Botanical Extracts: An Alternative to the Chemical Pesticides

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Abstract

The twenty first century has witnessed a growing emphasis on sustainable agricultural practices to address challenges posed by environmental degradation, pest resistance and the negative effects of synthetic chemical pesticides on organisms that are not the target. Insects, pests and diseases are few of the negative interactions that can cause partial or total crop failure. For management of these biotic factors nowadays, majority of the farmers depend on agro-chemicals but these chemicals create a great health hazard to the human being and animals by accumulating their residue in the water, food, soil and also develop resistance in biotic agents like insects, pathogens and weeds. The extracts of the botanicals are known to safe for human, environmental health and that are used alternative to synthetic chemical pesticides.

Keywords: Botanicals pesticides, Essential oils, Neem products, Secondary metabolites

Introduction

Excessive and indiscriminate application of chemical pesticides in pest control has led to significant harms including pest resistance, negative impact on the environment as well as on non-target organisms (including beneficial ones like microflora, macroflora and flora). Furthermore, chemical residues in food and environmental pollution are also significant health threats to humans and animals, highlighting a need for safer and more sustainable alternatives in pest control. And to screen more plants and purify more novel, interesting bioactive compounds that are unlikely to be of much value, perhaps it's time for the research community to return its attention to the development, and use, of known botanicals. (Isman, 2021). Botanical pesticides, derived from plant extracts or secondary metabolites, offer numerous advantages. These biopesticides are biodegradable, leaving minimal residues in the environment and are generally considered safe for organism those non-targeted and humans. At present more than 2,400 plants identified as having pesticidal properties (Kiri *et al.*, 2024). Pesticides based on botanicals and plant essential oils are just beginning as useful plant protectants. Botanical pesticides are naturally founding chemicals extracted from plants or plant parts and used to control insect pests, pathogen and weeds.

Impact of Synthetic Pesticides

Synthetic pesticides help to produces more food in per unit area but beside of those pesticides are very dangerous for the human health and causes environmental pollution (such as soil, water and air pollution). Chemical pesticides can cause human exposure directly as well as indirectly by virtue of their polluting effects on food, water or the air. Acute reactions from direct contact can cause rashes, headaches, nausea, vomiting and sneezing. Exposure to pesticides over a long period of time may cause chronic diseases such as cancer, necrosis, asthma, neurotoxicity, reproductive issues and heart problems (Pathak *et al.*, 2022). Pesticide exposure has been linked in studies to neurodegenerative diseases, endocrine disruption, respiratory problems and birth defects. Numerous routes, including contamination of the air, water and soil, can allow pesticides to enter the environment, eventually make their way in-to the food chain and causes bioaccumulation. Research has also shown that pesticides can expose non-target organisms, such as those found in nature conservation areas. Pesticide-induced ecological process disruption can lower biodiversity and weaken ecosystems' resistance to shocks.

Why Botanicals?

Botanical pesticides act through diverse modes of action, including antifeedant, repellent and growth-inhibitory effects. Botanicals typically extracted from different plants with pesticidal properties, such as *Azadirachta indica* (Azadirachtin), *Chrysanthemum cinerariifolium* (pyrethrum) and *Capsicum annum* (capsaicin), nicotine's etc. Botanicals are the major control measures that are used alternative to chemical pesticides against insect pest and it is one of the important tools of Integrated pest management.

The use of the neem tree (*Azadirachta indica* Juss.; Meliaceae) (Philogène *et al*., 2005), followed by the use of different plant as pesticides by the ancient Chinese, Egyptians and Greeks (Iqbal *et al*., 2021) was mentioned in the Veda script which is the collection of manuscripts composed in ancient Sanskrit that date back at least 4,000 years

Major Used Botanicals Pesticides and their Mode of Actions

1. Neem Products (Azadirachtin)

Indian neem tree, *Azadirachta indica* (Meliaceae), can be used to make two different kinds of botanical pesticides, by cold pressing seeds yields neem oil, which is helpful in controlling phytopathogens as well as soft-bodied insects and mites. Neem oil's disulfides probably contribute to its bioactivity in addition to its physical effects on fungi and pests. Seed residue extracts with a medium polarity succeeding the oil extracted are more valuable than neem oil because they contain the complex triterpene azadirachtin. Although there are over a dozen azadirachtin analogues found in neem seeds, azadirachtin is the main form and the other minor analogues probably don't add much to the extract's overall effectiveness. Significant amounts of triterpenoids, particularly nimbin, salannin and their derivatives, are present in seed extracts. For to produce the concentrate azadirachtin (which is typically found in 0.2-0.6% of neem seeds by weight) some novel solvent partitions or chemical processes are necessary.

Since, different products of neem are intricate blends of many biologically active ingredients, it can be challenging to determine the precise mechanisms of action of different preparations or extracts. Although, it can be used as a repellent, oviposition suppressant, growth regulator, toxin and sterilant, neem is most effective in insects as a feeding deterrent. Neem acts as a repellent, keeping insects from starting to feed. It deters insects from feeding by making them stop. As a feeding, either right after the initial "taste" (because deterrent taste factors are present) or shortly after consumption (because of the deterrent substance's secondary hormonal or physiological effects). Neem is a growth regulator that is believed to interfere with chitin synthesis and disturb normal development.

2. Nicotine

Nicotiana tabacum (tobacco plants) and other tobacco species will produce an alkaloid agent with a long history of uses as pesticide (in particular insecticide). Two of the alkaloids — nicotine and nornicotine —are synaptic poisons that mimic the neurotransmitter acetylcholine. Hence, they produce poisoning symptoms similar to those induced by insecticides containing organophosphates and carbamates. These insecticide compounds attaching themself to acetylcholine receptors on nerve synapses and cause uncontrollably firing nerves, it competes with the acetylcholine which is a primary neurotransmitter. The physiological systems that rely on nerve input for optimal operation rapidly fail as a result of this disturbance of normal nerve impulse activity. Only specific insect species are impacted by nicotine's relatively selective action in insects.

3. Rotenone

Rotenone has a long history used as a fish poison (pesticide) over 150 years. The tropical legumes *viz*., Lonchocarpus, Derris and Tephrosia produce rotenone and other isoflavonoids in their roots or rhizomes. The majority of rotenone used today is derived from Lonchocarpus, also known as cube root, which is cultivated in Peru and Venezuela. According to studies, the main constituents are rotenone (44%) and deguelin (22%). Resins containing up to 45% total rotenoids are produced when the root is extracted using organic solvents. The cellular respiration process, at the cellular level, which converts nutrient compounds into energy, is strongly inhibited by rotenone. Rotenone's toxic effects in insects are mainly felt by nerve and muscle cells, which lead to an abrupt stop in feeding and causes death within few hours to a few days. Because rotenone act as piscicide, that extremely toxic to fish.

4. Sabadilla

The Sabadilla commonly known as South American lily (*Schoenocaulon officinale*) contains the active compounds specially cevadine-type alkaloids extracted from the seeds which are highly toxic to mammals (rat oral LD_{50} is approximately 13 mg kg^{-1}) and their commercial preparations normally contains the active ingredient less than 1%, which offers a margin of safety. Despite not having the same structure, alkaloids are strikingly similar to the pyrethrins. Sabadilla are used mostly in California, on avocado and citrus crops, are mostly used by organic growers. Toxic alkaloids found in sabadillas impair the function of nerve cells, resulting in paralysis, death and losses of nerve function in arthropods. Many insect pests are instantly killed by sabadilla, while others may remain paralyzed for a few days before deaths.

5. Ryania

Another plant is Ryania, which is made by grinding the wood of the *Ryania speciosa* (Flacourtiaceae) shrub, which is mostly grows in the Caribbean. Less than 1% of the wood powder contains rinodine, an alkaloid that prevents muscle tissue from releasing calcium. To control the codling moth, *Cydia pomonella* the organic apple growers use it to a limited degree.

Ryania causes insects to cease feeding shortly after consumption because of its stomach poison nature, despite the fact that it does not result in rapid knockdown paralysis. Regarding its accurate mechanism of action in insect systems, not much has been published. Piperonyl butoxide (PBO) efficiently synergizes Ryania, which is said to work best in hot conditions.

6. Pyrethrum

The dried flower head of the *Chrysanthemum cinerariaefolium* (Asteraceae), (daisy) is known as pyrethrum. Kenya produces the majority of the world's *Chrysanthemum* flowers.

Directly row flower dust itself is called "pyrethrum," and the six related pesticidal compounds that are naturally occur in the crude materials of pyrethrum flowers are commonly referred as "pyrethrins." Hexane or another nonpolar solvent is used to extract the powdered flowers and when the solvent is removed, an orange liquid containing the active ingredients is produced. The sodium and potassium ionic exchange process in the nerve fibers of insects is interfered with, which culminates in the blocking of the transmission of the nerve impulse during the action of the pyrethrin. Due to their extreme fast action, pyrethrin insecticides causes immediate paralysis of the insects.

7. Plant Essential

As far as oils from fragrant plants are concerned, steam distillation remains the most widely employed method of extraction. For quite a long time, these oils have served as basic constituents for perfume fragrances and also as flavor constituents in food. Lamiaceae is the mint family, and many species are also parts of the marjory family. If you look at the more complex structure of these oils, they mostly contain sesquiterpenes, phenolic compounds, and various monoterpenes. Readers can consider the following examples. 1,8-cineole, which is the main component of eucalyptus (Eucalyptus globulus) and rosemary (*Rosmarinus officinalis*) oils. Or eugenol from clove oil (*Syzygium aromaticum*), or thymol from thyme (*Thymus vulgaris*) or menthol which some species of mint produce. Essential oils have shown insecticidal properties, fumigant and contact, with *Acanthoscelides obtectus* and other pests of stored products. Moreover, lethality and knockdown effects have been seen in *Blatella germanica* and *Periplaneta americana* and *Musca domestica* with these oils.

8. Annonaceous acetogenins

Annona species (Annonaceae) a tropical plant which is used as a botanical pesticide belongs to the family of custard apples. sweetsop (*A. squamosa*) and soursop (*A. muricata*) are significant fruit producers in Southeast Asia in this family Annonaceae. After in detail the acetogenins (long-chain fatty acid derivatives) was isolated which is the main reason for their pesticidal bioactivity. Annonin I, also known as squamocin, is the main acetogenin that can be extracted from *A. squamosa* seeds. By using a constant volume manometer a similar substance called asimicin was also extracted from the bark of an American pawpaw tree, *Asimina triloba.* It decreased the rate at which fourth-instar *Ostrinia nubilalis* consumed oxygen. O_2 was measured polarographically in mitochondria that were separated from *O. nubilalis* fifth instar midguts in order to further investigate the respiratory effect of asimicin.

Diverse use of botanicals pesticides

1. Insecticides

- Act as larvicides to control immature insect stages.
- Regulate growth, disrupting insect development.
- Exhibit ovicidal properties, preventing egg hatching.
- Work as antifeedants, reducing insect feeding.

- Function as sterilant, inhibiting reproduction.

2. *Fungicides*

- Inhibit spore germination, preventing fungal spread.
- Suppress mycelial growth, restricting fungal expansion.
- Delay sporulation, reducing further infections.
- Lower pathogenicity, weakening fungal virulence.
- Decrease disease incidence and severity.

3. *Virucides*

- Induce systemic resistance, enhancing plant defence.
- Inhibit viral transmission between hosts.
- Reduce symptoms, minimizing crop damage.
- Prevent viral penetration into plant cells.
- Suppress viral proliferation, limiting infection.

4. *Nematicides*

- Reduce nematode growth and development.
- Suppress gall formation on plant roots.
- Decrease motility, limiting nematode movement.
- Inhibit infectivity, preventing plant invasion.
- Cause nematode mortality, reducing populations.

5. *Bactericides*

- Inhibit bacterial growth and multiplication.
- Reduce incidence of bacterial diseases.
- Suppress bacterial populations in crops.
- Inhibit severity, minimizing damage.
- Cause bacterial mortality, eliminating infections.

Barriers in Commercialization of Botanicals in India

However, challenges such as limited shelf life, variable efficacy under field conditions and higher production costs remain barriers to their widespread adoption. Despite their advantages, there are a number of barriers of to the commercialization of botanical pesticides in India. The absence of standardized formulations and variations in efficacy brought on by different plant sources and extraction techniques are two significant problems. Botanical pesticides can be widely adopted in India if these issues are resolved through policy changes, formulation improvement research and farmer education.

Conclusion

Botanical pesticides are sustainable, biodegradable and environmentally friendly way to manage the different insect pest and an alternate for synthetic pesticides. Their broad-spectrum activity against Insect pest, bacteria, nematodes, viruses and fungi reduces the risks to the human health and control environmental pollution, while also lowering disease incidence and pest populations. Because of their various modes of action, which include growth inhibition, reproduction suppression and the induction of systemic resistance, botanical pesticides are an effective component in integrated pest management (IPM). Given the growing care about pesticide residues and resistance, botanical pesticides hold great promise for enhancing agricultural sustainability and food security. But for them to be widely used, serious problems with formulation stability, field efficacy and regulatory frameworks must be fixed.

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