that produces insecticidal proteins called Bt toxins. Bt toxins have shown specific toxicity against several insect pests, including caterpillars, beetles, and mosquitoes. They act by binding to specific receptors on the insect's midgut cells, leading to cell lysis and death[45, 46].

Currently available insecticides in the market and their drawbacks related to their uses on human health

Insecticides are chemicals used to control insects and pests that can cause damage to crops, spread diseases, and cause harm to humans. However, many of the insecticides currently available in the market have drawbacks related to their use on human health. Synthetic insecticides such as organochlorine and organophosphate compounds are commonly used, but they can be harmful to human health, target non-intended insect species, and lead to the evolution of resistance among insect populations.
To address these issues, researchers are exploring alternative insecticides that are environmentally safe and effective. One such alternative is erythritol, a non-nutritive sugar alcohol that is toxic to fruit flies and has been approved by the US FDA as a food additive[47].Other alternatives include biorational insecticides, which are derived from natural sources and have low environmental impacts. These include essential oils, soaps, detergents, and diatomaceous earth, which have been found to be effective against pests such as the fall armyworm and the bean weevil[48, 49].
In addition to alternative insecticides, researchers are also exploring alternative methods of application. For example, drip chemigation is the application of pesticides to the soil through trickle irrigation systems, which can reduce insecticide inputs, utilize more selective and environmentally compatible insecticides, and reduce the time lost to reentry intervals, while maintaining comparable efficacy and economic returns[50].Overall, while many of the insecticides currently available in the market have drawbacks

related to their use on human health, researchers are exploring alternative insecticides and methods of application that are environmentally safe and effective.

Plants with potential insecticidal effect

Several plants have been found to have potential insecticidal effects:

Mentha pulegium (pennyroyal) and *Rosmarinus officinalis* (rosemary) essential oils have shown insecticidal effects against Culexpipiens, a mosquito vector of diseases like West Nile virus[51].

Basil (Ocimumbasilicum), black seeds (*Nigella sativa*), and lavender (*Lavandula angustifolia*) essential oils have demonstrated insecticidal activity against Sitophilus oryzae, a major stored product pest[52].

Extracts from native plants in Mato Grosso do Sul, Brazil, such as *Tapiriraguia nensis, Schinustereb inthifolius, Tabebuia heptaphylla, and Gomphrenaelegans*, have shown insecticidal effects against Sitophilus zeamais, a pest of stored grains[53].

Zinc oxide and titanium dioxide nanoparticles have exhibited insecticidal effects against *Bactericera cockerelli*, a pest of tomato plants[54].

Bioactive components having potential insecticidal effect

Several bioactive components have been identified to have potential insecticidal effects. Some examples include: Podophyllumsinense, a traditional herbal medicine, contains lignans, flavonoids, anthraquinones, and volatile oils that demonstrate insecticidal effects[55].

Terminalia arjuna, a widely used medicinal plant, contains phytochemical constituents like triterpenoids, glycosides, flavonoids, and tannins that exhibit insecticidal activities[56].Decalepishamiltonii, a climbing shrub, has tuberous roots with reported insecticidal properties[57].

Bacillus thuringiensis, a microbial insecticide, contains various bioactive components such as insecticidal crystal proteins and vegetative insecticidal proteins[58].

Artemisia lavandulaefolia essential oil contains a component called (-)-4-terpineol. (-)-4-Terpineol, isolated from the essential oil of *Artemisia lavandulaefolia*, has insecticidal activity against Plutellaxylostella[59].Pulegone and piperitenone, found in the essential oil of *Mentha pulegium* L., exhibit fumigant effects against *Sitophilus oryzae*[60].

Isoflavones, such as biochanin A and biochanin B, found in chickpeas (Cicer arietinum), possess insecticidal properties [61].oil from *Dyssodiata getiflora*, containing six monoterpenes, has insecticidal activity against Drosophila melanogaster larvae[62].Tannins extracted from Cydonia oblonga fruit show bio-insecticidal effects against *Tribolium confusum*[63].

Efficacy and stability

Pesticides derived from plants have gained popularity as a possible substitute for synthetic pesticides in pest control. These insecticides have a broad-spectrum action and have been demonstrated to be effective against a variety of insect pests. However, a number of variables can impact the stability of plant-based insecticides, which can lessen their efficacy. Thus, further research is required to create new formulations and delivery systems that might increase the stability and effectiveness of plant-based insecticides. To address this issue, researchers are exploring methods to stabilize plant extracts, such as encapsulation and formulation with other ingredients [64].Insecticides are a crucial tool in the management of crop pests and diseases. However, the safety and environmental impact of synthetic insecticides have raised concerns.

The natural insecticides are safe for the environment and biodegradable. Furthermore, plant-derived pesticides contain a variety of chemical compounds that work cooperatively to affect both behavioural and physiological processes, in contrast to conventional pesticides that are based on a single active ingredient [65]. One plant species may have compounds with a variety of functions; for instance, extracts from the *Azadirachta indica* neem tree are antifeedant, antioviposition, repellant, and growth-regulating. The toxicity of traditional synthetic pesticides, in contrast, is primarily limited to neuro-muscular function [66]. In recent years, plant-based insecticides have emerged as an alternative to synthetic insecticides. A chemical insecticide greatly disturbs the natural balance of the crop ecosystem. It also causes harmful impact to honeybees and pollinators [67].

Market share of currently used synthetic insecticide versus plant as a source of insecticide

In the past three decades, the use of contemporary organic synthetic pesticides has increased by nearly 40 times. Another article explores the growing acceptance and market share of biorational pesticides in the worldwide insecticide market. The use of biorational products for the control of insect pests has developed significantly in recent years, which has increased their popularity and market share on the international insecticide market, according to the article [68].

It is evident that the negative impact synthetic pesticides have on the environment and human health have made their use a subject for worry. Due to this, interest in biorational pesticides, which are made of natural compounds or their derivatives, has increased [69].

The search results mention neonicotinoids, which have over 25% of the global market share and have emerged as the most frequently used, well-liked, and rapidly-growing class of synthetic insecticides in modern agriculture [70]. Pyrethroid insecticides are also frequently employed to protect plants, accounting for 25% of the market for insecticides used for plant protection in 1986 [71].

More than 50% of the worldwide biopesticide market is held by bioinsecticides such those made from *Bacillus thuringiensis* (Bt)-derived insecticides [72]. Although the market penetration of biopesticides has significantly increased, they still account for only a small portion of pest management options. Just 4.2% of India's entire pesticide market is made up of biopesticides, yet that sector is expected to grow at an astounding 10% annually [73].

The demand for natural pesticides might change based on the type of pest, the crop, and the geographic area, it is necessary to keep in mind. To ascertain the present level of demand for natural insecticides on the international market, additional investigation and analysis are required.

CONCLUSION

In conclusion, plant extracts have the potential to be a useful alternative to synthetic pesticides for controlling pests and diseases in crops. They are considered to be safer for human health and the environment compared to synthetic pesticides, but their efficacy and stability can be limited. Additionally, the potential environmental impact of plant extract production must also be considered. Further research is needed to optimize the use of plant extracts as pesticides, such as improving their stability, increasing their efficacy against specific pests, and reducing their environmental impact.

Concerns for the environment and public health have been raised as a result of the sharp increase in the usage of synthetic pesticides. Biorational insecticides made from natural ingredients are becoming more popular. Although bioinsecticides, such as those made from Biorational, have a sizable market share, more research is required to estimate the need for natural insecticides globally. Overall, plant extracts as pesticides offer a promising alternative for sustainable pest management in agriculture. However, it is important to use them judiciously and in an integrated pest management approach that considers their limitations and potential impact on the environment.

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