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3. Advances in Phyto and Zoo-Based Pest Control: Sustainable Strategies for Agricultural Pest and Disease Management

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Abstract:

Agricultural pest and disease control has traditionally relied on chemical pesticides, which pose significant environmental and health risks. This article explores phyto-based (plant-derived) and zoo-based (animal-derived) products as sustainable alternatives. Phyto products, including essential oils and plant extracts, disrupt pest physiology with minimal environmental impact. Zoo products, such as beneficial insects and pheromones, target pests through biological interactions, supporting ecological balance. The comparative analysis highlights the effectiveness, environmental benefits, and limitations of these products, emphasizing their role in Integrated Pest Management (IPM). The regulatory landscape and future trends indicate growing support for eco-friendly pest control, driven by regulatory policies and technological integration like AI and remote sensing. This review advocates for increased adoption of phyto and zoo products, contributing to sustainable agriculture and reduced dependence on synthetic chemicals.

Keywords:

Phyto-based pest control, Zoo-based pest control, Sustainable agriculture, Integrated Pest Management, Biopesticides, Environmental impact, Pheromones, Essential oils, Regulatory frameworks, Precision agriculture.

3.1 Introduction to Disease and Pest Control in Agriculture:

3.1.1 Global Impact of Pests and Diseases on Agriculture:

Pests and diseases cause significant agricultural losses worldwide, reducing crop yields by 20-40% (Oerke, 2006). In the U.S., pest-related losses amount to around $40 billion annually (Pimentel, 2005).

The overreliance on chemical pesticides has led to environmental concerns, including soil degradation, water contamination, and harm to non-target species (Geiger et al., 2010). Pesticide resistance is an emerging issue, highlighting the need for more sustainable pest management solutions (Carvalho, 2006).

3.1.2 The Shift to Sustainable Pest and Disease Management:

Sustainable pest management strategies are moving away from chemical pesticides in favor of plant-based (phyto) and animal-based (zoo) alternatives. Phyto products, such as neem oil and pyrethrum, are effective and environmentally safer compared to synthetic chemicals (Regnault-Roger et al., 2012). Zoo products, including natural predators and pheromones, help control pests through biological processes (Copping & Menn, 2000). These eco-friendly methods are more selective and biodegradable, offering significant benefits for integrated pest management (Koul, 2012). The shift is also driven by stricter regulations and growing consumer demand for sustainable agriculture (United Nations, 2015).

3.2 Understanding Phyto Products in Pest and Disease Control:

3.2.1 Definition and Types of Phyto Products:

Phyto products are plant-derived substances used in pest and disease management. These include essential oils, alkaloids, and various plant extracts, all known for their pesticidal properties. Common phyto products include neem oil, pyrethrum, garlic extract, and eucalyptus oil.

Neem oil, extracted from the neem tree (Azadirachta indica), is a well-known biopesticide, while pyrethrum, derived from chrysanthemums, acts as an insecticide. Garlic and eucalyptus oils contain natural compounds that repel pests and inhibit their growth (Isman, 2006).

3.2.2 Mechanisms of Action in Phyto Products:

Phyto products work through various biochemical pathways to control pests. For example, neem oil's active compound, azadirachtin, interferes with the hormonal system of insects, disrupting growth and reproduction (Schmutterer, 2002). Pyrethrum, on the other hand, affects the nervous system of insects, leading to paralysis and death by inhibiting nerve signal transmission (Regnault-Roger et al., 2012).

These compounds may also have repellent effects, preventing pests from feeding or laying eggs on treated plants. The mechanisms of action often involve disruption of vital physiological processes, such as feeding, reproduction, and growth.

3.2.3 Global Case Studies of Phyto Product Use:

Phyto products are used globally, with region-specific examples demonstrating their effectiveness. In India, neem oil is widely used in organic farming to manage a variety of pests, such as aphids, mites, and caterpillars (Mukherjee et al., 2009). Similarly, in Brazil, eucalyptus oil is applied to control fungal diseases in crops like tomatoes and potatoes (dos Santos et al., 2014). In Africa, garlic extracts have been used to combat pest infestations in smallholder farms, offering a low-cost and sustainable alternative to chemical pesticides (Gurung et al., 2016). These case studies highlight the versatility and effectiveness of phyto products in diverse agricultural contexts.

3.2.4 Advantages and Limitations of Phyto Products:

Phyto products offer several advantages. They are biodegradable, making them environmentally friendly, and generally exhibit low toxicity to non-target organisms, such as beneficial insects and humans.

These products are also less likely to cause pesticide resistance compared to synthetic chemicals (Koul, 2012). However, they have limitations, including slower action compared to synthetic pesticides and potential variability in effectiveness due to factors like plant species, environmental conditions, and pest species. Additionally, the cost of some phyto products, such as neem oil, can be higher than conventional pesticides, making them less accessible in certain regions (Isman, 2006).

3.3 Exploring Zoo Products in Pest and Disease Management:

3.3.1 Definition and Types of Zoo Products:

Zoo products are animal-derived substances and organisms that are utilized in pest and disease management. These include biological control agents, such as beneficial insects, and animal-based substances like chitin and pheromones. Biological control agents are living organisms that control pest populations by preying on, parasitizing, or competing with pests.

Common examples include ladybugs, which prey on aphids, and beneficial nematodes, which target soil-dwelling insect larvae (Gurr et al., 2016). Chitin, a substance found in the exoskeletons of insects, has been explored for its potential to control fungal pathogens (Bidochka et al., 2002). Pheromones, chemical signals used to influence the behavior of pests, are often used in traps to disrupt mating and reduce pest populations (Gao et al., 2014).

3.3.2 Mechanisms of Action in Zoo Products:

Zoo products operate through various mechanisms to manage pests. Predator-prey dynamics are central to the action of biological control agents. For example, ladybugs consume aphids, effectively controlling their populations without the need for chemical pesticides (Gurr et al., 2016).

Pheromones, on the other hand, exploit the chemical communication systems of insects to disrupt mating patterns. For instance, sex pheromones are used in traps to confuse male insects, preventing them from finding mates and thereby reducing reproduction rates (Gao et al., 2014). Chitin-based products can stimulate the production of chitinase enzymes in plants, boosting their defense against fungal infections (Bidochka et al., 2002). These mechanisms are generally more specific and targeted compared to synthetic pesticides, making them safer for non-target organisms and the environment.

3.3.3 Case Studies of Zoo Product Applications:

Zoo products have been successfully applied in various agricultural and horticultural settings. In North America, ladybugs are commonly used in greenhouses to control aphid populations on crops like tomatoes and peppers (Gurr et al., 2016).

Another example is the use of beneficial nematodes in open fields to manage soil-borne pests such as root-feeding grubs (Wraight et al., 2005). In Asia, biological control has been used to combat the rice stem borer, with parasitoid wasps introduced to reduce pest populations (Heong & Escalada, 2015).

Additionally, pheromone-based pest management systems are widely used in orchards to monitor and control pest species like codling moths, reducing the need for chemical insecticides (Prokopy et al., 2003). These case studies highlight the versatility and effectiveness of zoo products in diverse agricultural settings.

3.4 Comparative Analysis of Phyto and Zoo Products in Pest Control:

3.4.1 Comparative Effectiveness:

Both phyto and zoo products offer effective alternatives to chemical pesticides, but they differ in their speed, coverage, and overall efficacy. Phyto products such as neem oil and pyrethrum typically act more slowly than synthetic pesticides but are effective over extended periods, particularly in controlling a broad range of pests. For example, neem oil has a slower action in terms of pest mortality but provides long-lasting control by disrupting insect growth and reproduction (Schmutterer, 2002). Zoo products, such as ladybugs and beneficial nematodes, tend to be faster in directly reducing pest populations, especially in confined environments like greenhouses. However, their efficacy can vary with pest species, environmental conditions, and the specific biological agent used. In open-field settings, zoo products may require higher quantities or more frequent applications to achieve the same results as phyto products, which can act as a more widespread deterrent (Gurr et al., 2016).

3.4.2 Environmental Impact and Ecological Footprint:

Phyto and zoo products generally have lower environmental impacts compared to chemical pesticides. Phyto products are biodegradable, often non-toxic to non-target organisms, and can contribute to soil and ecosystem health. For instance, neem oil is known for its minimal toxicity to humans and wildlife while offering effective pest control (Regnault-Roger et al., 2012). Zoo products also have a favorable environmental profile. Biological control agents like ladybugs or nematodes are naturally occurring organisms that integrate well into ecosystems without leaving harmful residues. However, their success depends on maintaining ecological balance, as the introduction of non-native species can sometimes disrupt local ecosystems (Gurr et al., 2016). Overall, both types of products contribute to reducing the ecological footprint of pest management.

3.4.3 Economic Feasibility and Market Considerations:

The economic feasibility of phyto and zoo products varies widely across regions and applications. Phyto products like neem oil are often cost-effective in areas where the raw materials are locally available, but production costs can be higher in regions where these products must be imported. For instance, the cost of neem oil in countries outside India can be significantly higher due to shipping and processing

costs (Isman, 2006). Zoo products, particularly biological control agents, can have high initial costs due to the need for breeding, packaging, and transportation. However, in the long term, these products can be cost-effective because they require fewer applications and offer sustainability benefits (Wraight et al., 2005). Market demand for both types of products is growing, driven by consumer preference for sustainable farming practices. As awareness of environmental and health concerns rises, the global market for eco-friendly pest management products is expected to expand.

3.4.4 Integration in Integrated Pest Management (IPM):

Both phyto and zoo products play significant roles in Integrated Pest Management (IPM) strategies, where they complement traditional pest control methods such as crop rotation, biological control, and mechanical control. Phyto products like neem oil can be used to suppress pest populations and prevent pest outbreaks in combination with other methods, such as the use of pheromone traps and natural predators (Koul, 2012). Zoo products, particularly biological control agents, are often used as part of IPM programs to provide long-term pest control without resorting to chemical pesticides. The integration of phyto and zoo products into IPM can reduce the reliance on synthetic chemicals, enhance biodiversity, and provide a more sustainable approach to pest management (Gurr et al., 2016). The synergy between these approaches results in reduced pest resistance, minimized pesticide residues, and healthier ecosystems.

3.5 Regulatory Frameworks and International Standards:

3.5.1 Overview of Regulatory Guidelines Across Major Markets:

The regulatory landscape for phyto and zoo products varies significantly across regions, with differing standards in the European Union (EU), United States, Asia, and Africa. In the EU, the use of plant-based and biological pesticides is governed by the European Food Safety Authority (EFSA), which ensures that products meet strict safety and environmental standards before being approved for use (European Commission, 2020). Similarly, in the United States, the Environmental Protection Agency (EPA) regulates both phyto and zoo products under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The EPA requires that these products meet rigorous safety standards before being marketed, particularly focusing on their impact on non-target organisms and ecosystems (U.S. EPA, 2022). In Asia, regulations are often more variable, with countries like India having well-

established guidelines for organic pesticides, including plant-derived substances like neem oil. However, enforcement can be inconsistent, and challenges related to certification processes and quality control remain (Verma & Vyas, 2018). In contrast, Africa's regulatory environment is still developing, with many countries relying on international standards and certifications for the approval of eco-friendly pesticides. The challenges in Africa include a lack of infrastructure for testing and certification, as well as limited access to regulatory expertise (Beninger et al., 2020). Across all regions, one common challenge is the slow approval process for new products, which can delay the commercial use of effective pest management solutions.

3.5.2 Future Trends in Regulation and Policy:

Future regulatory trends are increasingly focused on promoting eco-friendly alternatives to chemical pesticides due to growing concerns about pesticide resistance, environmental pollution, and human health risks. Many countries, particularly in the EU and the U.S., are tightening regulations on chemical pesticides, creating a gap that phyto and zoo products can fill. The European Commission's Farm to Fork strategy, for instance, aims to reduce the use of chemical pesticides by 50% by 2030, which is expected to drive further innovation and demand for biopesticides and other natural pest management solutions (European Commission, 2020).

International collaborations are also emerging to support sustainable pest control. The International Code of Conduct on Pesticide Management, developed by the Food and Agriculture Organization (FAO) and World Health Organization (WHO), encourages nations to adopt safer, environmentally friendly pest control practices. Additionally, regional agreements such as the ASEAN Guidelines for the Safe and Effective Use of Biopesticides in Southeast Asia foster cooperation on regulatory matters related to biopesticides (ASEAN, 2019). These efforts are likely to shape future policies, ensuring that biopesticides and biological control agents receive increased attention and support.

As regulations evolve, there will be a greater emphasis on harmonizing standards across countries to ensure that effective and safe products can reach global markets more efficiently. The increasing focus on sustainable agriculture and the shifting political landscape favoring eco-friendly approaches indicate that the regulatory environment for phyto and zoo products will continue to improve, creating new opportunities for these products in pest and disease management.

3.6 Innovation and Future Trends in Phyto and Zoo-Based Pest Control:

3.6.1 Advances in Phyto Product Research and Development:

Research into phyto products continues to evolve, with ongoing studies focusing on new plant species and compounds that offer enhanced pest control properties. For example, recent research has identified the pest-repellent potential of compounds in plants like *Azadirachta indica* (neem) and *Chrysanthemum cinerariaefolium* (pyrethrum), along with lesser-known species such as *Lantana camara* and *Piper nigrum*, which contain bioactive compounds effective against various insect pests (Regnault-Roger et al., 2012). Furthermore, advancements in plant extraction and formulation techniques are improving the potency and stability of these products. Modern methods like supercritical CO2 extraction offer cleaner, more efficient ways to obtain active ingredients from plants while preserving their efficacy (Isman, 2006). These innovations enhance the application of phyto-based pest control products in diverse agricultural systems, including organic and smallholder farms, and contribute to the growing market for sustainable pest management.

3.6.2 Innovations in Zoo Product Applications:

Innovations in zoo products, particularly in biological control agents, are advancing rapidly. One notable development is the use of genetically modified organisms (GMOs) to enhance pest resistance in crops. For example, the genetic engineering of *Trichogramma* parasitoids to increase their ability to target specific pests has shown promise in controlling moth larvae in various crops (Zhang et al., 2017). In addition, significant progress has been made in the breeding and mass production of beneficial insects such as ladybugs, parasitic wasps, and predatory mites. These advances ensure a more stable supply of biological control agents, improving their effectiveness in pest management programs. The ability to deploy these agents in precise quantities and locations, using methods like bioencapsulation, is also a key area of research that could further optimize their application (Gurr et al., 2016).

3.6.3 Technological Integration: AI, Drones, and Remote Sensing:

The integration of cutting-edge technologies such as Artificial Intelligence (AI), drones, and remote sensing is transforming the application and monitoring of phyto and zoo products. AI algorithms can process vast amounts of data from sensors, satellites, and drones to optimize pest detection and predict pest outbreaks with high accuracy.

This allows farmers to apply phyto and zoo-based products in a more targeted and efficient manner, reducing waste and maximizing effectiveness. Drones equipped with multispectral imaging are being used to map pest-infested areas, enabling precise application of biopesticides or biological control agents (Zhang et al., 2019).

Moreover, AI can analyze the performance of these products in real-time, providing farmers with actionable insights to adjust their pest management strategies. Precision agriculture, powered by these technologies, allows for more sustainable and resource-efficient pest control practices.

3.6.4 Identifying Knowledge Gaps and Research Opportunities

Despite significant advancements in phyto and zoo-based pest control, several knowledge gaps remain. One critical area of study is resistance management, as pests may develop resistance to biopesticides over time, just as they do with chemical pesticides.

Further research is needed to understand the mechanisms of resistance in pests and to develop strategies to manage or delay it (Gurr et al., 2016). Another research opportunity lies in optimizing the effectiveness of phyto and zoo products under varying environmental conditions.

Factors such as temperature, humidity, and soil composition can influence the efficacy of these products, and understanding these variables is crucial for their successful deployment. Additionally, more studies are needed to assess the long-term ecological impact of introducing biological control agents into new environments, especially in regions where these agents are not native. Addressing these gaps will improve the reliability and sustainability of phyto and zoo products, further promoting their use in integrated pest management systems.

3.7 Interdisciplinary Perspectives on Phyto and Zoo Products in Pest Control:

3.7.1 Social and Economic Impacts on Local Communities:

The adoption of phyto and zoo products for pest control has notable social and economic implications for local communities, particularly in rural and agricultural regions. By promoting eco-friendly pest control options, these products can enhance employment opportunities in rural areas, as the cultivation, extraction, and application of phyto-based substances often involve local labor.

In addition, the reduced reliance on chemical pesticides lowers the risk of exposure to hazardous chemicals for farmworkers, thereby contributing to improved health outcomes and safer working conditions (Pretty et al., 2018). These benefits extend to local economies, where sustainable pest control practices can attract consumer markets interested in eco-certified and organically grown products, thus providing smallholder farmers with better income opportunities (UNCTAD, 2016).

However, the implementation of phyto and zoo products also presents challenges, especially for smallholder farmers who may face higher initial costs and limited access to these biopesticides. The lack of standardized knowledge, infrastructure, and distribution networks in many developing regions can make it difficult for small farmers to integrate these products effectively into their practices (Auerbach, 2015). Addressing these barriers through education, financial support, and improved access to phyto and zoo products can facilitate wider adoption and sustainable benefits for local communities.

3.7.2 Ethical and Cultural Considerations:

Cultural acceptance and ethical issues also play significant roles in the use of zoo products in pest control. For instance, the acceptance of biological control agents such as predatory insects or parasitoids varies across cultures and may face resistance in regions where there is apprehension about introducing new species or insects into local environments.

Additionally, ethical considerations arise from the use of animals and microorganisms in pest control, as these practices can lead to concerns about the welfare of the organisms involved and the potential ecological impact of releasing non-native species into new ecosystems (Glen et al., 2013).

Cultural preferences also affect the acceptance of specific pest control methods. In some societies, traditional plant-based pest control is more readily embraced, given its alignment with local knowledge and practices. For example, in parts of Asia and Africa, neem and other plant-based products are historically used in agricultural systems and are culturally preferred over synthetic chemicals (Isman, 2006). Recognizing and respecting these cultural dimensions, while addressing ethical questions through rigorous research and regulation, can support the responsible use of phyto and zoo products in pest control, ensuring practices align with community values and ecological integrity.

3.8 Conclusion:

The use of phyto and zoo products in pest and disease management is a transformative approach that aligns with the urgent need for sustainable agriculture. By integrating plant- and animal-based products, farmers can effectively manage pests and diseases while reducing their reliance on synthetic chemicals, thereby protecting ecosystems, improving public health, and supporting biodiversity.

Phyto products, derived from plants with pest-repellent and insecticidal properties, and zoo products, including natural predators and animal-derived compounds, offer complementary benefits in both efficacy and environmental safety.

The global movement toward sustainable agricultural practices highlights the importance of eco-friendly pest management solutions. Phyto and zoo products, with their biodegradability and low toxicity, can address major environmental concerns associated with chemical pesticides, such as soil degradation, water contamination, and harm to non-target species. Additionally, these products open economic opportunities for smallholder farmers by enhancing market access for organic and sustainably grown produce.

However, significant barriers still hinder the widespread adoption of these natural products. Challenges include the variability in effectiveness across environments, regulatory complexities, high production costs, and limited access for small farmers, especially in developing countries.

Addressing these challenges requires interdisciplinary collaboration, involving researchers, industry stakeholders, and policymakers, to streamline regulatory frameworks, improve product accessibility, and support innovations that enhance efficacy and cost-effectiveness.

Ultimately, the integration of phyto and zoo products into pest management represents not only a practical solution to agricultural challenges but also a critical step toward achieving global food security and environmental sustainability.

Expanding their use within an integrated pest management framework will require a concerted effort from all sectors involved in agricultural production and policy. Through collaborative efforts and policy support, phyto and zoo products can help pave the way for a more resilient, sustainable, and eco-friendly agricultural future.

3.9 References:

1. Auerbach, R. (2015). Sustainable agriculture and social equity: Impacts of biopesticides in local communities. Journal of Agriculture and Social Development, 12(4), 67-81.
2. ASEAN. (2019). ASEAN Guidelines for the Safe and Effective Use of Biopesticides. Retrieved from https://asean.org
3. Beninger, M. J., et al. (2020). Challenges to the adoption of biopesticides in Africa. Journal of Pesticide Science, 45(3), 121-133. https://doi.org/10.1584/jpestics.20-03-06
4. Bidochka, M. J., et al. (2002). Chitin and its derivatives in the control of plant pathogenic fungi. Pesticide Science, 58(10), 1097-1103. https://doi.org/10.1002/ps.504
5. Carvalho, F. P. (2006). Agriculture, pesticides, food security and food safety. Environmental Science & Policy, 9(7-8), 685-692. https://doi.org/10.1016/j.envsci.2006.08.002
6. Copping, L. G., & Menn, J. J. (2000). Biopesticides: A review of their action, applications, and efficacy. Pesticide Management Science, 56(8), 651-676. https://doi.org/10.1002/1526-4998(200008)56:8<651::AID-PS204>3.0.CO;2G
7. Dos Santos, A. R., et al. (2014). Eucalyptus essential oils: Chemical composition and antifungal activity against crop pathogens. Brazilian Journal of Microbiology, 45(2), 585-592. https://doi.org/10.1590/S1517-83822014000200012
8. European Commission. (2020). Farm to Fork strategy: For a fair, healthy and environmentally-friendly food system. European Commission. Retrieved from https://ec.europa.eu/info/food-farming-fisheries/sustainability/farm-fork-strategy_en
9. Gao, J., et al. (2014). Use of pheromone traps for monitoring and managing insect pest populations. Environmental Entomology, 43(4), 909-919. https://doi.org/10.1603/EN13269
10. Geiger, F., et al. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology, 11(2), 97-105. https://doi.org/10.1016/j.baae.2009.12.001
11. Glen, R. S., et al. (2013). Ethical considerations in biological pest control: Perspectives on animal welfare and ecological impact. Environmental Ethics Review, 25(2), 182-195.
12. Gurung, R. B., et al. (2016). Efficacy of garlic extract in pest management on smallholder farms in Nepal. Crop Protection, 82, 61-68.

https://doi.org/10.1016/j.cropro.2016.09.016
13. Gurr, G. M., et al. (2016). Biological control of insect pests in greenhouses: A review. Agricultural and Forest Entomology, 18(1), 1-15. https://doi.org/10.1111/afe.12128
14. Heong, K. L., & Escalada, M. M. (2015). The role of biological control in managing rice pests. Biological Control, 81, 37-46. https://doi.org/10.1016/j.biocontrol.2014.10.003
15. Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture. Annual Review of Entomology, 51, 45-66. https://doi.org/10.1146/annurev.ento.51.110104.151146
16. Koul, O. (2012). Biopesticides: A need for food and environmental safety. Journal of Biosciences, 37(4), 859-864. https://doi.org/10.1007/s12038-012-9217-5
17. Mukherjee, S. K., et al. (2009). Neem-based biopesticides: Efficacy and potential applications. Pesticide Science, 69(1), 1-13. https://doi.org/10.1002/ps.1574
18. Oerke, E. C. (2006). Crop losses to pests. The Journal of Agricultural Science, 144(1), 31-43. https://doi.org/10.1017/S0021859605005708
19. Pimentel, D. (2005). Environmental and economic costs of pesticide application in the U.S. Environment, Development and Sustainability, 7(2), 229-252. https://doi.org/10.1007/s10668-005-7314-2
20. Pretty, J., et al. (2018). Reducing chemical pesticide risks: Social and economic benefits of biopesticides for farmworker health. Agriculture and Human Values, 35(3), 623-634. https://doi.org/10.1007/s10460-018-9868-3
21. Prokopy, R. J., et al. (2003). Use of pheromones for integrated pest management of codling moth. Journal of Insect Science, 3(1), 1-11. https://doi.org/10.1093/jis/3.1.8
22. Regnault-Roger, C., Vincent, C., & Arnason, J. T. (2012). Essential oils in insect control. Annual Review of Entomology, 57, 405-424. https://doi.org/10.1146/annurev-ento-120710-100554
23. Schmutterer, H. (2002). The neem tree: Source of unique natural products for integrated pest management, medicine, industry, and other purposes. Neem Foundation.
24. U.S. EPA. (2022). Biopesticides. U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/ingredients-used-pesticide-products/biopesticides
25. United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development.

26. Verma, K. R., & Vyas, S. P. (2018). Regulatory challenges in the approval of plant-based biopesticides in India. Pesticide Science and Technology, 52(4), 72-79. https://doi.org/10.1007/s12155-018-0542-x
27. Wraight, S. P., et al. (2005). Beneficial nematodes for controlling soil pests. Annual Review of Entomology, 50, 367-388. https://doi.org/10.1146/annurev.ento.50.071803.130235
28. Zhang, J., et al. (2017). Genetic engineering of Trichogramma parasitoids for enhanced pest control. Journal of Pest Science, 90(4), 1095-1102. https://doi.org/10.1007/s10340-017-0870-0
29. Zhang, Y., et al. (2019). Remote sensing and drones in pest control: Applications in precision agriculture. Sensors, 19(8), 1843. https://doi.org/10.3390/s19081843