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Botanical insecticides; prospects and way forward in India: A review

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Abstract
Insecticides are complex mixtures of substances used to prevent and management the various pests. Insecticidal plants, referred to as botanical pesticides, are of naturally occurring pesticides derived from plants. Normally Most of the plants produce complex mixture of bioactive molecules that deters pest species, often producing a mixture of compounds that repel and stop feeding. The botanicals are broad spectrum in pest management, safe to apply, unique in mode of action, and can be easily developed and applied. In spite of the advantages and disadvantages of botanical insecticides there are problems towards registration and commercialisation in India with, availability and sustainability of raw material, stability, aspects of quality control, chemically complex extracts, regulatory approval and expensive cost on toxicological evaluation of the botanicals. In order to mitigate the major issues of the registration and commercialization of botanicals insecticides has to be regulated unlike the synthetic insecticides which are available in India.

Keywords: botanical insecticides, insects, synthetic pesticides, insecticidal plants, complex mixture

1. Introduction
Pesticidal plants have used from way back 1940s itself, in commercial agriculture, since when drastically increased the modern synthetic pesticides in Agricultural system and excess application synthetic insecticides cause a problem of such as environmental contamination, residue problem and various health hazarders to public and it also evident that continues use of synthetic pesticides has create resistance problems in various insects and other negative impact to natural enemies and pollinators. Nearly 98 percent of sprayed pesticides substances are do not reach to their respective target site and they can easily penetrate the groundwater and cause the environment pollution. Looking for these disadvantages of synthetic pesticides, it is necessary to search for the alternative one such as botanical pesticides. These plant-based pesticides are alternative solution for address the present problems. In this context botanicals are the most promising solution owing to their broad spectrum of action like repellent, antifeedant, growth regulatory and oviposition deterrent. Botanical insecticides as an alternative solution to synthetic pesticides trough which their non-phytotoxicity, biodegradability and rapid break down ability. However, only a few plant-derived products have well demonstrated their effectiveness against various insects like neem, lemongrass, etc. Botanical extracts induce insecticidal activity, repellence to pests, antifeedant effects and insect growth regulation, toxicity to nematodes, mites and other pests [29, 30].
Pesticides are generally persistent in nature. Unfortunately the extensive use of synthetic insecticides led to problems unforeseen at the time of their introduction. Insecticides residues are found in food, water and even in breast milk. USA alone 200 deaths were occurring every year due to their pesticide poison. WHO estimated each year 25 million cases of pesticide poisoning was recorded primarily in developing countries. However, the use of synthetic pesticides has been restricted because of their ill effects to environment [9, 31, 12, 21]. Continues use of synthetic pesticides has create pesticide residue hazards, affect the balance of nature through natural enemies, pollinators and other wild life disruption [9].

2. Promising plant species
Nearly More than 6000 species of various plants have been screened and more than 2500 plants belonging to 235 families were found to possess biomolecules against various types of pests [39]. In that important plant families are, *Apocyanaceae, Asteraceae, Euphorbiaceae, Fabaceae, Meliaceae (maximum), Myrtaceae, Ranunculaceae and Rosaceae.* Along with their

mode of action of major botanical pesticides and promising plant species are documented in Table 1 and Table 2 respectively [39].

Table 1: Important botanicals and their mode of action

Name	Source	Mode of action	Uses
Pyrethrum	Flowers	Interfere with Na & K ion movement in nerve axons	Aerosol bombs for mosquitoes
Rotenone	Roots	Disrupts energy metabolism in mitochondria in nerve axons	Beetles, fish poisoning
Sabadilla	Seeds	Interferes with Ns & k ion movement in nerve axons	Control of squash bug and citrus thrips
Ryania	Woody stem	Activates Ca ion release channels & causes paralysis in muscles	Control of caterpillars and thrips
Nicotine	Tobacco plants	Mimics the neurotransmitter Acetylcholine	Control of aphids, thrips and bugs

Table 2: Promising insecticidal plant species with their properties

Plants	Active compounds	Activity
Abiesbalsamea	Juvabione	JH agonist
Acoruscalamus	Asarone	Antifeedant
Ageratum houstonianum	Precocene, Anacylin	Anti-JH
Ajugaremota	Ajygarin	Feeding deterrent
Allium sativum	Diallyl sulfide	Repellent
Atlantiaracemosa	Luvangetin	Antifeetant
Citrulluscolocynthis	Cucurbitacin-B	Antifeedant
Citrus paradisi	Isolimonic acid	Oviposition deterrent
Clerodendroninfotunatum	Clerodin	Antifeedant
Curcuma longa	Termeron	Growth inhibitor
Glycine max	Glyceollin	Antifeedant activity
Tagetesminuta	E-Ocimenone	Repellent
Ricinuscommunis	Ricinine	Oviposition deterrent
Medicago sativa	Butyric acid	Repellant
Ocimum basillicum	Juvocimene	JHA
Partheniumhysterophorus	Parthenin	Growth inhibitor
Piper nigrum	Piperin	Oviposition deterrent
Quassiaamara	Quassin	JHA
Pongamiapinnata	Karanjin	Antifeedant, JHA

3. Types of botanical insecticides

Essential oils

Essential oils extracted from various aromatic plants have larger demand in perfumery and also as insecticides products. They have repellent, antifeedants, growth inhibitors, oviposition inhibitors, ovicides, and growth-reducing effects on a variety of insects [10, 11, 23, 26, 28, 34, 40, 44, 48]. Essential oils having a insecticidal activity and repellent action against cockroach, headlices, ants, flies, bedbugs, and moth and toxic to termites. Essential oil obtained from Pepper mint (*Mentha piperita*) repels ants, flies, lice, moths and is effective against *Callosobruchus maculatus* and *Tribolium castaneum* [22]. The oil from *Trachyspermum* sp. has larvicidal property against *Aedesaegypti* and southern house mosquito (*Culex quinquefasciatus*) [47].

Alkaloids

Alkaloids are very important natural substances primarily due to their insecticidal properties [3, 33]. Pyridine are obtained from *Ricinus communis*is effective against malaria vector *Anopheles gambiae* [50]. Alkaloids from *Arachis hypogaea* extract have larvicidal activity against chikungunya and malarial vectors [49].

Flavonoids

Flavonoids are widely distributed in insecticidal plants and performing many functions. Thatsy it can be used in pest management aspects. Flavonoids play a major role in the protection of plants against the various herbivores [1]. Normally both flavonoids and isoflavonoids rescue the plant against various insect pests by influencing their behaviour, growth, and development [42, 41]. Ex three flavones glucosides inhibit digestion in *Nilaparvata lugens* and other herbivores in rice ecosystem [1, 14].

Glycosides

Cyanogenic glucosides present in plant species have important role in plantdefense against herbivores [52, 8]. Anthrax quinones isolated from *Cassia* species have antimalarial and insecticidal activity. Glycosides of *A. hypogaea*extract have larvicidal activity against chikungunya and malarial vectors [49].

4. Commercialised botanical pesticides in Agricultural pest management.

Neem based insecticides

Neem products are usually extracted from the *Azadirachta indica*, [7]. Main active ingredients of the neem are azadirachtin, meliantriol, salannin, desacetylsalannin, nimbin, desacetylnimbin, and nimbidin. Azadirachtin concentration from 0.2 to 0.6% in seeds compared to other parts [15]. Azadirachtin is a broad range of mode of actins on various insect pests such as repellents, antifeedant, insect growth regulatory and anti–ovipositional properties [37, 6]. Azadirachtin is most effective against nearly 550 insect species, mostly on Dictyoptera, Orthoptera, Heteroptera, Isoptera, Lepidoptera, Diptera, Coleoptera, Homoptera, Siphonaptera and Hemipteran orders [36]. Neem extract was the most effective insecticide against various sucking insect pests, like, white fly, jassid, and mites [2].

Rotenone

Rotenone is normally broad spectrum of botanical pesticide that is extracted from the roots and stems of tropical legumes *Derris* (*Derris elliptica*), *Lonchocarpus (Lonchocarpus utilis*, *Lonchocarpus urucu*) and *Tephrosia virginiana* Chemically, rotenone is the is of lavonoid [51]. The active ingredient is Rotenone, which acts as a contact and food poison, cellular respiratory enzyme inhibitor, stomach poison.

Pyrethrum

Pyrethrum is one of the most important botanical pesticides used in India, which is extracted from the flowers of *Chrysanthemum cinerariaefolium.* The higest concentration of pyrethrumis found mainly in the flowers compared to other parts of the plant [35, 45] Pyrethrum is the mixture ofsix active ingredients, namely, pyrethrin I, pyrethrin II, cinerin I, cinerin II, jasmolin I, and jasmolinII. Pyrethrin I, cinerin I, and jasmolin I are the esters of chrysanthemic acid, whereas pyrethrin II, cinerin II, andjasmolin II are the esters of pyrethric acid [17, 16]. Pyrethrins are the most dominant form of active ingredients compared to cinerins and jasmolins interms of concentrations.

5. Effects of botanicals on insects

Botanical insecticides affect various insects in different ways depending on the physiological characteristics of the insect

species as well as the type of the insecticidal plant (biomolecules). The components of various botanical insecticides can be classified into six groups namely; repellents, feeding deterrents/ antifeedants, toxicants, growth retardants, chemosterilants, and attractants [21].

6. Advantages of botanicals

Botanical insecticides have some advantages like they do not persist in the environment, relatively low risk and non-toxic to beneficial predators, parasites and relatively mammals [51, 38]. Botanicals are normally break down easily in the environment and are rapidly metabolized by animals [25]. Botanicals having high degradation rate and low persistence in environment. Neem based pesticides formulations are one of the most used botanical pesticides followed by Pyrethrums, and Eucalyptus oil based pesticides. Numbers of botanical pesticides are used in the integrated pest management and undergo lack of persistence and bioaccumulation in the environment, selectivity towards predators, parasitoides and pollinators are very less [16], these features are attracted significant studies of regarding botanical pesticides from different plant sources. Botanical pesticides are usually extracted from different plant sources and which can apply in integrated pest management system. They are generally no effect to humans and the environment compare to other chemical pesticides.

7. Scope of botanicals in present Indian agriculture

Botanical pesticides are environmentally safer, unique with novel and diversified mode of action and are rich source of biologically active compounds. The field of agrochemicals are usually unexploited area but complex mixture of various stereoisomers exhibited excellent activity in pharmaceuticals industries [13].Naturally occurring botanical pesticide are huge demand in pesticidal market. A large number of botanicals products have been released some have played a leading role in the insecticidal market. Around 6000 plant species have been identified and screening against the pest in all over the world. A number of plant products derived from various plants like neem, custard apple, tobacco, pyrethrum, etc. have been used so for as safer insecticides because of their environment friendly nature against predators, parasitiodes, and pollinators. Naturally available native plants species have some secondary metabolites like, phenolics, terpenes, alkaloids, lignans and their glycosides play important role in plant defence against the various pest. This unique characteristics are attracts the researchers and farmers for commercialisation of novel botanicals in India [19]. The communal approach of farmers helps in collection, conservation and cultivation of such botanical plant species for larger production of cost effective biopesticides over synthetic insecticides [27].

8. Botanical pesticides status in India

In order to consumption of pesticides for the agricultural or any other purpose, the pesticides and its formulations first we have to registered under the Insecticide Act, 1968 according to this guidelines and rules prescribed by the Central Insecticide Board & Registration Committee (CIBRC), Department of Agriculture and Farmer's Welfare. In India, only three botanical pesticides are Azadirachtin (Neem Based Formulations), Pyrethrum, and Eucalyptus Leaf Extract has been registered and allowed to use as botanical pesticides commercially for various purposes. Out of these three botanicals, neem based pesticidal products have mostly used as the botanical pesticides in the agricultural purpose followed by pyrethrum, and Eucalyptus Leaf Extract respectively.

9. Ideal characteristics of insecticidal plants

a. It should be a perennial.
b. It should have a wide distribution and be present in large numbers in nature. Policy measures should come into form for their extensive cultivation.
c. There should be easy in detachment of plant part viz. Leaves, flowers or fruit.
d. Harvesting should not mean destruction of the plant (avoid the use of roots or bark).
e. Plants requiring minimum space with minimum management of irrigation and fertilization is desirable.
f. Apart from insecticidal properties, plant should have additional uses like medicinal and value addition for greater benefit to mankind.
i. The plant should be cost effective.
j. The active ingredient should be effective at low rates.

10. Problems/barriers in commercialization of botanicals in India

A number of problems have been encountered during commercializing the botanical pesticides such as quality control aspects and product standardization. The problems in commercialization of botanicals are given along with the technical case studies. As like as synthetic pesticides products, botanical pesticides may also develop pest resistance. Major concern for botanical pesticides is to low mammalian toxicity but have some significant toxicity to fish and aquatic invertebrates in pyrethrum. Rotenone is also exhibit their extremely toxicity to fish and other aquatic organisms. Commonly fish poison are recorded oral LD50 of approximately nearly 350 mg/kg. Nicotine is highly toxic to all warm blooded animals and insects having an oral LD50 of 50 mg/kg [18]. *Tephrosia vogelii* having well-known adverse effects against fish. The phytotoxicity is also a major problem in tomato, brinjal and ornamental plants. Although botanicals plant extracts are considered to be relatively safe to humans, but still, not yet confirmed for all plant species such as *Aconitum spp.* and *Ricinus communis* have notoriously high toxicity to man. Neem is one such potent plant species having large group of biomolecules with diversified mode of action against different pests. The drawback, of the biomolecule (Azadirachtin) obtained from Neem have photosensitive nature and it break down rapidly in sunlight. Synergism is another issue in developing pyrethrum products for the organic market. Synergists are essential because pyrethrum is quickly metabolized and rapidly loses activity against insects when applied alone. Conventionally the synergist piperonyl butoxide (PBO) has been used which enhances pyrethrin activity about 4 times through the inhibition of cytochrome P450 enzymes. PBO is a synthetic compound and therefore not suitable for use in organic agriculture [20].

There are several barriers in commercialization of botanical insecticides, such as production of raw materials for commercial scale, standardization of formulations for chemically complex extracts, requires minimum regulatory approval for their slow mode of action with lack of residual effects and most tested plant-derived pesticides have not been officially recommended for use in pest management. In addition to other drawbacks of botanicals, essential oil posses high boiling point, high molecular weight and low vapour pressure, these characters hinder for large scale applications

[18, 19, 9]. Market based challenges are, toxicology for testing the new products is higher, market opportunities of the botanical pesticides have unique problem of higher cost for registration because of their complex mixtures of bioactive constituents. Since most of the botanicals are generally degrade within few days or sometimes within a few hours due to this, application rate will be higher and requires frequent application coupled with exorbitant will leads to higher cost of production. Other Market challenges include economical supply of plant product, quality control and lack of stability, as well as competition from other bio pesticides and bio control agents. Technical grade of botanicals is another issue lies with supply of homogeneous plant material with biomolecule which is largely influenced by method of cultivation, harvest stages, post-harvest storage and primary processing and manufacturing aspects. Plants produce avariety of secondary metabolites including various alcohols, terpenes and aromatic compounds which are influenced based on the geographical areas and climatic conditions (e.g. sunshine hours, rain fall, and soil). However, keeping the negative effects of the synthetic chemicals on human health, environment and ecosystem, the regulatory authorities are likely to look largely for botanical pesticides, with lesser market hurdles [18].

11. Conclusion

Naturally producing botanical pesticides have greater scope in international level as present days botanical pesticides have promoted modern agriculture and gradually replace the synthetic pesticides. A large number of botanical pesticides have been already released and played a leading role in the market. In insect pest management, a number of plant products derived from neem, custard apple, tobacco, pyrethrum *etc*. have been used as safer insecticides as compared to chemical pesticides. Botanical pesticides have less environmental hazards, easily volatility, fast degradation, less phyto toxicity, less insect resistance, low resurgence effect and provides residue free commodity. These botanicals features trigger the scientist to use botanicals as component of integrated pest management and since these are the major alternatives to synthetic pesticides. Mean time the factors for less commercialisation of botanicals in market are, the availability and sustainability of raw materials, stability and standardisation of quality control aspects of complex extracts and regulatory approval. In present review aimed at to gathering information on, present status of botanicals in India, mode of action of different botanicals and barriers in commercialization of botanical pesticides in brief. At last we need to tackle all the problems/ barriers and formulate a newer formulation with greater stability of the botanical pesticide, regulation of registration formalities to be made easier to tap the market demand in a huge way for commercialisation of botanical insecticides in India.

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