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Application and impact of botanical extract for insect pest management of tomato in Punjab: A review

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Abstract
This comprehensive review focuses on insect pests problem of tomato crop and their management in Punjab, India. In response to the need of sustainable and eco-friendly pest management practices, the application of botanical extracts is a alternative way for pest management. This study consolidate on existing literature, focusing on thorough analysis of the effectiveness, application methods, and modes of action of different plant based pesticide for the major insect pests management of tomato. Moreover, here discussed on advantages and limitations of botanical extract as well as their suitable integration with IPM. The important factors such as dosage, application timing, formulation, and potential interactions with different IPM practices are also discussed, emphasizing their role in achieving eco-friendly pest management. Additionally, this review identifies research gaps and proposes future directions to enhance the practicality and efficacy of botanical for insect pest management of tomato in Punjab. Overall, this review serves as a valuable resource for extension workers, policymakers and researchers offering valuable insights into the uses of botanical extract for insect pest management in tomato production.

Keywords: botanical extract, bio pesticides, insect pests, IPM, tomato, sustainable agriculture, Punjab

Introduction
Tomato (*Solanum lycopersicum* L.) is an important vegetable crop growing in different part of the World, it is having second position in vegetable consumption after the potatoes (*Solanum tuberosum* L.). It is Originated at Peru and Ecuador of South America, first time its domesticated at Mexico during historical times (Benton, 2007). During 16th century, tomato was introduced to Europe and was primarily featured in early herbals. Despite its visually attractive fruits, There were limited consumption in most regions due to its toxicity in wild species. Only in the 1800s, tomato gained recognition as a valuable and safe vegetable for consumption.

Tomatoes having appealing taste, color, flavor, and high nutritional value, so it is widely cultivated crop. Tomatoes are consuming as fresh or in various processed forms, making them a important part of the diet. It provide us numerous health benefits such as low in calories and abundant in essential nutrients like vitamin A, vitamin C, and minerals. Additionally, tomato having small quantities of B vitamins such as thiamin, riboflavin, and niacin (Sainju and Dris, 2006) [43].

Tomatoes are also a good source of iron and are known for their nutritional diversity. While yellow tomatoes are richer in vitamin A, red tomatoes contain lycopene, which acts as an antioxidant and may have cancer-protective properties (Naika *et al*., 2005) [32]. New literature reported that lycopene consumption is help to reduce the risk of prostate cancer (Miller *et al*., 2002) [29]. Moreover, the regular feeding of tomatoes has been linked to a lower likelihood of developing gastrointestinal diseases, including colon, rectal, and stomach cancer. Apart from their health benefits, tomatoes are easily digestible, and their vibrant color has the added advantage of stimulating appetite (Sainju and Dris, 2006) [43]. As a result, tomatoes play a significant role in promoting overall well-being and are considered an important component of a balanced and nutritious diet.

Over the past five decades, the tomato has gained significant popularity and witnessed extensive growth in large-scale farming, particularly in the United States and Europe. Global tomato production has increased by 164% in the last 40 years, accompanied by a remarkable 314% rise in tomato consumption worldwide (FAO, 2008) [15]. In tomato consumption its rising annually at average rate of 3% Globally. (Xinhua, 2007) [53]. Processing of tomato also has been increased from 25 to 36 million tons in last one decade (Colvine, 2008) [10].

The ideal temperature range for the growth of tomato plants is between 20 and 27 °C, while low temperatures below 10 °C and high temperature above 38 °C may cause the damage to crop (Naika *et al*., 2005) [32].

Advance technologies of breeding and genetic engineering have been used in tomato for improvement in quality, quantity, pest resistance, storage durability and processing techniques, helps to making of new tomato-based products (Preedy and Watson, 2008) [37]. Currently, global tomato production is about 397.4 million tons which cultivating in 4.8 million hectares of 166 countries (FAO, 2022). Top 10 tomato producing countries are China which holding the first position in production as well cultivation area after then USA, Turkey, India, Egypt, Italy, Iran, Spain, Brazil, and Mexico are also good producers of the tomato.

Many effort for the high production of tomato have been done, in spite that, insect pests and mites pose significant challenges to tomato cultivation, and conventional methods of control have been widely used but are losing effectiveness due to resistance development against many insecticides (Reddy and Miller, 2014; Silva *et al*., 2019) [29, 46]. In Africa, farmers are depends on regular insecticide for pest management. Which resulting various adverse consequences, on soil, water resources, pest resurgence, increased resistance and ill effect on human health (Asante *et al*., 2013; Ochilo *et al*., 2018) [3, 35].

For the pest management of tomato we are using different types of insecticide as well as high doses and frequent application of chemical resulted less effective due to development of resistance. Therefore, Its an urgent need to explore and implement alternative control measures (Biondi *et al*., 2018; Lemic *et al*., 2020) [5, 27].

Botanical Extract

Botanical extract are natural compounds found in plants, known as secondary metabolites or phyto chemicals. They are extracted for their ability to control pests, making them valuable tools in insect pest management. Botanical extract are safer for environment as well as humans when compared to conventional synthetic chemicals. These extract work effectively by repelling, inhibiting growth, or eliminating pests, and they are extensively used to manage insect pests. Researchers have conducted significant studies to explore their efficacy in this area. Botanical extract playing a crucial role for insect pest management. Botanical insecticides are dominated in global market among different plat based pesticide. These plant based compounds have genetic insecticidal properties and used in plant protection throughout the history of agriculture, highlighting the effectiveness and importance of botanical extract for insect pest management of crops.

Many plants are having pesticidal activity are abundant on the Earth and they are have multiple uses, such as pesticide, culinary, including medicinal, ornamental and as food. Botanical pesticides are cost-effective and easily integrated with insect pest management because they are widespread available in nature. Botanical extract such as Pyrethrum, Neem, and Sabadilla are well known botanical pesticides commercialized for their low toxicity to pollinators, fish, natural enemies, human being and other organism, which make them reliable, highly effective and suitable for crop protection. Moreover, botanical extract are environmental preservation and ensuring consumer safety, because there are no harmful residues on crop produce as well on environment by botanical extract (Dubey *et al*., 2008) [13].

Application of botanical pesticides leads to reduced chances of pest resistance development because naturally available plant-based biochemical are responsible for attacking the pest. Additionally, Botanical are safe for non-target organisms, such as predators and pollinator because target specificity of biochemicals are found in botanical extracts and essential oils. Botanical extract's effectiveness depends on many factors, like plant species used, the extraction solvents, whether it is dry or fresh and the extraction methods used. These pesticides shows different modes of action, such as toxicity, growth regulation, repellent and structural modification, making them suitable in insect pest management of agricultural commodities.

Regulation for application, processing and manufacturing of botanical extract in India

Utilization of insecticide in agriculture or other uses are regulated by the Insecticide Act of 1968 in India. The responsibility of registering pesticides and their formulations in compliance with the prescribed guidelines. A pesticide or insecticide and their formulations have to be legally employed, they must undergo the registration process mandated by this Act.

As of the present, India has approved and registered botanical pesticides such as Neem- Based Formulations (Azadirachtin), Eucalyptus Leaf Extract and Pyrethrum, these are most widely used botanical pesticide for insect pest management in agriculture. It is very important to Ensures required safety and efficacy standards, making botanical pesticides viable and sustainable registration and approval process for the management of insect pest of different crops in India.

The need for safe pest management

- Botanical pesticides offer a viable alternative to conventional synthetic pesticides in agriculture.
- Heavy reliance on synthetic pesticides has led to various environmental problems, including rapid development of pest resistance.
- Increased insect outbreaks have been observed due to the use of conventional pesticides.
- The application of synthetic pesticides often suppresses beneficial parasitoids and predators, disrupting natural pest control mechanisms.
- Environmental and food chain contamination is a significant consequence of widespread synthetic pesticide use.
- Acute occupational pesticide poisoning cases in developing countries reach approximately 25 million annually (Jeyaratnam, 1990) [22].
- Fatal injuries from pesticide exposure have reached 10%, with occupational injuries accounting for 14% (ILO, 1996) [20].
- Disposal and storage of unused pesticides in developing countries present additional environmental hazards.
- Non-target organisms, including domestic animals, wildlife, and aquatic systems, experience adverse effects due to the application of synthetic pesticides.
- Embracing botanical pesticides can help address these environmental challenges and promote more sustainable agricultural practices.

Benefits of botanical extract application in Integrated Pest Management

1. Less toxic: Botanical pesticides possess inherently lower toxicity compared to conventional pesticides, ensuring safety against non-target organisms as well human being.
2. Specific nature: Bio pesticides impact only intended pest and its related species, sparing other organism such as beneficial insect, birds and mammals.
3. Less pollution: Extract of Botanical may overcome the pollution concerns related with synthetic insecticide by requiring smaller quantities and rapid environmental degradation.
4. Compatibility with environment: By the available literature it has been analyzed that botanical extract such as Neem is relatively safe for environment and its biotic factor as higher animal and beneficial organism.
5. Less health hazards: Botanical extract reduced health risks during application compared to conventional synthetic insecticide.
6. Enhanced quality of food: Botanical extract helps to improved food quality by minimizing pesticide residue problem in food products.
7. Safety for consumers and farmers: The use of extract of botanical enhances safety for farmers and consumers, promoting eco-friendly and farmer-accepted practices.
8. Comparable efficacy: Botanical pesticides exhibit efficacy comparable to chemical pesticides against a wide range of pests across various environmental conditions.
9. Diverse pest control: Botanical pesticides demonstrate efficacy against insects, mites, nematodes, snails, crustaceans, parasitic species, and other pest.
10. Handling of Resistance: Different plant based chemicals obtained from botanical pesticides challenge pests to develop resistance, making them effective in resistance management strategies.
11. Comprehensively analyze the utilization of prevalent botanical extracts, essential oils, and bio pesticides as alternatives for tomato pest management.
12. Assess the effectiveness of these botanical agents against significant tomato insect pests in the agricultural region of Punjab, India, including aphids, whiteflies, and fruit borers.
13. Investigate the diverse modes of action employed by botanical compounds and their impact on insect pests, elucidating the underlying mechanisms of pest control and suppression.

Application methods and formulations of botanical extract

- Conduct a comprehensive comparison of different application techniques, such as foliar sprays, seed treatments, and fumigation, in the context of utilizing botanical-based approaches for pest control.
- Examine the influence of formulation types and carrier agents on the effectiveness and longevity of botanical pesticides, delving into their impact on pest management outcomes.
- Address the crucial aspects of dosage determination, timing of application, and frequency of treatment, highlighting their significance in optimizing the efficacy and uses in pest management.

Compatibility of botanical extract with IPM

Evaluate the botanical extract and its integration in Integrated Pest Management protocols in tomato crop, assessing their potential to complement and integrate seamlessly with existing practices for sustainable pest management. Investigate the potential synergistic or antagonistic effects arising from the combination of botanicals with other pest control methods, such as biological control and cultural practices, aiming to elucidate how such interactions may enhance or hinder pest control efficacy. Examine the risk of resistance development to botanical-based pest control agents and propose strategies to mitigate and manage this challenge, seeking to maintain the long-term effectiveness of botanicals as essential components of pest management programs in tomato production.

Limitations of botanical extract application

Thoroughly assess the environmental and human health advantages derived from employing botanical-based pest control methods in tomato cultivation, highlighting their potential to reduce harmful impacts on the environment and promote safer conditions for farmers and consumers. Examine the challenges and constraints related to the utilization of botanicals, encompassing factors such as cost, availability of botanical products, and storage stability, to gain insights into the practical limitations and potential improvements required for broader adoption. Analyze the economic considerations and practical feasibility of implementing botanical-based pest control strategies for tomato farmers in the agricultural region of Punjab, India, aiming to provide valuable insights into the financial viability and adaptability of these approaches in diverse farming contexts.

Research gaps and future directions

Thoroughly identify critical knowledge gaps pertaining to the utilization of botanical-based pest control methods in tomato production within the region of Punjab, India, aiming to highlight areas that require further investigation and understanding. Outline potential avenues for future research, encompassing aspects such as the refinement and optimization of botanical formulations, exploration of untapped botanical sources with pest control potential, and the development of effective strategies to manage and prevent resistance in pest populations. Emphasize the importance of future research endeavors in enhancing the practicality, efficacy, and sustainability of botanical-based pest control approaches, ultimately contributing to the advancement of integrated pest management practices and the promotion of environmentally friendly and economically viable solutions for tomato growers in the region.

Conclusion

Present study concluded, the available knowledge of botanical extract for the insect pest management of tomato in Punjab botanical extract having significant potential as sustainable approach towards insect pest management and minimize the uses of conventional synthetic insecticides. The review cover the detail study on important parameters such application methods of various botanical extract, modes of action, efficacy and related studies including essential oil and bio pesticides for the management of insect pest of tomato in Jalandhar region of Punjab.

Botanical pesticides offer several advantages, including low toxicity, target-specific control, reduced pollution impact, compatibility with natural enemies and ecosystems, and improved food quality. They also promote farmer and consumer safety, exhibit comparable efficacy to chemical

pesticides, and demonstrate diverse pest control capabilities. Moreover, these natural compounds mitigate resistance development and facilitate the utilization of indigenous plant sources, offering cost reduction opportunities through village cooperatives.

However, challenges and limitations associated with botanical use, such as cost, availability, and storage stability, need to be addressed for broader adoption. Additionally, considerations regarding dosage determination, application timing, and integration with Integrated Pest Management (IPM) practices are crucial for optimizing the effectiveness of botanical-based pest control in tomato cultivation.

Future research should focus on optimizing formulations, exploring novel botanical sources, and developing resistance management strategies to enhance the practicality, efficacy, and sustainability of botanical-based pest control practices. By bridging knowledge gaps and implementing recommendations, tomato growers in Punjab can effectively harness the potential of botanicals, achieving environmentally friendly, economically viable, and efficient pest management solutions, while preserving human health and ecosystem integrity.

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