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Botanical Pesticides: An Insecticide from Plant Derivatives

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Abstract

Synthetic pesticide is a promising tool for controlling insect pests globally but have negative impacts such as residual toxicity, insect resistance development, effects on non-target organisms and other adverse environmental impacts. For sound management of pests, there is an increasing interest in biotic control using plant products and its derivatives, which is eco-friendly with highly reduction in those impacts. Botanical insecticides such as neem, nicotine, pyrethrum, rotenone etc, are used universally having both biochemical and biophysical properties against insect pests. Pyrethrum and Neem including essential oil are well established commercially. Azadirachtin, bioactive compound of Neem shows insecticidal properties like antifeedant, repellent, ovipositional deterrent, fecundity reduction and longevity. Quick knockdown effect of Pyrethrum and various nerve poison compounds like nicotine in tobacco are very effective in pest management. Using powdered and extract products from plants for small scale farmer is feasible due to its simple application process, less residual and toxicity.

Introduction

Conventional broad-spectrum insecticides such as carbamate and organophosphate compounds can provide good crop protection in field and in stored grains from feeding by insects and other pests. Due to high usage of synthetic insecticides we can see the consequence in the form of resistance development, pest resurgence, secondary pest outbreak, acute and chronic poisoning of applicators, farmers, and even consumers; disturbance in aquatic life and birds, and other wildlife; disruption of natural biological control and pollination; extensive groundwater contamination, potentially threatening human and environmental health. The practice of using botanical insecticides which are naturally occurring insecticides derived from plants that have been formulated specifically for their ability to control insects. Botanical insecticides reported to have inhibitory developmental action and have reproductive sterility effects against insects on agricultural crops that are under constant assault by pests, making use of insecticides essential to reduce losses. Botanical insecticides degrade readily in the sunlight, air, and moisture, breaking down into less toxic or nontoxic compounds and possess less risk to non-target organisms. However, the efficacy, simplicity, flexibility of synthetic insecticides makes it an important tool for pest management but after creating a number of ecological and environmental problems. In addition to aggravation of pest attacks once again, we are giving focus to botanical insecticide an alternative means of insect control which is also tends to be less expensive than synthetic insecticides. Botanicals may not kill an insect for hours or days, but they act very quickly to stop its feeding and it did not damage plants and many botanicals are low to moderate in toxicity to mammals, but there are exceptions.

Neem

Neem, *Azadirachta indica* A. Juss. (Fam. Meliaceae) is indigenous to India from where it has spread too many Asian and African countries and it has both insecticidal and medicinal properties. All parts of the neem tree possess insecticidal activity but the most active compound is found in seed kernel. It has been found that neem bark, leaf, fruit and oil as well as extracts with various solvents especially ethanol exhibit activity against insect pests. Active principles include protolimonoids, limonoids or tetranor-triterpenoids, pentanortriterpenoids, hexanortriterpenoids. It has phagorepellent, antifeedant, ovipositional deterrent effect. Among all Azadirachtin is the most potent biologically active component of neem showing antifeedant, insect growth regulator etc, and due to its systemic action, it is effective against field insect and stored grain insect pest.

Nicotine

1,3-(Di-methyl Pyrrolidine) pyridine ($C_{10}H_{14}N_2O_4S$) the principal alkaloid in tobacco was discovered in 1828. Nicotine is found in the leaves of *Nicotiana tabacum* and *Nicotiana rustica* from 2-14% and also in *Duboisia hopwoodii* and *Asclepias syriaca.* Nicotine is the most important one contributing about 97% among all other compounds found in tobacco and the other two insecticidal value are nornicotine (3-(2 pyrrolidinyl) pyridine) and anabasine (1-3(2-pyridyl) pyridine). Nornicotine occurs in 1-2% in the shoots of *Anabasis aphylla* and about 1% in *Nicotiana glauca.* Nicotine and the other two closely related alkaloids, nornicotine and anabasine are synaptic poisons that mimic the neurotransmitter acetylcholine. The alkaloids are appreciably volatile and basic whereas nicotine sulphate is more stable and less volatile. It is a nerve poison being highly toxic when absorbed through cuticle or taken in through the trachea or when ingested. Owing to the extreme toxicity of pure nicotine to mammals and its rapid dermal absorption in humans, nicotine has seen declining use.

Pyrethrins

Pyrethrum as an insecticide which was first used by about 1800 in Transcaucassus region of Asia. Initial source of pyrethrum were from *Chrysanthemum coccineum* and *Chrysanthemum carneum* (Compositae). However, only since 1840 *Chrysanthemum cinerariafolium* became the chief source which is in the powdered form of dry flower head. Most of the world's pyrethrum crop is grown in Kenya. The term "Pyrethrum" is the name for the crude flower dust itself, and the term "Pyrethrins" refers to the six related insecticidal compounds that occur naturally in the crude material, the pyrethrum flowers. The insecticidal properties of pyrethroids are attributed by six esters (Pyrethrins I and II, Cinerins I and II & Jasmoline I and II) which are predominantly found in the achenes of flowers from 0.7 to as much as 3%. The esters are derived from two acids (Chrysanthemic acid and Pyrethric acid) and alcohols Cinerolone, Pyrethrolone and, Jasmolone. The esters containing pyrethrolone are called Pyrethrin I, if the acid is chrysanthemic acid, and Pyrethrin II, if pyrethric acid. Similarly, those containing Cinerolone are called Cinerin I, if the acid is chrysanthemic acid and Cinerin II if pyrethric acid.

The insecticidal action of the pyrethrin is characterized by a rapid knockdown effect in flying insect pests. It has been observed that Pyrethrin shows recovery action over application. The recovery is due to rapid enzymatic detoxification in the insect body. To bring about a mortality equivalent to knock down effect about three-fold increase in dosage may be required. Compounds such as piperonyl butoxide, propyl isome and sulfoxide are known to inhibit the detoxification enzymes and increases the toxicity of pyrethroid. The symptoms observed are hyperactivity and convulsions in most insects as a result of the neurotoxic action of the pyrethrins, which block voltage-gated sodium channels in nerve axons. Pyrethrins are especially labile in the presence of the UV component of sunlight, a fact that has greatly limited their use outdoors.

Rotenone

$C_{23}H_{22}O_6$ is the main insecticidal compound present in the roots of *Derris* and *Lonchocarpus* plants and in leaves and seeds of *Tephrosia* plants. Rotenone is a broad spectrum insecticide which is an odourless and colorless, crystalline ketonic chemical compound. Though rotenone is reported from 68 species of leguminous plants, principal commercial sources are *Derris elliptica* and *Derris malaccensis* from Malaysia and *Lonchocarpus utilis* and *D. urucu* from S. America. Among the toxicants, in roots and seeds, rotenone is the chief compound occurring in *Derris* roots (4-9 %) and *Lonchocarpus* (8-11 %) and the others being elliptone, sumatrol, malaccol, toxicarol and deguelin which show toxic as well as various behavioural and physiological effects on the insects. It is oxidized to non insecticidal compound in the presence of light and air and hence rotenone residues are difficult to find after 5 to 10 days of application in normal sunlight. Insects poisoned with rotenone stops feeding, leading to their demise via starvation and interference with respiration at the cellular level. *Derris* root is a well known fish poison. It is very specific being highly toxic to fish and to most insect species but almost harmless to warm blooded animals except pigs.

Sabadilla

It is a selective botanical insecticide which acts as contact and stomach insecticide. It is found in the ground seeds of *Schoenocaulon officinale* (Liliaceae) of South and Central

America. The seeds contain 2 to 4% of mixture of veratrine alkaloids. The insecticidal active compounds are cevadine ($C_{32}H_{49}NO_9$) and veratridine ($C_{36}H_{51}NO_{11}$). Other alkaloids present in the seed include Sabadinine, Sabadiline and Sabadine. It is effective against leafhoppers, stink bugs, thrips, most caterpillars and squash bugs. It repels slugs, snails and, many crawling pests. It is toxic to honeybees and degrades rapidly on exposure to sunlight and leaves very minimal trace toxicity.

Ryania

It is found in the ground roots and stem of *Ryania speciosa* (Flacourtiaceae) in S. America which is a contact and stomach poison. The powdered wood contains <1 % ryanodine including 9,21-dehydroryyanidine, an alkaloid that interferes with calcium release in muscle tissue. The wood contains 0.16 to 0.20 % insecticidal alkaloids, the most important being ryanodine. It is a stomach poison effective against lepidopterous pests.

Chinaberry

Melia azderach L., commonly known as Dharek. Active principles include tetranortriterpenoids (limonoids) related to azadirachtin were present, compounds like melianone, melianol, meliantriol, tossendanin, meliacarpinin etc, are present. It exhibit phagodeterrent, oviposition deterrent, fecundity and longevity reducing, development disrupting and toxic effects.

Pongram

Pongamia pinnata L., known as *karanja*. Active component identified as karanjin, a fluvaflavone. Bioactivities like antifeedant, fecundity curtailing and toxic are observed.

Custard Apple

Annona squamosa L. and related plants contain number of mono or sesquiterpenes like α-pinene, β-pinene, germacrene-D etc. other compounds like Annonine, Annonacin and Annonidines act growth disrupter, reduced oviposition, reduced adult emergence and moderate toxicity.

Quassia

Quassia amara L. (Simaroubaceae) a Central American tree with a characteristically bitter bark and wood. Active compound Quassin, a water soluble molecule which act as contact and stomach poison.

Essential Oil

Various essential oils are derived from different plant which are Eugenol from Cloves, *Eugenia cryophyllus* (Sprengel), 1,8-cineole from Eucalyptus, *Eucalyptus globules* (Labill.), Citronella Lemon grass, *Cymbopogon nardus* (Linnaeus), Thymol and Carvacrol from Thyme, *Thymus vulgaris* (Linnaeus), Pulegone from Pennyroyal, *Mentha pulegium* (Linnaeus), Ginger oleoresin from Ginger, *Zingiber*

Table 1: Mechanism of action of pesticides of plant origin (El-Wakeil, 2013)

System	Mechanism of action	Compound	Plant source
Cholinergic system	Inhibition of Acetylcholinesterase (AChE)	Essential oils	*Azadirachta indica, Mentha* spp., *Lavendula* spp.
	Cholinergic acetylcholine nicotinic receptor Agonist/ antagonist	Nicotine	*Nicotiana* spp., *Haloxylon salicornicum, Stemona japonicum*
GABA system	GABA-gated chloride channel	Thymol,Silphinenes	*Thymus vulgaris*
Mitochondrial System	Sodium and potassium ion exchange Disruption	Pyrethrin	*Crysanthemum cinerariaefolium*
	Inhibitor of cellular respiration (mitochondrial complex I electron transport inhibitor (METI)	Rotenone	*Lonchocarpus* spp.
	Affect calcium channels	Ryanodine	*Ryania* spp.
	Affect nerve cell membrane action	Sabadilla	*Schoenocaulon officinale*
Octopaminergic System	Octopaminergic receptors	Essential oils	*Cedrus* spp., *Pinus* spp., *Citronella* spp., *Eucalyptus* spp.
	Block octopamine receptors by working through tyramine receptors Cascade	Thymol	*Thymus vulgaris*
Miscellaneous	Hormonal balance disruption	Azadirachtin	*Azadirachta indica*

Table 2: Toxicity level of various botanical pesticides

Generic name	Oral LD50	Dermal LD50	Signal word
Neem	13000	-	Caution
Pyrethrins	1200-1500	>1800	Caution
Rotenone	60-1500	940-3000	Caution
Sabadilla	4000	-	Caution
Rynia	750-1200	4000	Caution
Nicotine	50-60	50	Danger

officinale (Roscoe), Turmerone and dehydroturmenone from Turmeric, *Curcuma longa* (Linnaeus) and Allin, Allicin, Garlicin, opin and allyl sulfides from Garlic, *Allium sepa* (Linnaeus) etc.

Conclusion

In order to minimize the use of hazardous synthetic insecticides and to manage the insect pests and diseases attack as well as to increase the crop productivity, it is necessary to implement a scheme to strengthen and modernization of pest management approach by adopting Integrated Pest Management (IPM) as cardinal principle and main plank of plant protection strategy in overall crop production program. Botanical pesticides help in preventing the dumping of thousands of tons of pesticides on the earth, they are environmentally safe as they are biodegradable and do not have longer residual effect. Although botanical insecticides are not helpful in controlling major agronomic crops (cotton, maize, soyabean, rice, oilseeds) (Isman, 2010) they are promising alternatives to conventional insecticides in the developed world.

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