# Natural Protective Products for Protecting Plants against Insects

Subjects: Forestry

Contributor: Katarzyna Rzyska, Kinga Stuper-Szablewska, Danuta Kurasiak-Popowska

Plant protection against insects relies on four main pillars: prevention and biological, chemical, and physical action. The use of chemical insecticides, a common practice, should be avoided unless all other methods have failed due to their potential negative impact on both humans and the environment.

Keywords: bioinsecticides ; Brassica carinata ; Camelina sativa ; insecticides ; plant oils

## 1. Introduction

Insecticides are a vast family of preparations used to control harmful insects. They can be made of natural or synthetic substances [1]. The active ingredients of these preparations can penetrate a pest’s body through its epidermis (contact agents) or digestive system (gastric agents). Some agents affect an insect’s respiratory system, while others use a combination of methods. Insecticides that enter a pest’s body through the digestive route are administered directly to the plant to enable their preventive effect. There are three types of insecticides, which are segregated based on their modes of action for use in protecting a plant: surface insecticides, depth insecticides, and systemic insecticides. Surface insecticides remain and act on the surface of a plant, depth insecticides penetrate the leaves, and systemic insecticides penetrate the plant and are transported with the sap to all parts of the plant. Insecticides must not exhibit toxicity toward plants. The main classification of insecticides is based on their chemical nature (**Figure 1**) [2].

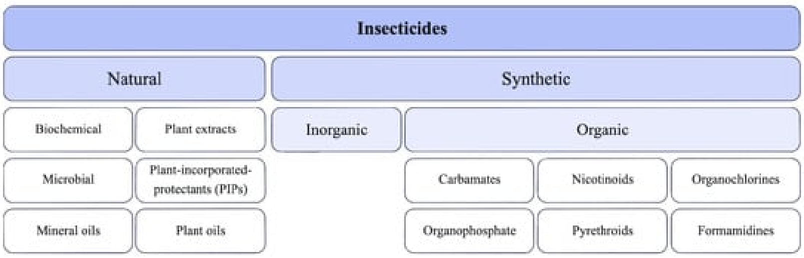


**Figure 1.** Insecticide classification.

## 2. Natural Protective Products for Protecting Plants against Insects

### 2.1. Mechanical Methods

Pests can be removed from plants through physical means, such as spraying a plant with water or manually picking insects off. Traps and barriers can also be employed to protect a plant from an insect attack. Placing sticky bands on tree trunks is a commonly used physical method [3].

### 2.2. Biological Methods

Biological control can be used alone or in combination with other control methods in IPM (Integrated Pest Management) programs. It focuses on using natural enemies to reduce populations of harmful insects without the use of synthetic insecticides [4][5]. There are three main approaches to biological control:

- Augmentative biological control—increasing the density of native or non-native natural enemies through regular releases;
- Conservation biological control—the manipulation of a habitat to increase the reproduction, survival, and effectiveness of natural enemies already present in the affected area;

- Classical biological control (CBC)—the introduction of a natural enemy of native origin to control a pest, which is usually also non-native, to determine whether the population of the natural enemy is sufficient to achieve permanent control of the target pest.

## 2.3. Bioinsecticides

Bioinsecticides are a competitive category of insecticides that include naturally occurring compounds or agents derived from microorganisms, plants, and animals. They inhibit the growth and rapid spread of insect pests through various mechanisms of action (in addition to disrupting the nervous system) [6][7][8]. These preparations do not pose a threat to living beings and do not adversely affect the environment. Sustainable agroforestry management based on biopesticides is socially accepted, promotes economic productivity, and contributes to environmental stewardship, constituting the basis of sustainable development [9].

Bioinsecticides can be classified based on their origin and the type of compound required to form an effective formulation. The classification includes microbial, biochemical (such as essential oils, plant extracts, insect growth regulators, and insect pheromones), and plant-incorporated protectants (PIPs) [10][11]. Currently, microbial biopesticides are the most significant. Biopesticides are widely used due to their low toxicity, selectivity of action, and ability to be easily biodegraded [12]. Transgenic plants (PIPs) offer an attractive alternative. They contain molecules such as Bt Cry proteins, α-amylase inhibitors, or double-stranded ribonucleic acid (dsRNA), which deter insect pests from targeting these plants [13][14][15].

Over the past decade, the proportion of biopesticides used in crop protection products has varied greatly (**Figure 2**). In 2020, there was a significant increase in the use of botanical insecticides, although they remain a niche category of crop protection products. This is primarily due to their high production cost and the labor- and time-consuming process of introducing them to the market. Additionally, their limited durability and effectiveness are correlated with changing atmospheric conditions. Furthermore, they have targeted action against a specific pathogen species [7].

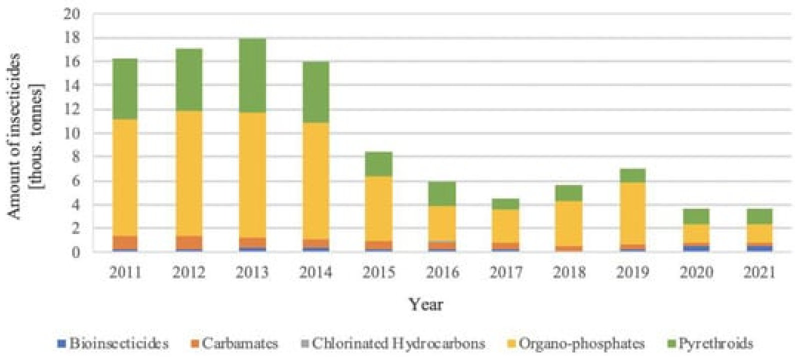


**Figure 2.** Share of particular classes of insecticides in Europe. (https://www.fao.org/faostat/en/#data/RP, accessed on 20 September 2023).

## 2.4. Oils as Botanical Pesticides

An important issue in the chemical control of insects is the presence of pesticide residues in the environment. This depends not only on the type of pesticide used but also on the dosage, the number of treatments, the form of preparation, the type of plant and soil, and weather conditions. As the product will be subject to runoff or be washed away by rain after treatment, penetrate deep into a plant, and accumulate in the mulch, it is extremely important to observe the withdrawal period indicated on the label. In this respect, botanical insecticides are a promising alternative to conventional products. They usually have a relatively short withdrawal period, and their use does not put non-target organisms at risk. They do not tend to accumulate in the soil because they degrade quickly. Their use also reduces the likelihood of insects developing resistance. These characteristics are making botanical insecticides increasingly popular. This relationship is illustrated by the frequency of searches for combinations of phrases such as “botanical extract” and “insecticide”, which almost tripled between 2012 and 2022, increasing from 1158 to 3377 reports, and this number is steadily increasing (Scopus database, https://www.scopus.com, accessed on 29 November 2022).

Among biopesticides, plant extracts are important components in addition to insect pheromones, microbial pesticides, or insect growth regulators. These are naturally occurring insecticides in plants containing a number of bioactive phytochemicals [16]. They are found in the form of plant oils and essential oils. The former are obtained by extracting or pressing seeds and other plant parts, while essential oils are produced through distillation [17].

### 2.4.1. Essential Oils

Essential oils are fragrant mixtures of volatile organic compounds synthesized by plants as secondary metabolites. They are found in plants or their individual parts—such as flowers, leaves, fruits, roots, or seeds. They are localized in specific structures of secretory tissues (glandular hairs, secretory cavities, and resin ducts), where they accumulate as final products of metabolism [18][19]. Chemically, oils are complex mixtures of different compounds, the composition of which is not always completely known and is often variable. Usually, the dominant compound imparts a fragrance to the oil. The main constituents of essential oils are terpene compounds: mono-, sesquioxin-, and diterpenes (terpene oils) and phenylpropane derivatives (non-terpene oils). The compounds they contain are hydrocarbons, alcohols, aldehydes, ketones, esters, and ethers [20]. The composition of the oil also depends on the part of the plant from which it is obtained. An example is bitter orange (*Citrus aurantium*), which produces three different oils in young shoots, leaves, and flowers [19][21][22].

The compounds contained in essential oils have been used as flavorings in the food and perfume industries but also in medicine, mainly as medicinal herbs, and as an element of aromatherapy. There is growing interest in their use as natural plant protection agents [23]. The modes of action of essential oils in this area are very diverse. They can interfere with the gas exchange process in insects, as well as their ability to identify host plants, and egg laying [24][25][26]. Some also act as antifidants, attractants, or repellents. To a large extent, they affect the hormonal balance, causing malformations, overstimulation, and consequently death in insects [27][28]. Essential oils can also form mixtures with synthetic insecticides, increasing their effectiveness [29].

#### 2.4.2. Plant Oils

Contact formulations based on vegetables oils, which are characterized by limited persistence, are an alternative to the use of conventional insecticides. Their precursors were paraffin-oil-based formulations derived from petroleum refining, which showed high insecticidal efficacy. The main limitation to their use was their high phytotoxicity. This was largely reduced by selecting distillates with specific boiling ranges and appropriate refining parameters. The multi-stage and labor-intensive production process, increased raw material costs, and potential toxic effects on plants prompted the search for more environmentally friendly substrates. Following this trend, the combination of highly refined paraffinic oil with vegetable oils seemed to be the solution. This resulted in formulations characterized by high efficacy and low phytotoxicity.

Their main mechanism of action is based on the physical blocking of insects' respiratory tracts (fistulas). The oil preparation applied to them forms a thin, hydrophobic layer and prevents gas exchange, resulting in suffocation. They also interfere with insects' ability to feed on oil-coated surfaces. In some cases, oils can also interact with insects' fatty acids, disrupting their metabolism [30]. Oils can be mixed with other insecticides to provide a broader spectrum of activity and longer-lasting formulations. The insects most commonly controlled in this way include spider mites, whiteflies, and juvenile scales. Vegetable oils also perform well as preparations for preventing the transmission of viruses by insects and as fungicides (e.g., against powdery mildew) [31].

The most common ingredient in oil-based insecticide formulations is oil from the seeds and bark of the Indian honeybush (*Azadirachta indica*). This oil is readily available, relatively inexpensive, and, most importantly, does not harm birds or other beneficial insects. It owes its action to triterpenes, compounds from the limonoid group, the main representative of which is azadirachtin. It is described as an antifidant compound that interferes with the feeding and reproductive abilities of insects [32]. An affected insect does not die directly as a result of azadirachtin entering the body but as a result of the loss of the ability to forage. The other compounds in neem oil interfere with an insect's normal development (molting and growth) and act as a deterrent against them [33][34]. The oil of *Pongamia pinnata* (L.) *Pierre* is also becoming increasingly important, containing about 5% flavonoids, of which 2% is the furanoflavonoid caranjin, which is responsible for the insecticidal activity of the oil [23]. Other common ingredients used in commercial insecticidal formulations are cottonseed oil and soybean oil.

The described ingredients included in natural preparations intended to repel insects feeding on tree stands are difficult to isolate, which makes them expensive and inefficient. It would be unprofitable to use them in forest stands. Therefore, it is necessary to look for cheaper and more effective preparations of plant origin, hence the idea to use oils from *Camelina sativa* and *Brassica carinata*. These oils are rich in bioactive compounds and have a hitherto unexplored potential to repel/kill insects that cause the degradation of tree stands.

## References


1. Jampílek, J.; Kráľová, K.; Fedor, P. Bioactivity of Nanoformulated Synthetic and Natural Insecticides and Their Impact on Environment. In Nanopesticides; Springer International Publishing: Cham, Switzerland, 2020; pp. 165–225.
2. Ansari, I.; El-Kady, M.M.; Arora, C.; Sundararajan, M.; Maiti, D.; Khan, A. Ansari, I.; El-Kady, M.M.; Arora, C.; Sundararajan, M.; Maiti, D.; Khan, A. A Review on the Fatal Impact of Pesticide Toxicity on Environment and Human Health. In Global Climate Change; Elsevier: Amsterdam, The Netherlands, 2021; pp. 361–391.
3. Karuppuchamy, P.; Venugopal, S. Integrated Pest Management. In Ecofriendly Pest Management for Food Security; Elsevier: Amsterdam, The Netherlands, 2016; pp. 651–684.
4. Stenberg, J.A. A Conceptual Framework for Integrated Pest Management. Trends Plant Sci. 2017, 22, 759–769.
5. Jeffers, A.H.; Chong, J.-H. Biological Control Strategies in Integrated Pest Management (IPM) Programs. Clemson SC Clemson Coop. Ext. Land Grant Press Clemson Ext. 2021, 1111, 1–9.
6. Nuruzzaman, M.; Liu, Y.; Rahman, M.M.; Dharmarajan, R.; Duan, L.; Uddin, A.F.M.J.; Naidu, R. Nanobiopesticides: Composition and Preparation Methods. In Nano-Biopesticides Today and Future Perspectives; Elsevier: Amsterdam, The Netherlands, 2019; pp. 69–131.
7. Kumar, J.; Ramlal, A.; Mallick, D.; Mishra, V. An Overview of Some Biopesticides and Their Importance in Plant Protection for Commercial Acceptance. Plants 2021, 10, 1185.
8. Wattimena, C.M.; Latumahina, F.S. Effectiveness of Botanical Biopesticides with Different Concentrations of Termite Mortality. J. Belantara 2021, 4, 66–74.
9. Fenibo, E.O.; Ijoma, G.N.; Matambo, T. Biopesticides in Sustainable Agriculture: A Critical Sustainable Development Driver Governed by Green Chemistry Principles. Front Sustain. Food Syst. 2021, 5, 619058.
10. Ruiu, L. Microbial Biopesticides in Agroecosystems. Agronomy 2018, 8, 235.
11. Ram, K.; Singh, R. Efficacy of Different Fungicides and Biopesticides for the Management of Lentil Wilt (Fusarium oxysporum f. Sp. Lentis). J. AgriSearch 2021, 8, 55–58.
12. Mishra, J.; Dutta, V.; Arora, N.K. Biopesticides in India: Technology and Sustainability Linkages. 3 Biotech 2020, 10, 210.
13. Mangesh, P.M. Distribution of Vip Genes, Protein Profiling and Determination of Entomopathogenic Potential of Local Isolates of Bacillus thuringiensis. Bt Res. 2013, 4.
14. Parker, K.M.; Sander, M. Environmental Fate of Insecticidal Plant-Incorporated Protectants from Genetically Modified Crops: Knowledge Gaps and Research Opportunities. Environ. Sci. Technol. 2017, 51, 12049–12057.
15. Wei, J.-Z.; O'Rear, J.; Schellenberger, U.; Rosen, B.A.; Park, Y.-J.; McDonald, M.J.; Zhu, G.; Xie, W.; Kassa, A.; Procyk, L.; et al. A Selective Insecticidal Protein from Pseudomonas mosselii for Corn Rootworm Control. Plant Biotechnol. J. 2018, 16, 649–659.
16. Magierowicz, K.; Górska-Drabik, E.; Golan, K. Effects of Plant Extracts and Essential Oils on the Behavior of Acrobasis advenella (Zinck.) Caterpillars and Females. J. Plant Dis. Prot. 2020, 127, 63–71.
17. Abdelatti, Z.A.S.; Hartbauer, M. Plant Oil Mixtures as a Novel Botanical Pesticide to Control Gregarious locusts. J. Pest Sci. 2020, 93, 341–353.
18. Fahn, A. Structure and Function of Secretory Cells; Academic Press: London, UK, 2000; pp. 37–75.
19. El Asbahani, A.; Miladi, K.; Badri, W.; Sala, M.; Addi, E.H.A.; Casabianca, H.; El Mousadik, A.; Hartmann, D.; Jilale, A.; Renaud, F.N.R.; et al. Essential Oils: From Extraction to Encapsulation. Int. J. Pharm. 2015, 483, 220–243.
20. Chouhan, S.; Sharma, K.; Guleria, S. Antimicrobial Activity of Some Essential Oils—Present Status and Future Perspectives. Medicines 2017, 4, 58.
21. Boussaada, O.; Chemli, R. Chemical Composition of Essential Oils from Flowers, Leaves and Peel of Citrus aurantium L. Var. Amara from Tunisia. J. Essent. Oil Bear. Plants 2006, 9, 133–139.
22. Bora, H.; Kamle, M.; Mahato, D.K.; Tiwari, P.; Kumar, P. Citrus Essential Oils (CEOs) and Their Applications in Food: An Overview. Plants 2020, 9, 357.
23. Roman, P. History, Presence and Perspective of Using Plant Extracts as Commercial Botanical Insecticides and Farm Products for Protection against Insects—A Review. Plant Prot. Sci. 2016, 52, 229–241.
24. Huang, Y.; Ho, S.-H.; Lee, H.-C.; Yap, Y.-L. Insecticidal Properties of Eugenol, Isoeugenol and Methyleugenol and Their Effects on Nutrition of Sitophilus Zeamais Motsch. (Coleoptera: Curculionidae) and Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). J. Stored Prod. Res. 2002, 38, 403–412.

25. Adedire, C.O.; Obembe, O.M.; Akinkurolere, R.O.; Oduleye, S.O. Response of Callosobruchus maculatus (Coleoptera: Chrysomelidae: Bruchinae) to Extracts of Cashew Kernels. J. Plant Dis. Prot. 2011, 118, 75–79.
26. Ileke, K.D.; Olotuah, O.F. Bioactivity of Anacardium occidentale (L) and Allium sativum (L) Powders and Oils Extracts against Cowpea Bruchid, Callosobruchus maculatus (Fab.) . Int. J. Biol. 2011, 4.
27. Isman, M.B. Bioinsecticides Based on Plant Essential Oils: A Short Overview. Z. Für Naturforschung C 2020, 75, 179–182.
28. Ibrahim, S.S. Essential Oil Nanoformulations as a Novel Method for Insect Pest Control in Horticulture. In Horticultural Crops; IntechOpen: London, UK, 2020.
29. Fazolin, M.; Estrela, J.L.V.; Medeiros, A.F.M.; da Silva, I.M.; Gomes, L.P.; de Silva, M.S.F. Synergistic Potential of Dillapiole-Rich Essential Oil with Synthetic Pyrethroid Insecticides against Fall Armyworm. Ciência Rural. 2016, 46, 382–388.
30. Quesada, C.R.; Sadof, C.S. Efficacy of Horticultural Oil and Insecticidal Soap against Selected Armored and Soft Scales. Horttechnology 2017, 27, 618–624.
31. Piccinini, E.; Ferrari, V.; Campanelli, G.; Fusari, F.; Righetti, L.; Pagnotta, E.; Lazzeri, L. Effect of Two Liquid Formulations Based on Brassica Carinata Co-Products in Containing Powdery Mildew on Melon. Ind. Crops Prod. 2015, 75, 48–53.
32. Siegwart, M.; Graillot, B.; Blachere Lopez, C.; Besse, S.; Bardin, M.; Nicot, P.C.; Lopez-Ferber, M. Resistance to Bio-Insecticides or How to Enhance Their Sustainability: A Review. Front Plant Sci. 2015, 6, 381.
33. Kilani-Morakchi, S.; Morakchi-Goudjil, H.; Sifi, K. Azadirachtin-Based Insecticide: Overview, Risk Assessments, and Future Directions. Front. Agron. 2021, 3, 676208.
34. Muhammad, A.; Kashere, M.A. Neem, Azadirachta indica L. (A. Juss): An Eco-Friendly Botanical Insecticide for Managing Farmers’ Insects Pest Problems—A Review. Fudma J. Sci. 2021, 4, 484–491.