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Effect of Plant Based Pesticides in Grain Storage Management

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ABSTRACT

The utilization of plant-based pesticides in grain storage management presents a promising avenue for sustainable pest control. This review paper examines the efficacy, mechanisms of action, and challenges associated with the adoption of botanical alternatives in grain storage facilities. Highlighted are the diverse phytochemical compositions of plant-based pesticides, their low toxicity to non-target organisms, and their compatibility with integrated pest management strategies. Despite their potential benefits, obstacles such as formulation complexities, limited chemical data, and regulatory hurdles hinder their widespread use. Addressing these challenges through collaborative research efforts and regulatory support is crucial to realizing the full potential of plant-based pesticides in grain storage management. By integrating these natural solutions into storage practices, we can promote food security while mitigating environmental and health risks associated with synthetic pesticides.

Keywords: plant-based pesticides, grain storage management, agriculture, integrated pest management, pest control.

1. INTRODUCTION

Grain storage management is a critical aspect of agricultural practices worldwide, ensuring the preservation of harvested crops for sustained food security and economic stability. With the global population steadily increasing, the demand for grain production has risen exponentially, accentuating the importance of effective grain storage solutions.

1.1. Background and Importance of Grain Storage Management

Grain storage has been a fundamental practice since the advent of agriculture, enabling farmers to store surplus harvests for consumption during lean periods and trade. Over the centuries, various methods of grain storage have evolved, ranging from simple underground pits and granaries to modern silos and warehouses equipped with sophisticated technologies. [1]

The significance of grain storage management extends beyond mere preservation; it plays a pivotal role in mitigating post-harvest losses caused by pests, pathogens, and environmental factors [2]. Inadequate storage facilities or improper management practices can lead to substantial grain losses, threatening food security and causing economic hardships for farmers and communities.

1.2. Need for Effective Pest Control

Pests pose a significant threat to stored grains, causing extensive damage and contamination if left unchecked. Common grain pests include insects, fungi, rodents, and birds, which proliferate in conducive environments and feed on stored grains, reducing quality and quantity.

Conventional pest control methods often rely on synthetic pesticides, which, while effective, raise concerns about environmental pollution, human health risks, and the development of pesticide-resistant pests. As a result, there is a growing emphasis on exploring alternative pest management strategies that are both effective and sustainable. [3]

1.3. Rise of Plant-Based Pesticides in Agricultural Practices

In recent years, there has been a resurgence of interest in plant-based pesticides as eco-friendly alternatives to synthetic chemicals. Plant-based pesticides, derived from botanical sources such as neem, pyrethrum, and essential oils, offer promising solutions for pest management while minimizing adverse effects on the environment and non-target organisms.

The use of plant-based pesticides aligns with the principles of organic and sustainable agriculture, emphasizing the preservation of natural ecosystems, soil health, and biodiversity. Furthermore, plant-based pesticides often exhibit multiple modes of action, reducing the likelihood of pest resistance and offering a more holistic approach to pest control.

1.4. Purpose and Scope of the Review

This review aims to explore the effectiveness of plant-based pesticides in grain storage management, examining their mechanisms of action, efficacy, safety, and environmental implications. By synthesizing existing literature and empirical evidence, this review seeks to provide insights into the potential role of plant-based pesticides in sustainable grain storage practices.

Through a comprehensive analysis of the current state of knowledge, this review will elucidate the opportunities and challenges associated with the adoption of plant-based pesticides in grain storage management. Additionally, it will highlight future research directions and policy considerations to promote the integration of plant-based pesticides into mainstream agricultural practices.

1.5. Plant-Based Pesticides: Overview and Classification

1.5.1. Definition and Characteristics of Plant-Based Pesticides

Plant-based pesticides, also known as botanical pesticides or biopesticides, are derived from natural sources such as plants, fungi, bacteria, and minerals. Unlike synthetic pesticides, which are chemically synthesized, plant-based pesticides are formulated from botanical extracts or essential oils. These compounds often possess pesticidal properties due to their bioactive constituents, which interfere with the physiological processes of pests or disrupt their life cycles.

Characteristics of plant-based pesticides include their biodegradability, low toxicity to non-target organisms, and reduced environmental persistence compared to synthetic chemicals. Moreover, many plant-based pesticides are compatible with organic farming practices and are exempt from certain regulatory requirements, making them attractive options for sustainable pest management.

1.5.2.Classification Based on Sources and Chemical Composition

Plant-based pesticides can be classified into several categories based on their sources and chemical composition. Common types include: [4]

1. **Botanical Extracts**: Derived from various plant parts such as leaves, seeds, fruits, and roots, botanical extracts contain bioactive compounds with insecticidal, fungicidal, or herbicidal properties. Examples include neem oil, pyrethrum extract, and rotenone.
2. **Essential Oils**: Extracted from aromatic plants through steam distillation or cold pressing, essential oils contain volatile compounds that repel or kill pests. Essential oils like peppermint, eucalyptus, and thyme are known for their insecticidal and repellent effects.

3. **Microbial Pesticides**: Produced from beneficial microorganisms such as bacteria, fungi, and viruses, microbial pesticides target specific pests or pathogens while posing minimal risk to non-target organisms. Examples include Bacillus thuringiensis (Bt) for insect control and various fungal species for disease suppression.
4. **Mineral-Based Pesticides**: Formulated from naturally occurring minerals like diatomaceous earth, kaolin clay, and sulfur, mineral-based pesticides act as physical or chemical barriers against pests and diseases. These products are often used in organic farming to control insects, mites, and fungal pathogens.

1.5.3.Comparative Analysis with Synthetic Pesticides

In comparison to synthetic pesticides, plant-based pesticides offer several advantages, including:

- **Environmental Safety**: Plant-based pesticides are typically less harmful to beneficial insects, birds, mammals, and aquatic organisms due to their natural origins and mode of action. They also degrade more rapidly in the environment, reducing the risk of pollution and ecosystem disruption.
- **Reduced Resistance Development**: Plant-based pesticides often target pests through multiple modes of action or biochemical pathways, making it less likely for pests to develop resistance compared to single-mode synthetic chemicals.
- **Compatibility with Organic Farming**: Many plant-based pesticides are approved for use in organic agriculture and are compliant with organic certification standards, allowing farmers to manage pests while adhering to sustainable farming practices.

However, plant-based pesticides may also have limitations, such as variable efficacy, shorter residual activity, and potential phytotoxicity at high concentrations. Additionally, their production and formulation can be more labor-intensive and costly compared to synthetic pesticides.

1.6. Mechanism of Action of Plant-Based Pesticides

Understanding the mode of action of plant-based pesticides is essential for optimizing their efficacy and minimizing unintended effects. Plant-based pesticides exert their pesticidal activity through various mechanisms, including: [5]

- **Neurotoxicity**: Some plant-based compounds disrupt the nervous system of pests, causing paralysis, convulsions, or death. For example, pyrethrins found in chrysanthemum flowers target insect nerve cells, leading to rapid immobilization and mortality.
- **Insect Growth Regulation**: Certain plant-derived compounds mimic insect hormones or interfere with developmental processes, disrupting the growth, molting, or reproduction of pests. For instance, azadirachtin in neem oil disrupts insect molting and metamorphosis, leading to developmental abnormalities and reduced fecundity.
- **Antifeedant and Repellent Effects**: Many plant-based pesticides act as feeding deterrents or repellents, deterring pests from feeding on treated crops or entering protected areas. Essential oils like citronella and garlic emit odors that repel insects, while capsaicin in chili peppers causes irritation and avoidance behavior in mammals and insects.
- **Antimicrobial Activity**: Plant-based pesticides containing antimicrobial compounds inhibit the growth and reproduction of fungal, bacterial, or viral pathogens responsible for plant diseases. Essential oils like tea tree oil and cinnamon oil possess broad-spectrum antimicrobial properties, making them effective against various plant pathogens.

1.7. Efficacy of Plant-Based Pesticides in Grain Storage

Plant-based pesticides offer a promising alternative to synthetic chemicals for controlling pests in stored

grains, with studies showing their effectiveness in reducing insect infestations and fungal contamination. Neem-based formulations and essential oils from plants like peppermint and cloves have demonstrated insecticidal properties against common storage pests.

Factors affecting their efficacy include the type of pest, grain type, environmental conditions, and application method. Integrating plant-based pesticides into integrated pest management (IPM) strategies can enhance their effectiveness while reducing reliance on synthetic chemicals. [6]

Further research is needed to optimize their use and develop tailored IPM approaches for different cropping systems and storage facilities. Education and outreach efforts are crucial for promoting their adoption among farmers and stakeholders for sustainable grain storage practices.

1.8. Safety and Environmental Concerns

Plant-based pesticides offer a safer and more environmentally friendly alternative to synthetic chemicals. They typically have lower toxicity levels and degrade more rapidly in the environment, reducing the risk of harmful residues and ecosystem contamination. However, some plant-based compounds may still pose risks to non-target organisms and ecosystems if used improperly or in excessive quantities. Additionally, the production and formulation of plant-based pesticides may have environmental impacts, such as habitat destruction or water pollution. Regulatory oversight and proper stewardship practices are essential to ensure the safe and responsible use of plant-based pesticides while minimizing adverse effects on human health and the environment.

2. LITERATURE REVIEWS

The review study shows that agricultural growth is a global phenomenon with deep historical roots. There have been three distinct eras in the history of pesticide usage. Chemical class, functional group, mode of action, and toxicity are some of the ways pesticides are categorised. Insects, weeds, birds, fish, beneficial insects, non-target plants, water, soil, and crops are all susceptible to the hazardous effects of pesticides, which are formulated to kill pests and manage weeds using chemical components. In addition to polluting the environment, pesticide contamination spreads beyond the intended plants. Chemical residues have an effect on human health because they contaminate the environment and food. [7]

Synthetic pesticides were developed and used as a rapid and efficient way to manage agricultural pests and illnesses in response to the increased need for food to feed the ever-growing population. Due to their negative impacts on human health, the environment, and the development of resistant strains of pests and pathogens, synthetic pesticides should not be relied upon excessively. This, together with the rising interest in organically grown food, has prompted a hunt for new methods, and botanical pesticides are rising to the forefront of this trend. Botanical pesticides are great for controlling a wide range of agricultural pests; they are also cheap, biodegradable, effective in numerous ways, readily accessible, and relatively safe for non-target creatures. diverse plants have diverse phytochemical compositions, which is why they have various mechanisms of action. In this way, they may aid in sustainable agricultural output and be a part of integrated pest control systems. Problems with formulation and marketing stemming from a dearth of chemical data and positive controls have prevented botanical pesticides from achieving complete adoption. Botanical pesticides have been highlighted in several articles, with a bias towards their use in insect pest control. To combat pests that pose a threat to agricultural output, this study compiles data on botanical pesticides, including their phytochemical makeup and the processes by which they work. Additionally, the article details the biodegradation of several botanical pesticides, their function in IPM, and the difficulties associated with using them for long-term pest control in crops. [8]

Pest insects cause significant harm to grains that are kept for later use in various regions of the globe. Despite their effectiveness and reliability, synthetic pesticides have a number of negative qualities that have prompted agriculturists to seek for alternatives that are powerful, environmentally benign, and economically feasible. These include not biodegradability, high costs, and detrimental impacts on both people and the environment. It is recognised that insecticidal qualities are possessed by volatile organic chemicals found in plants. As a substitute for synthetic pesticides, they may be promoted. The potential use of botanical pesticides derived from plant volatile organic compounds was the main topic of this research. Such pesticides might lessen the need for synthetic insecticides for controlling pests in stored grain. I) accessibility of raw materials, ii) quality control, and iii) regulatory simplicity were some of the major obstacles to product commercialization covered in the study. Additionally, the study stresses the need of well-defined goals for biopesticide studies. Biopesticides have the potential to be more widely used if they were subject to a separate regulatory framework. [9]

Controlling insect pests in bulk storages has been done using natural plant compounds since the 1960s. Various insect-pest infestations during storage increased the economic significance of grain protection. One of the most popular methods of pest control, integrated pest management makes use of fumigants with other residual and contact insecticides. Today, synthetic pyrethroids are either limited or prohibited owing to the residual issue and the health dangers they pose to consumers. Insects and other pests have evolved resistance to the majority of fumigants and synthetic chemicals commercially available today. These limitations made it possible to substitute chemical pesticides with need-based plant-derived products. There is promising evidence that compounds produced from plants may kill insects, according to the studies. In addition, to determine the harmful effects on humans, animals, and crops, biosafety studies should be conducted on a variety of insecticides derived from plants. This study covers a lot of ground, including storage losses caused by pests, the negative consequences of pesticides used as grain protectants, the use of plant products as a substitute for synthetic compounds, the categorization of plant-based compounds, and the formulation of grain protectants using powder and oil. [10]

Preserving stored goods against common pests has been a practice that dates back to the beginning of existence. By acting as “chemosterilants/reproduction inhibitors or insect growth and development inhibitors”, they also function as toxicants, repellents, antifeedants, and natural grain protectants. Some of the chemical components of these oils are known to disrupt the insect nervous system, according to the literature. There has been a significant uptick in the usage of environmentally friendly pesticides, which has stimulated considerable interest in insecticides derived from plants. Given the above, this review study focuses on botanicals used to fight stored pests in food grains, paying particular attention to their categorization, mechanism of action, recent advancements, and commercial and regulatory constraints. [11]

With an expected 9.1 billion people on Earth by 2050, there will be a 70% increase in food demand. Insect pests cause postharvest loss, which is a major problem for food security. There may be as much as $4 billion in postharvest grain losses in sub-Saharan Africa per year. Roughly 15% of all cereal crop output comes from this. Over the last half-century, chemical pesticides have been used to lessen insect damage to grain, but this practice has resulted in several concerns for both human and environmental health. Because of these issues, scientists have been working on less harmful alternatives. Innovations in pesticide technology that are safe for use in integrated pest management programmes, biodegradable, effective against a narrow range of pests, and unlikely to contaminate the environment are the focus of alternative strategies. Insect pests of stored grains may be managed with the use of some natural plant products that

match these characteristics. Nonetheless, in most areas of sub-Saharan Africa, there is a lack of knowledge on the use of botanical pesticides in storage pest management systems. Few people make and utilise plant-based products that really work. The first stage in addressing the gaps is to compile and distribute a synthesis of the existing knowledge. So, to sum up, this study provides an overview of the new and improved botanical pesticides for stored grain pest control, encompassing past, present, and future problems with insect pest management. [12]

For the purpose of safeguarding stored grains, the European Council has only approved a small number of pesticides so far. The creation of environmentally friendly instruments is a need due to resistance challenges and worries about ecotoxicity. This review focuses on the latest research on plant extracts and pure compounds produced from plants that show promise as biopesticides for items that are kept, as well as in terms of their biological activity. Biopesticides are designed to effectively combat certain pests while minimising damage to both people and the environment. There are many plant species that are safe for people to eat, including those mentioned below. You may safely utilise edible plant extracts made with inorganic solvents as contact insecticides, fumigants, or repellents. Products intended for human consumption often include spices with strong biological properties, such as cinnamon, rosemary, parsley, garlic, oregano, and basil. Among the botanical matrixes studied, cinnamon has shown the highest effectiveness in killing the insect and mite species included in this study (Acaroidea, Coleoptera, and Lepidoptera). Basil and garlic are the next most commonly examined, after cinnamon. Azurinda indica, Prunus persica Additionally, A. Juss and Carum sp. show great promise as insecticides and/or miticides; a plant-derived acaricidal compound of A. indica is now available for purchase. [13]

Due to the excessive usage and dependence on pesticides, pest control is now facing significant economic and environmental challenges on a global scale. We must immediately begin to address the growing concern about the non-target toxicity, lingering consequences, and problematic biodegradability of these synthetic pesticides by finding and implementing more effective and environmentally friendly alternatives. Interest in pest management methods using environmentally benign plant-based insecticides has been sparked by the growing concern for environmental safety. A wide variety of harmful pests and illnesses may be effectively countered by botanical pesticidal components. The fact that they are cheap, readily available, easily biodegradable, and relatively harmless to benefiting agents is even more crucial. The different ways in which different plant species ward against pests and illnesses are a result of their unique phytochemical makeup. However, they have not been widely accepted or used because of formulation issues and a lack of suitable chemical data. Thus, the purpose of this study is to bring attention to the current state, phytochemical compositions, insecticidal processes, and difficulties associated with using pesticides derived from plants in environmentally friendly farming practices. [14]

Included in this review is a list of stored-grain bug species along with descriptions on how to identify them. Various methods of management are detailed, including state-of-the-art storage facilities (hermetic and low-pressure storages), altered or regulated storage environments, ozone fumigant application, irradiation, and physical alternatives. Semiochemicals, natural enemies, biopesticides, and entomopathogenic nematodes are some of the sustainable biological choices that have their details augmented. It incorporates the use of inert dusts as a grain protector, both alone and in conjunction with the living thing. Also shown are studies on nanotechnology for stored grain security, innovative management choices, and alternative fumigants. Molecular biology methods like RNAi and CRISPR are also mentioned. The many approaches for managing the insects that cause storage losses are explained in this overview, which also allows the reader to grasp the general issues impacting grain storage. [15]

A botanical pesticide may be more efficiently and pragmatically developed by conducting large-scale bioassay-guided fractionation to ensure it meets all the necessary requirements and reaches commercial status. Put simply, by conducting bioassays on various plant extracts and their constituents, regardless of how they were purified, we can potentially identify the most effective compound or combination of compounds linked to the pesticide activity of each species. The isolated molecule has the potential to serve as a model for future pesticide derivative synthesis or semi-synthesis, which might lead to safer and more effective products using structure-activity relationship (SAR) methods. Because of the synergistic effect of compound mixtures, extracts or fractions from a certain plant species can be more effective than their isolated compounds. This discovery could lead to the production of raw materials for commercial biopesticides, as sometimes compounds exhibit no activity when presented in their isolated form. [16]

3. CONCLUSION

The reviewed literature underscores the pivotal role of plant-based pesticides in grain storage management. With growing concerns over the adverse impacts of synthetic pesticides on human health and the environment, plant-based alternatives emerge as promising solutions for sustainable grain storage. These botanical pesticides, derived from natural sources, offer diverse modes of action, minimal toxicity to non-target organisms, and rapid biodegradability, aligning with the principles of integrated pest management. Despite their efficacy, challenges persist in their formulation, commercialization, and regulatory frameworks, hindering widespread adoption. However, concerted efforts to address these challenges, coupled with increased research and dissemination of scientific knowledge, can accelerate the broader utilization of plant-based pesticides in grain storage management practices. Moving forward, a collaborative approach involving researchers, policymakers, and agricultural stakeholders is imperative to harness the full potential of plant-based pesticides and ensure food security while safeguarding human and environmental health.

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