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Botanic Plant Resources as Insect Pests Administrator of Field Crops

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ARTICLE INFORMATION

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ABSTRACT

Owing to growing public awareness and concern about the adverse effects of pesticides have necessitated the need to look for eco-friendly, safer, and effective organic methods of pest control. The best solution for this is to follow indigenous traditional ways of pest control by using plants, which have been once prevalent all over the world. But with the advent and use of modern synthetic pesticides, these botanicals more or less vanished. The successful utilization of botanicals can help to control many of the world's destructive insect pests of crops. The botanical pesticides could be divided into the 1st generation including nicotine, rotenone, sabadilla, ryania, pyrethrum, and plant essential oils; while the 2nd generation comprises synthetic pyrethroids and azadirachtin, as well as potential new botanicals. Botanical pesticides may affect insect nerves, while others may affect the molting process. Different botanical formulations have been reported from time to time showing pronounced insecticidal activity, repellence to pests, oviposition deterrence, adult emergence inhibition, ovicidal, larvicidal, pupaecidal activity, and feeding deterrence based on their contact toxicity and fumigation effects. Thus, managing of crop pests using plant secondary metabolites can be more easily integrated into agro-ecologically sustainable crop production systems.

1. INTRODUCTION

Nowadays, insect tormenter management must go about the economic and ecological consequences of the employment of aggressor management measures. Sustained struggles against harmful insects for exploitation of artificial and oil-derivative molecules have created perverse secondary effects (mammalian toxicity, insect resistance, and ecological hazards). The diversification of the approaches inherent in Integrated Pest Management (IPM) is critical for higher environmental protection (Sarwar, 2013a; 2019a; Sarwar et al., 2021).

Biological control has less practical application because of its dependence on environmental conditions (Sarwar, 2014; Sarwar and Salman, 2016). Hence, biochemical control is the most effective controlling measure in large-scale crop protection (Sarwar et al. 2005; Ahmad et al. 2011) resulting in being friendly to pollinators (Sarwar, 2020).

Among the choice ways, the utilization of plants, and insecticidal allele chemicals seems to be promising. Aromatic plants and their essential oils, are among the foremost economical botanicals. Their activities are manifold and they induce chemical and topical toxicity similarly as antifeedant or repellent effects. They are harmful to adults, however, conjointly inhibit replica. Although mechanisms depend upon phytochemical patterns and do not seem to be acknowledge, this widespread variety of activities is a lot and more being thought of for each industrial and household uses, whereas in essential oils are presently thought to be a brand-new category of ecological merchandise for controlling of insect pests (Sallam et al., 2009; Sarwar and Salman, 2015a).

Green pesticides, also called ecological pesticides, are pesticides derived from organic sources, which are considered environmentally friendly. Of the present concept of green pesticides, some rational attempts have been made to include substances such as plant extracts, hormones, pheromones, and toxins from the organic origin and also to encompass many aspects of pest control (Sarwar, 2015a; 2016a). More than 2500 plant species belonging to 235 families have been found to possess the characteristic properties required for an ideal botanical insecticide. Natural crop protectants or products are used as powder formulations or liquid or oil formulations (Karunamoorthi, 2012).

2. Botanicals Used to Control Different Insect Pests

The results of pesticidal and phytochemical screenings of a number of higher plants based on traditional knowledge have strongly indicated that plants are endowed with pesticidal properties that can be harnessed cheaply for use in agriculture and related fields (Sarwar, 2015b).

A field experiment has been conducted to test a synthetic insecticide and insecticidal properties of four selected plant origin materials against Helicoverpa species on chickpea crop. After treatment, counts for larval mortality and percentage of pods infestation showed that over all least pods infestation percentage and higher seed yield in treated crops have been significantly different than the untreated plants. However, as it is evident from the data the synthetic product gave the best results than all the sets of natural products for the parameters studied (Rajput et al., 2003).

Studies on the effect of pyrethroid (ripcord 0.5%) and different concentrations of neem (Azadirachta indica) seed extract on parasitoid Trichogramma chilonis (Ishii) (Hymenoptera: Trichogrammatidae) are conducted. Among different concentrations of neem seed extract (4,2,1,0.5 and 0.25%), the highest mortality (68.29%) of Trichogramma has been recorded with 4% neem seed extract and the lowest (35.83%) with 0.25% neem seed extract. Overall, the highest mortality (97.52%) of Trichogramma has been recorded with ripcard. It can be concluded that neem seed extract of less than 4 % concentration can be included in IPM to protect T. chilonis as biological control agent (Khan, 2011).

It has been contemplated to evaluate the efficiency of the botanical pesticide A. indica and its comparison with synthetic chemicals against gram pod borer Helicoverpa armigera (Hubner) (Fig. 1) on chickpea crop. Interestingly, the beneficial effects of all tested insecticides have been noted on plant stand. Results from the present investigations displayed that although both the botanical and synthetic insecticides contributed in reducing the pest population, yet the synthetic chemicals are still the first line of defense against the ravages of insects and can be used freely when any insect outbreak occurs (Sarwar, 2012).

Of particular economic significance among the plants is Rhododendron mole G. Don. The finely ground powder when applied as spray in suspension or as dust has been highly active against aphids, pentatomids and leaf-beetles as well as against caterpillars (Okwute, 2012).

The study has been reported the insecticidal property of botanicals and their potential as organic pest control agents for field management of aphid *Myzus persicae* (Sulzer) (Homoptera Aphididae) on canola Brassica napus L. (Brassicaceae). The effectiveness of four botanical pest control agents such as, tobacco (Nicotiana tabacum L.), garlic (*Allium sativum* L.), goosefoot (*Chenopodium album* L.), and *Aloe vera* L., has been assessed through foliar applications on canola (B. napus) crop. The A. vera (Aloeaceae) and to a greater extent *N. tabacum* at 10 % concentration have been the most effective botanicals and rated parallel for effectiveness in the treated crop, and resulted in the least aphid's damage and enhanced yield across all the seasons followed by *C. album* and *A. sativum* relative to the untreated control (Sarwar, 2013b).

Fig. 1. Gram pod borer

The genus Piper (family Piperaceae) is probably one of the most studied botanicals. With over 1000 species, about 112 genera have been screened for pesticidal activity and over 611 active compounds isolated and identified from various parts of the species. Perhaps, of great significance are extractives from Piper guineense, Piper longum and Piper retrofractum, which are known to be active against the garden insects. In these experiments, piperine has shown to be a synergist rather than an insecticide in crude extracts (Okwute, 1992).

The research has assessed the potential trade-offs of using pesticidal plant extracts on legume crop yields and the regulating ecosystem services of natural pests enemies. The application of six established pesticidal plants (*Bidens pilosa*, *Lantana camara*, *Lippiaja vanica*, *Tephrosia vogelii*, *Tithonia diversifolia* and *Vernonia amygdalina*) have been compared to positive and negative controls for their impact on yields of bean

(Phaseolus vulgaris), cowpea (*Vigna unguiculata*) and pigeon pea (*Cajanus cajan*) crops, and the abundance of key indicator pest and predatory arthropod species. Analysis of field trials showed that pesticidal plant treatments often resulted in crop yields that have been comparable to the use of a synthetic pesticide (lambda-cyhalothrin). The best-performing plant species have been *T. vogelii*, *T. diversifolia*, and *L. javanica*. The abundance of pests has been very low when using the synthetic pesticide, whilst the plant extracts generally have a higher number of pests than the synthetic but lower numbers than observed on the negative controls. Beneficial arthropod numbers have been low with synthetically treated crops, whereas the pesticidal plant treatments appeared to have little effect on beneficials when compared to the negative controls (Tembo et al. 2018). The outcomes of this research suggest that using extracts of pesticidal plants to control pests can be as effective as synthetic insecticides in terms of crop yields while tri-trophic effects have reduced, conserving the non-target arthropods that provide important ecosystem services such as pollination and pest regulation.

An outline of different botanical pesticides and their effects on various insect pests has appeared in Table 1.

Table 1. Native botanical sprays used to control insect pests in crops

Botanical	Target pests
Neem (*Azadirachta indica*) leaf extract	Defoliators and sucking pests
Garlic (*Allium sativum*) extract	*Spodoptera litura* (leaf-eating caterpillar), *Helicoverpa armigera* (fruit borer), and other lepidopteran pests
Garlic-Chilli (*Capsicum annum*) extract	*Helicoverpa armigera* (fruit borer), *Spodoptera litura* (leaf-eating caterpillar), *Leucinodes arbonalis* (Brinjal fruit & shoot borer), *Amsacta albistriga* (red-headed hairy caterpillar)
Datura (*Datura stramonium*) plant extract	Tea mosquito bugs, thrips, jassids, aphids
Calotropis (*Calotropis gigantean*) leaf extract	Termites
Lantana (*Lantana camera*) leaf powder	Aphids
Lantana leaf extract	Beetles, leaf miners, defoliators
Mixed leaves extract	Defoliators like *Spodoptera litura*, semi loopers
Eucalyptus (*Eucalyptus globules*) leaf extract	Jassids, aphids, scales
Adathoda (*Adathoda vesica*) leaf extract	Defoliators and sucking pests
Multiple plants leaf extract	Major pests and diseases
Nicotine (Nicotiana tabacum)	Aphids, thrips, caterpillars, mites, bugs, fungus gnat, leafhoppers
Rotenone (Lonchocarpus spp., Derris eliptica)	Bugs, aphids, potato beetles, spider mites, carpenter ants, bean leaf beetle, cucumber beetles, leafhopper, red spider mite
Ryania (Ryania speciosa)	Codling moths, potato aphids, onion thrips, corn earworms, silkworms, caterpillars, thrips, beetles, bugs, aphids
Sabadilla (*Shoenocaulon officinale*)	Grasshoppers, codling moths, armyworms, aphids, cabbage loopers, squash bugs, bugs, blister beetlesflies, caterpillars,potato leafhopper
Pyrethrum (*Chrysanthemum cinerariaefolium*)	Crawling and flying insects such as cockroaches, ants, mosquitoes, termites, caterpillars, aphids, leafhoppers, spider mites, bugs, cabbage worms, beetles
Essential oils	Caterpillars, cabbage worms, aphids, white flies, land snails
Neem products	Armyworms, cutworms, stemborers, bollworms, leaf miners, caterpillars, aphids, whiteflies, leafhoppers, psyllids, scales, mites and thrips
Citrus trees (d-Limonene, Linalool)	Fleas, aphids, mites, paper wasps, house crickets, dips for pets
Baobab chacal (*Adenium obesum*)	Cotton pests, particularly the larvae of bollworms Heliothis sp.)
Synthetic pyrethroids	Caterpillars, aphids, thrips

3. Botanicals and their parts used

Plant parts selected for botanicals show variations in their activities as shown in the study of Kabir and Muhammad (2010). When cowpea seeds are treated with powders of different parts of A. indica (leaf and stem bark powders) and the seed oil, the order of activity against *Callosobruchus maculatusis* found to be seed oil > leaf powder > stem bark powder. The study also proved that the insecticidal compound azadirachtin is found in fruits, bark, and leaves of the tree, but seeds have the highest concentration. Sometimes, the dust is made from the seeds and the active components are lacking in the other plant parts (roots, bulbs, stems, and leaves). It is interesting that the toxic constituents actually become more powerful after storage, for instance, in the case of sabadilla, also known as cevadilla, derived from the seeds of the sabadilla lily (Schoenocaulon officinale). The various plant parts like leaf, bark, seed powder, clove, fruit, flower, rhizome or oil extracts are used as an admixture to control insect pests as given in Table 2. The variations in the chemical composition of botanicals due to season, location or plant part also affects their pesticidal activity (Burt, 2004). Hence, it is strongly recommended to standardize the plant products before their application and commercialization.

Table 2. List of plants and their parts used for evaluation of pesticide activities

Common name	Scientific name	Family	Part use
Fingerroot	*Boesenbergia pandurate* Schltr.	Zingiberaceae	Rhizome
Belamcanda chinensis	*Kaempferia parviflora* Wall.	Zingiberaceae	Rhizome
Peacock ginger, resurrection lily	*Kaempferia pulchra* (Ridl.) Ridl	Zingiberaceae	Rhizome
Smith. Wild ginger, Martinique ginger	*Zingiberzer umbet* (L.)	Zingiberaceae	Rhizome
Ginger	*Zingiber officinale* Roscoe.	Zingiberaceae	Rhizome
Phlai, cassumunar	*Zingiber montanum* (Koenig) Link	Zingiberaceae	Rhizome
Kha, galingale, galangal	*Alpinia galangal* (L.) Swartz.	Zingiberaceae	Rhizome
Turmeric	*Curcuma longa* L.	Zingiberaceae	Rhizome
Curcuma	*Curcuma xanthorrhiza* Roxb.	Zingiberaceae	Rhizome
Lemongrass	*Cymbopogon citratus* Stapf.	Gramineae	Leaf
Leech lime	*Citrus hystrix* DC.	Rutaceae	Leaf
Ho-ra-pa, sweet-basil, basil	*Ocimum basilicum* Linn.	Labiatae	Leaf
Hairy basil	*Ocimum canum* Linn.	Labiatae	Leaf
Holy basil, sacred basil	*Ocimum sanctum* Linn.	Malvaceae	Leaf
Horseradish tree	*Moringa oleifera* Lam.	Moringaceae	Leaf
Sugar apple	*Annona squamosal* Linn.	Annonaceae	Leaf
Guava	*Psidium guajava* Linn.	Myrtaceae	Leaf
Red river gum, Murray red gum	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	Leaf
Jackfruit tree	*Artocarpus heterophyllus* Lam.	Moraceae	Leaf
Cha-plu	*Piper sarmentosum* Roxb.	Piperaceae	Leaf
Orange jessamine, satin-wood	*Murraya paniculata* (L.) Jack.	Rutaceae	Leaf
Kitchen mint, marsh mint	*Melissa officinalis* L.	Lamiaceae	Leaf
Kassod tree, siamesesenna	*Cassia siamea* (Lam.)	Fabaceae	Leaf
Neem	*Azadirachta indica* A. Juss.	Meliaceae	Leaf, fruit
Garlic	*Allium sativum* L.	Lilliacea	Clove
Chilli	*Capsicum annum* L.	Solanaceae	Fruit
Datura	*Datura stramonium* L.	Solanaceae	Leaf, fruit
Calotropis	*Calotropis gigantea* (L.) R. Br. Ex	Apocynaceae	Leaf, flower
Lantana	*Lantana camera* L.	Verbenaceae	Leaf, flower
Eucalyptus	*Eucalyptus globulus* Lab.	Myrtaceae	Leaf
Nerium	*Nerium oleander* L.	Apocynaceae	Leaf
Althea	*Althaea officinalis* L.	Malvaceae	Leaf, root
Visnaga	*Ammi visnaga* L.	Apiaceae	Fruit
Peppermint	*Mentha pipermita* L.	Labiatae	Leaf, flower
Spearmint	*Mentha spicata* L.	Lamiaceae	Leaf, flower
Acacia	*Acacia arabica* Lam.	Fabaceae	Flower, fruit
Capsicum	*Capsicum frutescens* L.	Solanaceae	Fruit
Castor bean	*Ricinus communis* L.	Euphorbiaceae	Fruit
Thymue	*Thymus vulgaris* L.	Lamiacae	Leaf
Marjoram	*Majora nahortenis* L.	Lamiacae	Leaf
Chamomile	*Matricaria chamomile* L.	Asteraceae	Flower
Pelargonium	*Pelargonium graveolens* Her.	Geraniaceae	Herbs
Pomegranate	*Punica grataum* L.	Punicaceae	Pomegranate peel

4. Resources of Botanical Pesticides and Their Mode of Action

At present, there are four major types of botanical products used for insect control (pyrethrum, rotenone, neem, and essential oils), along with three others in limited use (ryania, nicotine, and sabadilla). Additional plant extracts (garlic oil, Capsicum oleoresin) are seen in limited (low volume) regional use in various countries (Sarwar and Sarwar, 2022).

The botanical pesticides could be divided into two generations: the 1st generation includes nicotine, rotenone, sabadilla, ryania, pyrethrum, and plant essential oils; while the 2nd generation comprises synthetic pyrethroids and azadirachtin, as well as potential new botanicals as stated by Regnault-Roger et al. (2005) in the book: Biopesticides of plant origin.

4.1. The first-Generation Botanical Pesticides

The first-generation pesticides are organic compounds known as botanicals primarily used during the prior times.

4.1.1. Pyrethrum

Pyrethrum is the powdered, dried flower head of the pyrethrum daisy, Chrysanthemum cinerariaefolium (Asteraceae). The flowers are ground to a powder and then extracted with hexane or a similar nonpolar solvent; and removal of the solvent yields an orange-colored liquid that contains the active principles (Glynne-Jones, 2001). These are three esters of chrysanthemic acid and three esters of pyrethric acid. Among the six esters, those incorporating the alcohol pyrethrolone, namely pyrethrins I, and II, are the most abundant and account for most of the pesticidal activity. The modern synthetic pyrethroids bear a little structural resemblance to the natural pyrethrins and their molecular mechanism of action differs as well.

The insecticidal action of the pyrethrins is characterized by a rapid knockdown effect, particularly in flying insects, and hyperactivity and convulsions in most insects. These symptoms are a result of the neurotoxic action of the pyrethrins, which block voltage-gated sodium channels in nerve axons. Pyrethrins exert their toxic effects by disrupting the sodium and potassium ion exchange process in insect nerve fibers and interrupting the normal transmission of nerve impulses. Pyrethrins insecticides are extremely fast acting and cause an immediate "knockdown" paralysis in insects. Despite of their rapid toxic action, however, many insects are able to metabolize (break down) pyrethrins quickly. After a brief period of paralysis, these insects may recover rather than die. To prevent insects from metabolizing pyrethrins and recovering from poisoning, most products containing pyrethrins also contain the synergist, piperonylbutoxide (Rattan, 2010).

4.1. 2. Nicotine

An alkaloid nicotine obtained from the foliage of tobacco plants (Nicotiana tabacum) and related species, has a long history as an insecticide. Nicotine and two closely related alkaloids, nornicotine and anabasine, are synaptic poisons that mimic the neurotransmitter acetylcholine. As such, they cause symptoms of poisoning similar to those seen with organophosphate and carbamate insecticides (Regnault-Roger and Philogène, 2008). In both insects and mammals, nicotine is an extremely fast-acting nerve toxin. It competes with acetylcholine, the major neurotransmitter, by bonding to acetylcholine receptors at nerve synapses and causing uncontrolled nerve firing. This disruption of normal nerve impulse activity results in rapid failure of those body systems that depend on nervous input for proper functioning. In insects, the action of nicotine is fairly selective and only certain types of insects are affected.

4.1.3. Rotenone

Rotenone is one of several is flavonoids produced in the roots or rhizomes of tropical legumes, Derris, Lonchocarpus and Tephrosia. Most rotenone used at present comes from Lonchocarpus and is often called cube root. Extraction of the root with organic solvents yields resins containing as much as 45 % totalrotenoids. Studies indicate that the major constituents are rotenone (44 %) and deguelin (22 %) (Cabizza et al. 2004). Rotenone is a mitochondrial poison, which blocks the electron transport chain and prevents energy production (Hollingworth et al. 1994). As a pesticide, it is considered a stomach poison because it must be ingested to be effective. 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. Death occurs several hours to a few days after exposure.

4.1.4. Sabadilla

Sabadilla is a botanical pesticide obtained from the seeds of the South American lily *Schoenocaulon officinale*. In purity, the active principles, cevadine-type alkaloids, which are remarkably similar to that of the pyrethrins, despite their lack of structural similarity (Isman, 2006). In insects, sabadilla's toxic alkaloids affect nerve cell membrane action, causing loss of nerve cell membrane action, producing loss of nerve function, paralysis, and death. Sabadilla kills insects of some species immediately, while others may survive in a state of paralysis for several days before dying (Sarwar, 2021).

4.1.5. Ryania

Ryania is obtained by grinding the wood of the Caribbean shrub Ryania speciosa (Flacourtiaceae). The powdered wood contains < 1 % ryanodine, an alkaloid that interferes with calcium release in muscle tissue. It is used to a limited extent by organic apple growers for control of the codling moth Cydia pomonella (Fig. 2). Ryania is a slow-acting stomach poison. Although it does not produce rapid knockdown paralysis,it does cause insects to stop feeding soon after ingesting it (Weinzierl, 2000).

Fig. 2. Codling moth

4.1.6. Plant Essential Oils

Steam distillation of aromatic plants yields essential oils, which are since long been used as fragrances and flavorings in the perfume and food industries, respectively, and more recently for aromatherapy and as herbal medicines (Abd El-Aziz and El-Hawary, 1997; Buckle, 2003). Plant essential oils are produced commercially from several botanical sources, many of which are members of the mint family (Lamiaceae). The oils are generally composed of complex mixtures of monoterpenes, biogenetically related phenols, and sesquiterpenes. Examples include 1,8-cineole, the major constituent of oils from rosemary (Rosmari nusofficinale) and eucalyptus (Eucalyptus globus); eugenol from clove oil (Syzygiuma romaticum); thymol from garden thyme (Thymus vulgaris); and menthol from various species of mint (Mentha species) (Isman, 2008). Interest in the oils has been renewed with an emerging demonstration of their fumigant and contact insecticidal activities to a wide range of pests (Abdallah et al., 2004). The rapid action against some pests is indicative of a neurotoxic mode of action, and there is evidence interference with the neuromodulator octopamine by some oils and with GABA-gated chloride channels by others (El-Hosary, 2011).

As broad-spectrum pesticides, both pollinators and natural enemies are vulnerable to poisoning by products based on essential oils. On the other hand, plant oils have harmless effects on predacious mites (Sarwar, 2017). Contact and fumigant insecticidal actions of plant essential oils have been well demonstrated against stored product pests (*Acanthoscelides obtectus*). Knockdown activity and lethal toxicity via contact has been demonstrated in the American cockroach (*Periplaneta americana*), the German cockroach (*Blattella germanica*), and the housefly (Musca domestica) (Rice and Coats, 1994).

Certain essential oil monoterpenes are competitive inhibitors of acetylcholinesterase. The modes of action of limonene and linalool in insects are not fully understood. Limonene is thought to cause an increase in the spontaneous activity of sensory nerves. The central nervous system may also be affected, resulting in additional stimulation of motor nerves. Massive over stimulation of motor nerves leads to rapid knockdown paralysis. Constituents of essential oil like citronellal, thymol, and α-terpineol are most effective as feeding deterrents against tobacco cutworm (Fig. 3) *Spodoptera litura* synergism, or additive effects of the combination of monoterpenoids from essential oils are reported against *S. litura* larvae (Hummelbrunner and Isman, 2001).

Fig. 3. Tobacco cutworm

4.2. The Second-Generation Botanical Pesticides

The second-generation pesticides are largely included synthetic organic compounds against pests.

4.2.1. Synthetic Pyrethroids

The evolution of this class of compounds has since yielded a vast array of molecules, some with greater lipophilicity, extremely low water solubility, and considerable persistence because of the use of single or multiple halogen atoms. Synthetic pyrethroids are generally recognized as neurotoxicants that act directly on excitable membranes. These compounds induce intense repetitive activity in sense organs and in myelinated nerve fibers. In the lateral-line sense organ, this repetitive activity increases with cooling, a phenomenon that may be related to the negative temperature coefficient of toxicity of pyrethroids in insects (Sarwar and Salman, 2015b).

Pyrethroids are also known to cause prolongation of the sodium current together with repetitive activity in nerve fibers of invertebrates (Henk et al. 1982). It has been suggested that the sodium channel in the nerve membrane is the major target site of pyrethroids. Other results showed that these compounds modify sodium channel gating in a strikingly similar way and reduce selective rate of closing of the activation gate.

4.2.2. Neem Products (Azadirachtin)

Two types of botanical pesticides can be obtained from seeds of the neem tree (*Azadirachta indica*) (Meliaceae) (Fig. 4). Neem oil, obtained by cold-pressing seeds, can be effective against soft-bodied insects and mites (Sarwar, 2019b), but is also useful in the management of phytopathogens. Apart from the physical effects of neem oil on pests and fungi, disulfides in the oil likely contribute to the bioactivity of this material (Dimetry, 2012).

More highly valued than neem oil are medium polarity extracts of the seed residue after removal of the oil, as these extracts contain the complex triterpene azadirachtin. Neem seeds actually contain more than a dozen azadirachtin analogs, but the major form is azadirachtin and the remaining minor analogs likely contribute little to the overall efficacy of the extract. Seed extracts include considerable quantities of other triterpenoids, notably salannin, nimbin, and derivatives thereof. The role of these other natural substances has been controversial, but most evidence points to azadirachtin as the most important active principle (Isman, 2002). Neem seeds typically contain 0.2–0.6 % azadirachtin by weight, so solvent partitions or other chemical processes are required to concentrate this active ingredient to level 10–50 % seen in the technical grade material used to produce their products (Sallena, 1989).

Azadirachtin has two profound effects on insects. At the physiological level, azadirachtin blocks the synthesis and release of molting hormones (ecdysteroids) from the prothoracic gland, leading to incomplete ecdysis in immature insects. In adult female insects, a similar mechanism of action leads to sterility. In addition, azadirachtin is a potent antifeedant to many insects.

Fig. 4. *Azadirachta indica*

4.2.3.Melia Extracts

The remarkable bioactivity of azadirachtin from the neem tree (A. indica) led to the search for natural pesticides in the most closely related genus, Melia. Seeds from the chinaberry tree Melia azedarach (Fig. 5), contain a number of triterpenoids, the meliacarpins that are similar but not identical to the azadirachtins, and these also have insect growth regulating bioactivities (Kraus, 2002).

The M. azedarach growing in Argentina lacks meliatoxins, but produces triterpenoids (most notably meliartenin) that are strong feeding deterrents to insect pests and could prove useful for pest management (Carpinella et al., 2003). The Melia toosendan (Fig. 6), is a tree considered by most taxonomists to be synonymous with M. azedarach. An extract of its bark contains a number of triterpenoids based on toosendanin, a substance reported to be a stomach poison for chewing insects. Later studies suggest that this substance acts primarily as a feeding deterrent, but can also serve as a synergist for conventional insecticides (Feng. et al., 1995).

When M. toosendan came under scientific scrutiny, an investigation of the east African Melia volkensii (Fig. 7) demonstrated bioactivity in insects from seed extracts of this species. The active principles in *M. volkensii* include the triterpenoids alannin, also a major constituent of neem seed extracts, and some novel triterpenoids such as volkensin. Collectively these function as feeding deterrents and stomach poisons with moderate efficacy against chewing insects (Rembold and Mwangi, 2002). Neem products are complex mixtures of biologically active materials, and 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, and sterilant, or toxin. As a growth regulator, neem is thought to disrupt normal development interfering with chitin synthesis (Salama and Sharaby, 1988).

Fig. 5. Melia azedarach

Fig. 6. Meliat oosendan

Fig. 7. Melia volkensii

4.3. Potential new Botanicals

There are unlimited numbers of botanicals have potential for future commercialization as a biorational alternative to control the potential threat of insects in crops.

4.3.1. Annonaceous acetogenins

The acetogenin class of polyethers is found exclusively in the Annonaceae family of plants. Annonaceous acetogenins are an important group of long-chain fatty acid derivatives found exclusively in the plant family Annonaceae. Tetrahydrofuranoid acetogenins have been found to have potent pesticidal and feeding deterrent activities against a diverse variety of pests such as mosquito larvae, spider mites, aphids, Mexican bean beetle, striped cucumber beetle, blowfly larvae and nematodes. A new acetogenin called 'asimicin' has been isolated and is typical of the subject class of useful compounds: A quantitative liquid chromatography/tandem mass spectrometry method is established for the quality control of the annonaceous acetogenins in the extracts of the pawpaw tree Asimina btriloba (L.) Dunal (Annonaceae) (Fig. 8) (Gu et al. 1999). Novel member named asimicin Included within this class of compounds has been isolated from the bark and seeds of the pawpaw tree *A. triloba*.

Fig. 8. Asimina triloba

Botanical pesticides have been traditionally prepared from the seeds of tropical Annona species, members of the custard apple family (Annonaceae). These include the sweetsop (Annona squamosa) (Fig. 9) and soursop (*Annona muricata*) (Fig. 10), which are important sources of fruit juices. Detailed investigations in have led to the isolation of a number of long-chain fatty acid derivatives, termed acetogenins, responsible for insecticidal bioactivity. The major acetogenin obtained from seeds of *A. squamosa* is annonin I, or squamocin (Johnson et al. 2000). A simicint reduces the rate of oxygen consumption by fourth instar *Ostrinia nubilalisas* measured with a constant volume manometer.

Fig. 9. Annona squamosa

These compounds are slow-acting stomach poisons, particularly effective against chewing insects such as lepidopterans and the Colorado potato beetle

(Leptinotarsa decemlineata) (Fig. 11) (Johnson et al., 2000).

Fig. 10. Annona muricata

Fig. 11. Colorado

4.3.2. Polyesters of sugars

There are polyesters of sugars which include sucrose and sorbitol octanoates. The sugar or sucrose esters naturally occurring in the foliage of wild tobacco (*Nicotiana gossei*) (Fig. 12) are pesticidal to certain soft-bodied insects such as whitefly and mites (Buta et al. 1993). The glandular trichomes of wild tobacco contain complexes of either glucose or sucrose esters (sometimes both). These leaf surface lipids have biological activity against insects and microorganisms. This product is a contact pesticide that kills small insects and mites through suffocation (by blocking the spiracles) or disruption of cuticular waxes and membranes in the integument leading to desiccation.

There are other polyesters of sugars and including sorbitol octanoates. They are also isolated from the poisonous hairs on the tobacco leaves which hitherto are assumed to contain nicotine, a popular insecticide. When insects are contaminated by rubbing, they cause death of the insects by a dehydration process and rapidly degrade to harmless sugars and fatty acids. These polyesters are known to be effective against a variety of farm and domestic insect pests and the deadly parasitic Varroa mite, which usually settles on the back of honey bees (Sarwar, 2016b).

Fig. 12. Nicotiana gossei

5. Botanicals Mode of Actions

Knowing about the mode of action is integral to improving the quality and sustainability of a product. For understanding how pesticides work (their mode of action), it is necessary to understand how the pests targeted systems normally function. Another reason to understand the modes of action of pesticides is to prevent the development of pesticide resistance in the target pests. Using pesticides with the same mode of action contributes to this problem by killing the susceptible pests and leaving only those with resistance to the entire class of pesticides that work through similar mechanisms (Sarwar and Salman, 2015c; Sarwar, 2016c). Botanical pesticides can be grouped according to their mode of action or the way a pesticide destroys or controls the target pest. This is also referred to as the primary site of action. For example, one insecticide may affect insect nerves, while another may affect molting (El-Wakeil, 2013). There are many modes of actions for various botanical pesticides as shown in Table 3.

6. Biotechnology for Natural Product Synthesis

Currently, there has been a growing interest in research concerning the possible use of botanicals as alternatives to synthetic insecticides. Many higher plants produce economically important organic compounds such as oils, resins, tannins, natural rubber, gums, waxes, dyes, flavors and fragrances, pharmaceuticals, and pesticides. The generation of mutants is a tool available for increasing of natural product diversity. Furthermore, global society is demanding natural products and rejecting synthetic chemicals for all possible uses including crop protection. Although the search continues with increasing intensity, finding new and more useful products would not have matched the effort without the support of biotechnology. Although the most powerful approach is genetic manipulation, other techniques such as mutagenesis, breeding and protoplast fusion, and the relatively old biotechnology of plant tissue culture are very useful. These also include even more simple approaches such as optimizing culture conditions and the design of fermenters. The combination of technologies together with innovative ideas has already increased the production level of already existing natural products and expanded the diversity of products obtainable from biological sources (Hettiarachi, 2011; Roohi et al. 2019; Noreen et al. 2021). Therefore, there is a need for more intensive research on optimizing the production of already identified bioproducts, with simultaneous research efforts on new product formation.

Table 3. Mechanism of action by plant-origin pesticides

Insect system	Mechanism of action	Compound	Plant source
Cholinergic system	Inhibition of acetylecholinestrase (AChE)	Essential oils	*Azadirachtin indica*, *Mentha* spp., *Lavendula* spp.
	Cholinergic acetylcholine nicotinic receptor agonist/ antagonist	Nicotine	*Nicotiana* spp., *Haloxylonsa licornicum*, *Stemona japonicum*
Gamma-aminobutyric acid (GABA) system	GABA-gated chloride channel	*Thymolsil phinenes*	*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	*Azadirachtin indica*

Obviously, these results have equally established that plants belonging to certain families of vegetation are more likely to possess pesticidal activity. Thus, these upshots will serve as useful guides in the collection of plants for laboratory research studies and field trials.

CONCLUSION

The insecticides of plant origin could be exploited for the development of novel molecules with highly precise targets for sustainable insect pest management. Different types of plant preparations such as powders, solvent extracts, essential oils, and whole plants have been reported for their insecticidal activity against insect pests including their actions as fumigants, repellents, anti-fee dents, and insect growth regulators. Finally, it came to know through this chapter the identification of the botanicals, their corresponding plant, their parts used, and targeted pest. From the assignment, we can easily say that many field crops can be controlled from the potential threat of insects through the use of botanicals, and the use of botanicals is important and effective indeed.

Some newer plant-derived products and their application technologies deserve proper attention for use in the control of infestations of food commodities infested by different species of insect pests. Botanical pesticides (essential oils, flavonoids, alkaloids, glycosides, esters, and fatty acids) have various chemical properties and modes of action and affect insects in different ways namely; repellents, feeding deterrents, antifeedants, toxicants, growth retardants, chemosterilants, and attractants.

The conclusion can also be drawn that the botanical mixtures could form the basis for a successful formulation and commercialization of bio-pesticides in developing countries, where low agriculture inputs are in vogue. In several countries, such plants are readily available in the local markets all around for farmer's use to protect their crops. Since the materials are used in ethnobotany for the treatment of various ailments, they are safe, cheap, easily biodegradable, and technologically and environmentally friendly. They could provide valuable alternatives to synthetic insecticides in the management of insect pests of field crops in limited resource farmer's farms. Further studies are required to ascertain their optimum mixture levels and spraying schedules for optimum crop yield.

Although the search continues with increasing intensity, finding new and more useful products would not be possible without the support of biotechnology.

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