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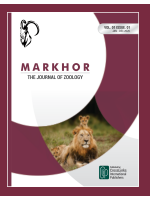

Review Article

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Impact of *Pinus* Essential Oil on Insects: A Review

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ABSTRACT

Insects are considered an important part of the ecosystem as they perform important roles like pollination, nutrient cycling, and pest control. But on the other hand, when they cross the threshold level, they achieve the status of pests. Insect pests cause damage to agricultural products. They also affect the health of people by spreading diseases. Traditionally, Insecticides were used to control insect pests, but they have very adverse effects on humans, animals, and the environment as they cause breathing difficulties and pollution, respectively. But now Essential oils of different plants are used to control them. Concentrated hydrophobic plant liquids containing certain volatile chemical compounds are called essential oils. There are several Essential Oils in which the impact of *Pinus* Essential Oil has been reviewed. It has various biological effects, which include anti-inflammatory, anti-microbial, and anti-cancer activities. It also has medicinal properties and holds industrial importance. The Pinaceae family contains 11 genera and about 225 species distributed in the Northern Hemisphere. The most common ingredient present in the *Pinus* genus is pinene, which has insecticidal, larvicidal, and pesticidal activities against insect pests. It has little or no harmful effect on the environment and non-target organisms.

INTRODUCTION

The importance and abundance of insects are ubiquitous. They are well adapted to survive in all environmental conditions and feed on any substance that has nutritional value [1]. Insects contributed to almost 66% of all known species on earth. They are good exploiters and dispersers and can be found everywhere, making a vital part of the ecosystem, and are important in chains of food supply, which perform valuable ecosystem services [2]. Insects are divided into two categories. One is the beneficial insects, and the other is the harmful insects.

Beneficial Insects

Beneficial Insects play a vital role in ecological processes as they offer many environmental services. They convert the biomass of plants into through fall, green fall, and frass and transform a major fraction of above-ground to below-ground Phosphorus and Nitrogen fluxes in the ecosystem. After pest management, beneficial insects decrease the need for chemical pesticides and promote environmentally friendly farming practices [3]. Insects are essential for pollinating over 72% of the world's crops. Around the world, pollinating insects increase the output of three-quarters of all crops. Important pollinators such as bees and butterflies promote the quality and crop yield with the help of efficient pollen transfer. Insects play a role in decomposing dung and take part in the health of soil by increasing phosphorus, nitrogen, and calcium, e.g., Dung Beetles. Beneficial insects shift their role because of some factors, which include landscape structure, climatic conditions, local biodiversity, and competing organisms [4]. Some ant species protect insect pests, which disturb

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the biological control. Unfavorable climatic conditions, such as drought and frost, can reduce beneficial insect populations[5].

Harmful Insects

Insect pests have become a serious threat to agriculture, and they cause economic losses of about 18-20% yearly. They also affect the health of people by acting as vectors of various diseases and contribute to the yearly mortality rate among both animals and humans[6]. *Aedes albopictus* and *Aedes aegypti* are responsible for the transmission of Dengue fever, Chikungunya, and Yellow fever, and *Culex pipiens* pallens transmits Japanese encephalitis, Meningitis, and West Nile virus [7]. Insect pests damage the crops of agriculture and forests. Adult and larval stages destroy the plants to complete their life cycle. The means through which they cause damage include chewing and biting, sucking mouth parts and piercing, leaf miners and boring, gall making, mutualism, vectors of pathogens, nest making, and tubers [8]. Protective and preventive measures like cultural practices, biological control, and chemical control are used to control the pests [9, 10]. Organophosphates were used to kill pests, but they cause serious health problems. It includes a large number of chemical substances and is formed by the process of esterification of phosphoric acid and alcohol. Organophosphates are used nowadays both in pesticides and herbicides, and also in nerve agents of chemical warfare. Thus, the majority of patients who are subjected to organophosphates are usually exposed to these substances by the use of insecticides and herbicides [11]. Organophosphates, when put into the body, suppress acetylcholinesterase (AChE), an enzyme, and lead to an excess supply of the neurotransmitter acetylcholine. The excess acetylcholine in the body is exerted through cholinergic toxidrome that encompasses the effects on nicotinic and muscarinic receptors in addition to the central nervous system. The onset of symptoms which varies based on the specific compound, frequently occurs within minutes and may take some weeks before it is resolved [12]. Globally, the mortality rates caused by organophosphate insecticides range from 2% to 25%. The insecticides that are most commonly linked with deaths are the fenitrothion, dichlorvos, malathion, and trichlorfon [13]. With the advancement in technology, natural products, including Essential Oils of different plants, are utilized for effective control of pests.

***Pinus* Essential Oil**

Essential Oils are hydrophobic liquids having various biological activities against insects. Among the various Essential Oils, *Pinus* Essential Oil is studied. The family Pinaceae comprises 11 genera and approximately 225 species, which are widespread in the Northern Hemisphere and have been introduced to multiple locations in the Southern Hemisphere [14]. Common ingredients present in *Pinus* Essential Oil are myrcene, camphene, beta-phellandrene, beta-pinene, limonene, alpha-pinene, and delta-3-carene [15]. The chemical composition of *Pinus wallichiana* Needle Essential Oil is α-Pinene (25.2%), β-Pinene (46.8%), Myrcene (9.5%), α-Terpineol (2.3%), Caryophyllene Oxide (2.1%), Trans Caryophyllene (1.8%), Limonene (1.0%), α- Cadinol (0.9%), Camphene (0.9%), α-Terpinyl Acetate (0.8%), Delta-3-Carene (0.8%), α-Bisabolol (0.6%), α-Humulene (0.5%), α-Phellandrene (0.4%), 8- Cadinene (0.4%), Trans-pinocarveol (0.4%), Geranyl acetate (0.1%) is the Essential Oil obtained by the process of distillation of oleo-resin, the latter is used as an insecticide. On steam distillation, the needles of *Pinus roxburghii* are reported to give 0.26% of colourless, volatile oil known as pine oil. It is comprised of alpha-limonene, alpha-phellandrene, borneol, longifolene, and alpha-cadinene in the oil [16]. Gas Chromatography/Mass Spectrometry (GC/MS) was used to determine the composition of the leaves of three *Pinus* species (*Pinus densiflora*, *Pinus rigida*, *Pinus thunbergii*). Examination of the oils from *Pinus* densiflora, *Pinus* thunbergii and *Pinus* rigida revealed the presence of spathulenol (2.04%, 0.34%, 2.78%), α-cadinol (1.85%, 0.97%, 2.60%), caryophyllene oxide (1.82%, 0.23%, 0.13%), and α-pinene (1.79%, 0.68%, 0.13%), α-humulene (18.09%, 19.5 [17]. *Pinus* essential oil has various impacts on insects[18](Figure 1).

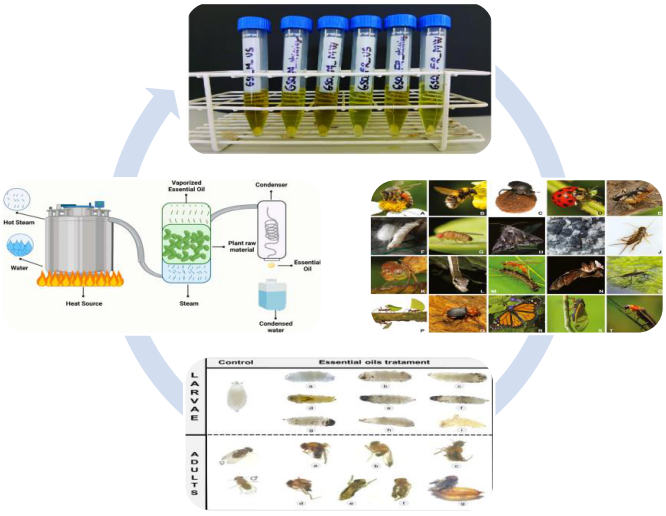

Figure 1: Impact of Pinus Essential Oil on Insects

Various varieties of extracting Essential Oils of plants are available, and they are hydro-distillation, Steam distillation, hydro-distillation adsorption, Solvent extraction, ultrasound-assisted extraction, and microwave-assisted extraction. One of the oldest techniques of extracting Essential Oils is hydro-distillation; however, today, the ultrasound-aided extraction and the microwave-aided extraction are viewed as innovative techniques of Oil Extraction [19]. Representatives of the genus *Pinus* are

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significant because of their medicinal value. *Pinus* resin and turpentine oil, the contents of *Pinus* Essential Oil, treat respiratory diseases, such as cough and cold [20, 21]. The use of *Pinus* Essential Oil does not provide any harm to other organisms and the environment [22, 23]. Apart from medicinal properties, it also holds industrial significance. The Oleoresin, which is extracted from *Pinus* species, is present in cosmetics [24], food, pharmaceutical industries, and paint [25]. *Pinus* species have the potential to store carbon in soil and biomass [26]. Pinus wood is also a source of pulp and the paper industry because of its long fibers [27]. The phytochemicals obtained from *Pinus* species include terpenes, polyphenols, flavonoids, alkaloids, and tannins that hold a wide spectrum of bioactivity [28-30]. Various bioactive compounds present in the EO of plants have little or no side effects on non-target organisms and the environment. *Pinus* Essential Oils are broad-spectrum pesticides as they negatively affect the beneficial insect populations by acting as OVI deterrents and phagodeterrents, which take part in natural pest control [31]. This study mainly focuses on observing and evaluating the Impact of *Pinus* Essential Oil on different biological activities of insect pests, which include repellent activity, mortality, delayed developmental time, larvicidal activities, and morphological and physiological deformities.

Biological Activity of *Pinus* Essential Oil against Insects

The chemical components present in *Pinus* Essential Oil have different impacts on the biological activity of insects (Table 1).

Table 1: Impacts of Pinus Essential Oil on the Biological Activity

Pinus Species Essential Oil	Chemical Composition	Biological Activity	References
Pinus merkusii	Alkaloids, flavonoids, tannins, triterpenoids, and saponins.	Insecticidal, larvicidal, and pest control properties against Mosquitoes.	[32]
Pinus eldarica	Delta-3-carene, longifolene, α-humulene, α-and β-pinene, β-caryophyllene.	Anti-insect properties against Cockroaches.	[33]
Pinus halepensis	Monoterpenes (eucalyptol and camphor) and sesquiterpenes (α-epi-cadinol)	Repellent activity against *Tribolium castaneum* and *Rhyzopertha dominica.*	[34]
Pinus halepensis, Pinus heldreichii, Pinus mugo, Pinus nigra, Pinus peuce, Pinus sylvestris	α-pinene	Fumigant toxicity to *Sitophilus oryzae, Plutella xylostella,* and *Megoura japonica.* Affect the reproduction of green peach aphid, *Myzus persicae.*	[35, 36]
Pinus heldreichii	Pinenes	Larvicidal activity against *Drosophila melanogaster.*	[37]
Pinus sylvestris, Pinus peuce	Pinenes	Larvicidal activity and delayed developmental time against *Drosophila melanogaster.*	[38]
Pinus peuce	Pinenes	Significant impact ($p<0.001$) on changes in wing shape of female *Drosophila melanogaster.*	[39]
Pinus heldreichii	Limonene, Germacrene D	Morphological and physiological deformities in *Drosophila suzukii.* Toxic effect on third-instar larvae of insects.	[40]
Pinus halepensis	Unsaturated fatty acids (Palmitoleic and Linolenic acids).	Repellent activity against *Liposcelis bostrychophila.*	[41]
Pinus halepensis	Saturated fatty acid (Palmitic acid, Lauric acid, Myristic acid)	Repellent properties against Spodoptera littoralis and *Plutella xylostella.*	[42]

There are gaps in knowledge, such as a lack of long-term ecological studies and effects on pollinators. Long-term studies refer to those that persist beyond the dominant organism's generation time in an ecosystem, or are sufficiently long to measure the most important processes to structure the ecosystem being examined. Long-term ecological research is significant in ecological conservation, environmental modification, natural resource regulation, and ecology. It is capable of giving more insight into complicated ecological systems [43]. Lack of ecological research is explained by the fact that it is not easy to sustain it over a long period of time, as it prolongs the periods of government rule and budgeting. Pinus Essential Oil has not induced acute lethal toxicity in pollinators, although its biochemical action has been different [44].

CONCLUSIONS

In conclusion, the impact of *Pinus* Essential Oil on insects is both promising and profound, but it demonstrates a multifaceted and complex picture. *Pinus* Oil and its components, such as α-pinene and β-pinene, represent very significant insecticidal properties functioning through a variety of both lethal and sub-lethal mechanisms. It is highly effective and an alternative to man-made pesticides. As for insecticide resistance and environmental pollution, the usage of naturally derived compounds like *Pinus* Essential Oil provides a safe and eco-

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friendly approach to pest control. However, its widespread adoption is based on addressing the important gaps in our understanding of its ecological consequences. This review article will be helpful for researchers in further pathways of research. Future research should focus on field studies, toxicity on non-target insects, and formulation development. The focus must be on the need to move from single-factor studies to the integrated and system-level approach. It involves the understanding of cascading and long-term effects of pesticides on the ecosystem and developing targeted, biodegradable, and innovative formulations.

Authors Contribution

Conceptualization: MR
Methodology: SM[1], SM[2], MB, NE, AH
Formal analysis: MR
Writing review and editing: MR, AH

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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