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Botanical Pesticides- An Alternative for Insect Pest Management

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Introduction

Human population is increasing at an alarming rate (i.e., 70 million per year) and if this trend continues, there will be 10 billion people in the world by the end of the century (Gerland *et al*., 2014; Tilman *et al*., 2002). The increased demand for food to feed the ever-growing population has led to the development and adoption of synthetic chemicals as a quick and effective strategy of managing crop pests and diseases. Overuse and misuse of synthetic pesticides can also result in toxicity to non-target organisms, thus impacting negatively on biodiversity. Constituent compounds of synthetic pesticides have been attributed to chronic human ailments either due to consumption or exposure. Most of the synthetic pesticides are not easily biodegradable thus accumulate in the environment and cause pollution to soil and ground water in addition to depletion of the ozone layer. Botanical pesticides are efficacious in managing different crop pests, inexpensive, easily biodegraded, have varied modes of action; their sources are easily available and have low toxicity to non-target organisms.

Pest management is one of the essential components in agriculture. Management of pests using plant-based products was practised over time until technology took over and synthetic pesticides were developed. The synthetic pesticides were immediately embraced due to their effectiveness and efficacy in managing serious crop diseases such as rusts and blights. Consequently, the use of natural products of plant origin slowly faded until recently when use of synthetic pesticides started threatening human health and environmental safety. Commonly used botanical pesticides are popular in organic farming where organically produced food fetches premium prices. Botanical pesticides are gaining popularity because they are safe to use on crops produced for human consumption and recently there is a lucrative market among consumers willing to pay more for organically produced food. They can play a much greater role in the production and postharvest protection of food in developing countries. Botanical pesticides are now emerging as a valuable component of IPM strategies in all crops due to their efficacy to insect pests and safety to their natural enemies. Therefore, they can be incorporated into integrated pest management systems and contribute to sustainable agricultural production.

Botanical Pesticides

Botanical pesticides are the naturally occurring secondary metabolites (phytochemicals) extracted from the plant sources which can control and kill the pests thus helping in the agricultural pest management. They are generally safer to humans and the environment than conventional chemical pesticides (Dimetry, 2014).

Botanical pesticides are derivatives of plants that repel, inhibit growth or kill pests. Most botanical pesticides are used to manage insect pests and many studies have focused majorly on insect pest management. They are one of the alternatives to conventional pesticides and sub group of biopesticides in agricultural pest management. Thus, they are of great importance in the field of research of pest management. Botanical insecticides constitute the largest share of botanical pesticides present in the market all over the world. They are natural compounds with insecticidal properties and their use in crop protection is as old as agricultural practice.

Botanical pesticides in agricultural production

Plants that are sources of botanical pesticides are easily available in the environment and most of them have multiple uses such as medicines, spices, ornamentals, food and or as feed. Their availability makes them inexpensive and hence they are easily incorporated into agricultural production systems. Commercialized pesticides from plants such as pyrethrum, neem and sabadilla are some of the least toxic especially to non-targets organisms such as pollinators and fish. This attribute makes botanical pesticides effective, reliable and acceptable in sustainable crop protection. In addition, they do not leave residues on crop produce and the environment thus contributing to environmental conservation and ensuring safety to consumers (Dubey *et al*., 2008). The interaction between botanical pesticides and the pests is naturally biochemical therefore pests are unlikely to develop resistance. The plant-based chemical compounds in extracts and essential oils are target specific which ensures safety on non-target organisms especially the beneficial organisms including pollinator bees and predators. Their efficacy is dependent on the species of the source plant, whether dry or fresh, solvents used for extraction and the extraction methods. Botanical pesticides exhibit varied modes of action on the target pests such as repellence, toxicity, growth regulation and structural modification making them suitable alternatives in crop pest management.

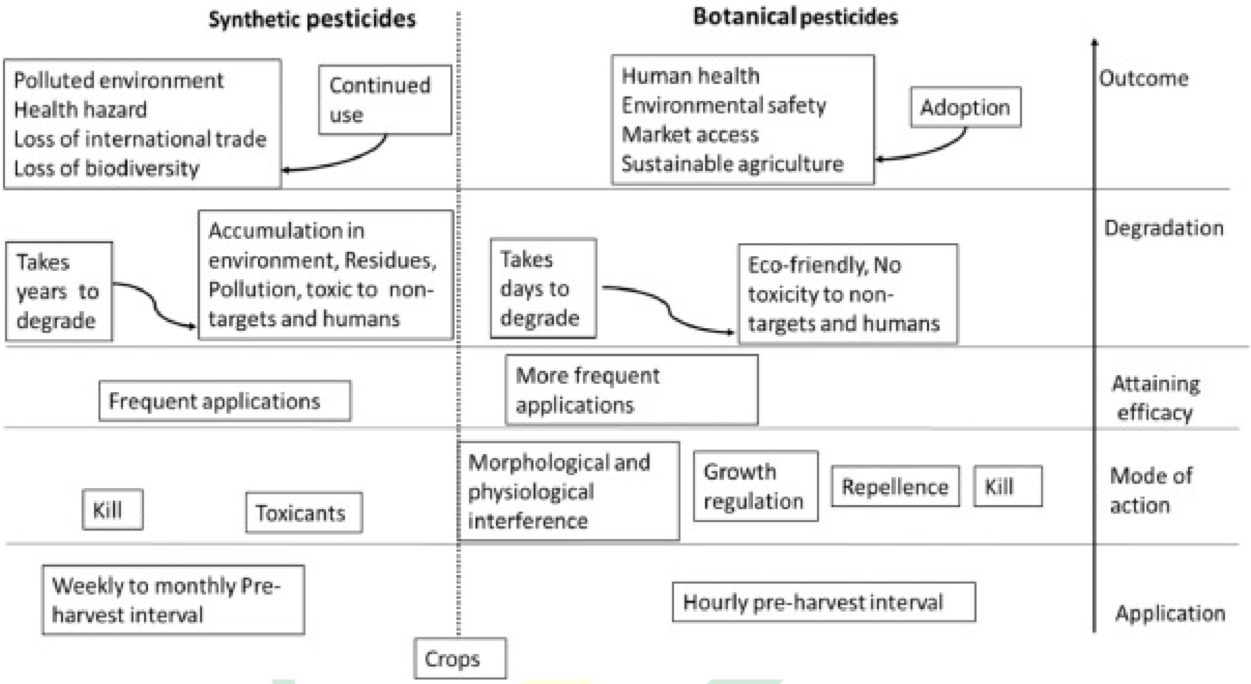

Fig. 1. A model illustrating differences between synthetic pesticides and botanical pesticides with respect to use, mode of action, persistence and effect on ecosystem.

Acceptance, adoption and utilization of botanical pesticides has been reviewed by various authors. Sufficient evidence and information regarding chemistry and efficacy of botanical pesticides is needed to satisfy the pesticides registration regulations (Isman and Grieneisen, 2014). This is in addition to information on their formulation, degradation, longevity and toxicity. Integration of botanicals in agricultural production systems ensures major benefits to the farmers including food safety, reduced pest levels, improved quality of produce which fetches higher prices and guaranteed market access. The consumers in lucrative markets are willing to pay higher prices for organically produced foods, thereby creating market opportunities for botanical pesticides. Possible adoption pathways guiding synthetic and botanical pesticides have been described in *Fig. 1*. Synthetic pesticides have a

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key role in crop pest management as they contribute to reduction in damage to crops and the resultant losses in produce and revenue. However, they need to be used judiciously and applied by trained personnel. This is especially important in the case of small holder farmers where a lot of care and sensitization is required to ensure human and environmental safety. Therefore, incorporating botanical pesticides into integrated pest management programs would reduce unnecessary usage of the synthetic pesticides.

Current Status of Botanical Pesticides in India

In order to use pesticides for agricultural or any purpose, the pesticides and its formulations must be registered under the Insecticide Act, 1968 according to the guidelines and regulations prescribed by the Central Insecticide Board & Registration Committee (CIBRC), Department of Agriculture and Farmer's Welfare in India. In India, only three botanical pesticides namely Azadirachtin (Neem Based Formulations), Pyrethrum, and Eucalyptus Leaf Extract has been registered and allowed to use as botanical pesticides commercially for various purposes under Insecticide Act, 1968. Out of three, Azadirachtin or neem- based pesticides are mostly used as the botanical pesticides in the agricultural pest management system followed by Pyrethrum, and Eucalyptus Leaf Extract.

Sources of botanical pesticides

Botanical pesticides are derived from plants belonging to different families and are either utilized as plant extracts, essential oils or both. Plant parts used to make botanical pesticides include barks, leaves, roots, flowers, fruits, seeds, cloves, rhizomes and stems. The plant part used is dependent on the targeted bioactive compounds and their abundance within that particular part.

Table 1: Important trees/shrubs and plants showing pesticidal properties.

Common Name	Scientific Name	Family	Plant parts used	Active principle
Neem	*A.indica, A.juss*	Meliaceae	Leaves,seed, oil, bark	Azadirachtin,Meliantriol, Nimbidin, Salanin, Nimbin
Dharek	*Melia azedarach L.*	Meliaceae	Leaves, fruits and bark	Nimbolin A, Nimbolin B, Meliatoxin A1
Pongam	*Pongamia glabra*	Leguminos	Leaves, fruits,	Pongamol, pongapin,

	vent. *P.pinnata L.*	ae	seeds, oil, roots and flowers	pongaglabrone, pongallone, pongone
Custard apple	*Annona squamosa*	Annonaceae	Leaves and bark	Annonin, squamocin
Mahua	*Madhuca indica(Koenig) Macbride* *M.longifolia Koen*	Sapotaceae	Oil and cake	α and β-amyrin, Quercetin, saponin-A
Derris	*Derris chinensis*	Leguminosae	Roots	Rotenone
Quassia	*Q.amara*	Simarubaceae	Wood and bark	Quassin, isoquassin, neoquassin and quassimarin
Ardusa	*Ailanthus excels*	Rutaceae	Leaves	Ailanthone
Eucalyptus	*Eucalyptus globulus Labill*	Myrtaceae	Leaves and oil	Camphene, limonene, linalool, α and β-pinenes, α-terpinol
Moringa	*Moringa oleifera Lamk*	Moringaceae	Flowewrs and Leaves	Moringyne
Khejri	*Prosopis jiliflora (Sw.) Dc.*	Mimosaceae	Leaves and seeds	Juliprosopine, julifloridine, juliflorinine, prosopidione
Pink oleander Yellow oleander	*Nerium oleander L.* *Thevetia neriifolia Juss. ex Steud*	Apocynaceae	Leaves, flower, seeds and whole plants	Oleanderol, oleanderin,oleanderolicacid
Clerodendron	*Clerodendron indicum (L.inn.) Kuntze*	Verbenaceae	Leaves	Trans-decalin, clerodin

Ipomoea	*Ipomoea fistulosa Mart. Ex Choisy I. Comea*	Convolvulaceae	Whole plant, leaves and flowers	Isopomin, ergine, isoergine, ipalbidinium
Ryania	*Ryania speciosa*	Flacourtiaceae	Roots, leaves and stalks	Ryanodine
Jatropha	*Jatropha curcas L.*	Euphorbiaceae	Leaves,seed,seed cake	Curcusone,jatrophol and jatrophin
Euphorbia	*Euphorbia tirucalli L.*	Euphorbiaceae	Branch	Euphorbosterol, euphorbol
Tobacco	*Nicotiana tabacum L. N. rustica L.*	Solanaceae	Leaves, whole plant	Nicotine, nornicotine, anabasine
Lantana	*Lantana camara L. L. trifolia L.*	Verbenaceae	Leaves, whole plant	Lantalonic acid, lantic acid, ursolic acid stearoylglucoside(UASG)
Indian Aloe	*Aloe vera (L.) Bum. Aloe barbadensis Mill.*	Liliaceae	Leaves,rhizomes	Aloesin, aloin
Mint	*Mentha spicata L. Mentha arvensis DC*	Lamiaceae	Leaves, flowers, whole plant, oil	Menthole, limonene, dihydrocarvone, menthone
Onion	*Allium cepa L.*	Alliaceae	abulb	Aoleic acid, cepocide-D, α and β- tocopherols
Garlic	*Allium sativum*	Alliaceae	Whole plant, bulb, leaves, flowers	Allicin, diallyl sulfide and diallyl disulfide
Chillies	*Capsicum annum L. C. Frutescens L.*	Solanaceae	Leaves, fruits	Capsicin
Sabadilla	*Sabadilla officinarum L.*	Liliaceae	Seeds	Cevadine, veratridine

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Mechanisms of action of botanical pesticides against insect pests:

Most plant extracts act on insects by repelling, deterring feeding and oviposition, toxicity, lethal activity and interfering with physiological activities. The multi-active role of botanical insecticides on insect pests makes them more popular in the market. For example, commercialised products from plants such as pyrethrum have been reported to possess among others the neurotoxicant effects on insect pests causing paralysis and knock down and consequently mortality. Botanical pesticides also interfere with production of important enzymes such as those responsible for moulting thus inhibiting growth and development. Some botanical pesticides have been associated with paralysis and blockage of electron transportation in respiratory processes of insects, immobilization and toxicity. In insects, neem is most active as a feeding deterrent, but in various forms it also serves as a repellent, growth regulator, oviposition (egg deposition) suppressant, sterilant, or toxin. As a repellent, neem prevents insects from initiating feeding. As a feeding deterrent, it causes insects to stop feeding. Rotenone is a powerful inhibitor of cellular respiration, the process that converts nutrient compounds into energy at the cellular level. In insects, rotenone exerts its toxic effects primarily on nerve and muscle cells, causing rapid cessation of feeding. Understanding the mode of action including the physical, biological and chemical interactions between the pest and pesticide is vital in pest management as it dictates the management strategy to be adopted.

Table 2: Major botanical pesticides 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, citrus thrips
Ryania	Woody stem	Activates Ca ion release channels & causes paralysis in muscles	For control of catterpillars and thrips
Nicotine	Tobacco plants	Mimics the neurotransmitter acetylcholine	For control of aphids, thrips and bugs

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Table 3: Mode of action of selected botanical pesticides on selected crop pests.

Source Plant	Mode of action	Target pests
Neem (*Azadirachta indica*)	Binding to acetylcholine receptors thereby disrupting the nervous system, Repellence, Feeding deterrence, Inhibition of oviposition, egg hatching and moulting	Insects
Garlic (*Allium sativum*)	Delay and inhibit spore germination, Inhibits protein and DNA synthesis, Inhibits production of mycotoxins, Disrupts cellular components and their activities, Hyphal and mycelial modifications	Fungi
Aloe vera	Inhibits cellular activities, Impairs permeability of plasma membrane, Denatures proteins, Inhibits ATP production and glucose uptake	Bacteria
Tagetes erecta	Inhibits egg hatching, Larval toxicity, Structural modification, Mortality	Nematodes
Nepeta nuda subsp nuda	Host plant manipulation, Inhibits virus replication and multiplication, Prevents virus adsorption, Inhibits nucleic acids liberation	Viruses

Conclusion

Natural environment is a rich source of a wide range of plants, some of which have been used to cure human, animal and plant diseases. Following concerns of human health, environmental safety and strict regulations on pesticide residues in agricultural produce, the use of synthetic pesticides needs to be done judiciously and only when absolutely necessary.

Nevertheless, even with cautious use of synthetic pesticides, continued reliance on those chemicals still poses a hazard to the environment, non-target organisms and human health because of their residual effects. Therefore, efficacy and role of botanical pesticides in managing crop pests needs to be reconsidered due to their renewable nature and contribution to human and environmental safety.

Considering the huge volumes of material needed to produce botanical pesticides, large scale cultivation of source plants could be done in marginal lands that are not suitable for arable agriculture to avoid competition with food crops. Commercialization of producing such plants would generate income that would help sustain the livelihoods of communities in semi-arid areas.

More research is required to improve exploitation of plants with bioactive compounds of relevance to crop protection. This may involve domestication and improvement of identified wild plants through breeding to improve content of the active molecules, in addition to developing appropriate husbandry practices, including plant nutrition and agronomic practices.

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