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THE STUDY OF PLANT PRODUCTS AS BOTANICAL PESTICIDES FOR PEST MANAGEMENT TO REDUCE POST HARVEST LOSSES: A REVIEW

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Abstract: Botanical pesticides are regarded as alternatives to replace synthetic chemical insecticides in the field of pest management in recent times, but their use has not been properly adopted by farmers due to improper dissemination of information to them on their positive impacts as a better grain protectants compared to chemicals that have hazardous effect on the consumers . On the other hand, a major constraint to farmers in agricultural practices is post-harvest losses, despite various food storage mechanisms designed for farmers to preserve their agricultural produce. Most food crops meant for long-term storage requires a preservative to ensure their safety, maintenance of their natural taste, including the quality (nutritional composition), and quantity. Researchers have discovered that farmers prefer the use of synthetic chemicals to botanical pesticides due to rapid active time which can be highly poisonous than the use of botanical pesticides which can be safe and healthy for consumers when used as a food preservative. This paper covers several works that have been carried out on the use of non-toxic natural food preservatives; their biological origins, biodegradability, mechanism of action; mode of application and target pests etc. has been reviewed.

Keywords: Botanical pesticides, Natural, Pests management, Post-harvest

Introduction

The main engine of broad-based economic growth in developing nations is agriculture. One of the biggest issues with agricultural practices today is the requirement for ever-increasing productivity in order to feed a population that is constantly growing and also to generate more funds from exportation to other countries. The losses of stored food products caused by pests seem to create barriers to attaining this. The preservation of food's quality and quantity after harvest is one of the biggest obstacles to having enough to eat every day. Food grains and other farm produce are badly harmed during storage by insect pests and microbial infestations. Also, approximately one-third of the global annual yield of agricultural produce is lost to pests every year, despite the adoption of every plant protection tool available (Lengai and Muthomi.,2018). One of the biggest issues with agriculture today is the deterioration of stored food commodities, which is mostly brought on by three agents of food destruction, namely fungi, insects, and rodents under various storage circumstances (Isman, 2006). In general, estimates of yield losses by insects and microbial infestations range from 5 to 10% in temperate regions and 50 to100% in tropical regions (Van Emden *et al.*, 1988).

Recently, there has been an increased focus on the use of botanical pesticides as innovative chemotherapy for plant protection in many parts of the world. This is because they have the potential to be useful in pest management due to their non-phytotoxicity, systemicity, simple biodegradability, and stimulatory nature on the host metabolism (Mishra and Dubey, 1994). Likewise, their use has gained popularity over the past few decades, especially those of natural origin and low mammalian toxicity (Subramanyam and Roesli, 2000). Many tropical medicinal herbs and spices have been employed as pesticides (Lale, 1992). Ash from charcoal is one of many plant materials that small-scale farmers and researchers claim to have been used successfully to control insect pests (Ajayi *et al.*, 1998).

Many researches have shown that botanical essential oils possess antifungal and antibacterial properties (Suhr and Nielson, 2003). Naturally occurring herbs from plants materials also has been documented to possess insect pest control properties in different parts of the world, including India, Australia, Argentina and Finland (Ahmad and Beg, 2001). These plant materials are known to have secondary metabolites that act on their host's metabolism, e.g. phenols, flavonoids, quinones, tannins, essential oils, alkaloids, saponins, and sterols. These compounds can be used for a variety of biological purposes and leave no hazardous leftovers or byproducts because they come from a natural source.

Botanical Pesticides

Before the invention of synthetic pesticides, botanical pesticides were widely used in both subsistence and commercial farming for thousands of years. Botanical pesticide components are naturally occurring chemical derivatives of plants that function as deterrents, attractants, antifeedants, and growth inhibitors (Mahmood *et al.*, 2006).

Botanical pesticides are created when these substances are extracted using the right solvents and/or combined with the required pesticide adjuvants. The use of botanical pesticides slowly decreased until recently when there was widespread use of synthetic pesticides; this occurrence is currently posing an immediate threat to environmental safety and human health due to the potency and effectiveness of synthetic pesticides being used against destructive crop diseases (Nikkhah *et al.*, 2017). Due to its safety record for crop consumption, botanical pesticides are becoming more popular in organic farming, and customers are prepared to pay more for organic products (Misra, 2014). The majority of botanical pesticides are used to manage insect pests, while few of the botanicals are being used to protect storage farm produce against plant parasites such nematodes, fungus, bacteria, and viruses (Waziri 2015). Botanical pesticides are preferred as alternatives to conventional instruments for integrated pest control since they have favorable effects on the environmental during crops preservation, minimal toxicity to mammals, and low danger of building resistance in target pests. (Liu *et al.*, 2017).

This review thus discusses vital information regarding the sources of botanical pesticides, their activity, mechanism of action and challenges of botanical pesticides and their utilization for sustainable crop management.

Sources of Botanical Pesticides

Botanical pesticides from plant sources are derived from barks/stems of different trees leaves, roots, flowers, fruits, seeds, cloves, and rhizomes. The intended bioactive chemicals and their concentration within the chosen plant portion usually determine which section of the plant is employed. There are a number of plant components that have been thought of for use as insect antifeedants or repellents. However, the success of botanicals appears to be constrained by a number of factors, such as availability of rival products (newer synthetics, fermentation products, and microbial disinfectants) that are more affordable and relatively safe than their forerunners, and notably regulatory obstacles. Botanical pesticides are most suited for use in the production of organic foods in developed countries, but they can be far more effective in the production and post-harvest preservation of food in developing nations (Isman, 2006). The plant parts are dried and ground into fine powder and extracted with organic solvents to obtain the targeted active ingredients. The extracts are then concentrated, formulated and evaluated for efficacy under laboratory, controlled or field conditions (Chougule and Andoji, 2016).

Types of Botanical Pesticides

Essential Oils:

Essential oils extracted from aromatic plants have increased considerably as insecticides, owing to their popularity with organic growers and environmentally conscious consumers. They have repellent, insecticidal, antifeedants, growth inhibitors, oviposition inhibitors, ovicides, and growth-reducing effects on a variety of insects, examples are terpenes, terpenoids and phenolics (Regnault-Roger *et al.*, 2012).

Alkaloids:

Alkaloids are the most important group of natural substances playing an important insecticidal role. For instance, pyridine alkaloids extracted from *Ricinus communis*, quinolone alkaloids extracted from *Ruta chalepensis* leaves, alkaloids extract of *Pergularia tomentosa*; pipernonalin; piperidine and Alkaloids from *Arachis hypogaea* extract have larvicidal and antifeeding effects (Velu *et al.*, 2015).

Flavonoids: Flavonoids could be useful in a pest-management strategy. Flavonoids play an important role in the protection of plants against plant feeding insects' and herbivores (Acheuk *et al.*, 2013). Both flavonoids and isoflavonoids protect the plant against insect pests by influencing their behavior, growth, and development (Simmonds, 2003).

Glycosides

Cyanogenic glucosides are found in plant species and considered to have an important role in plant defense against herbivores (Zagrobelny *et al.*, 2004). Cyanogenic glycoside can be extracted from different plant sources such as, *Digitalis purpurea* (cardenolide), *Calotropis procera* (iridoid glycosides), azadirachtin and neem oil from *Azadirachta indica*. They possess the ability to act against larvae and adult stages of some specific insects, thus inhibiting growth activity in some insects, antifeeding characteristics and they are effective also, against stored-product insects as fumigants (Park & Coats, 2002).

Esters and Fatty Acids

Fatty acids and methyl esters isolated from different plant sources such as *Solanum lycocarpum* , Allyl cinnamate (3-Phenyl-2-propenoic acid), ethyl (*E*,*Z*)-2,4-decadienoate (pear ester), saturated fatty acids (particularly C8, C9 and C10) and fatty acids mixture (C8910) have larvicidal activity ,some are used as repellents or antifeedants and insect repellence characteristics . (Yousef, *et al.*, 2013) Allyl cinnamate caused rapid toxic effects in *S. littoralis* larvae at low concentrations potential for use in pest control demonstrated that ethyl (*E*,*Z*)-2,4-decadienoate (pear ester) have insecticide against *Cydia pomonella* (Giner *et al.*, 2012).

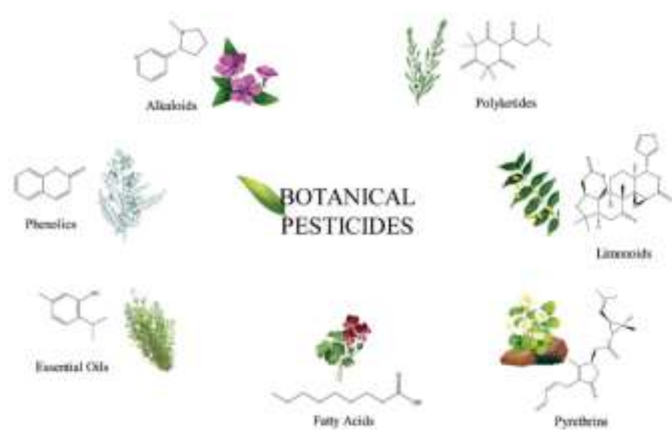

Figure 1: Different types of esters and fatty acids present in biopesticides. Source:Isman.,2006

Mechanism of Action and Applications of Botanical Pesticides

The mechanism of action of botanical pesticides can be described as the specific functional or physiological change that can affect a pest due to its exposure to a substance extracted from plant products. Therefore, different plant parts are used and their mechanism of action differs in protecting crops from infestation.

The mechanism of action of different botanical pesticides has been summarized in Table 1. The substantial sources from which botanicals are derived from, are been underutilized or neglected. New sources are being discovered of botanical pesticides to manage a variety of destructive pests and diseases, but very few have yet been isolated and analyzed to identify their bioactive ingredients. More research works are been carried out, so as to increase biopesticides agents, which is aimed at revealing their significance as nematicides, insecticides, fungicides, bactericides, and virucides (botanical bioactive substances); or as alternative pest management methods in order to create sustainable agriculture in relevant sectors.

Table 1 Mode of action of selected botanical pesticides on selected crop pests

Source Plant	Mode of action	Target pests	References
Neem (*Azadirachta indica*)	Disrupts central nervous system (CNS) by binds to acetylcholine receptors; inhibits oviposition, moulting, and egg hatching; deters/repels feeding.	Insects	Grdisa and Grsic 2013
Garlic (*Allium sativum*)	Inhibits spore germination, protein, and DNA; s deters formation of filaments and mycelium growth; disrupts cellular activity, including components	Fungi	Perrello *et al*., 2013
Aloe vera	It restrains the activities in the cell structures and also alters their functions. -Impairs permeability of plasma membrane -Denatures proteins -Inhibits ATP		
Tagetes erecta	-inhibits egg hatching, increased mortality rates of pests, structural modifications and larval toxicity.	Nematodes	Feyisa *et al*., 2015
Nepta muda subs muda	- Host plant manipulation, inhibits virus replication and multiplications, prevent virus adsorption, inhibits nucleic acid liberation	Viruses	Todorov *et al.*, 2015

Source: Kraiss, H., & Cullen, E. M. (2008)

Bactericides Some botanical pesticides inhibited cellular processes against bacteria, and increased permeability of plasma membrane could lead to leakage of cell contents and cell death (Khan *et al.,* 2009)

The botanical compositions also have multiple antibacterial properties. A study showed that acetone extracts of Aloe vera influenced growth of *Pseudomonas aeruginosa*, while its methanolic extracts inhibited *Escherichia. coli* and *Bacillus subtilis.* The phytochemicals that denature microbe proteins and disrupt their functionality were supposed to result in the antimicrobial activity of Aloe vera.

Nematicides: Lipophilic phytochemicals could easily disintegrate the cytoplasmatic membrane of nematodes by hindering protein structures that serve to enhance growth, development, and survival (Pavaraj *et al.,* 2008). Nematicides role of some botanical pesticides enable them to reduce growth in the targeted organism, suppress gall formation, they reduce motility and also cause mortality in the pest. Some plant constituents have affected the soil microbial population, which led to a reduction in eggs and survivability of the larvae of nematodes. Whereas some compounds caused second-stage larvae mortality and toxicity, reduced egg mass and galling, which suppressed nematode accumulation level (Kepenekei *et al.,* 2016). Under controlled conditions, the use of Lantana camara and Trichoderma harzianum inhibited reproduction rate, egg masses, and gall formation in root-knot nematodes in tomato crops (Feyisa *et al.*, 2015).

Fungicides

Extracts from many plant species are discovered to be efficacious against several plant pathogenic microorganisms without imposing ill side effects. They also inhibit spore germination, suppresses mycelial growth, reduce pathogenicity and reduce incidence severity in insects. In addition to inhibiting germ tube elongation and mycelial development, plant-based bioactive compounds,

Including alcohols, alkaloids, phenols, tannins, and terpenes delay sporulation, DNA, and protein synthesis (Lengai and Muthomi 2018). Moreover, they altered the structure of hypha and mycelia, inhibiting the production of toxic substances from mycotoxin-producing fungal such as Aspergillus spp. and Fusarium spp.; thus, reducing their pathogenicity (Martnez 2012).

Virucides

By preventing the spread of viruses and eliminating insect vectors, several plant chemicals have been shown to produce systemic resistance in the host plants (Waziri, 2015). Additionally, studies have shown that these plant chemicals reduce viral hemagglutination, replication, and penetration (Kohn et al., 2015).

Additionally, a reduction in virus infection on the hypocotyls as a result of the restriction of nucleic acid release caused by extract from Theileria orientalis suppressed the growth of the Mosaic Virus of Watermelon (Elbeshehy, 2015).

Insecticides

Some plant compounds such as pyrethrins plays the insecticidal action 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. As such, the mechanism of action of pyrethrins is qualitatively similar to that of DDT and many synthetic organochlorine pesticides (Casida and Quistad 1995)

Botanical Pesticides and Their Effects on Insects

Depending on the physiological traits of the insect species as well as the type of the insecticidal plant, botanical insecticides have varying effects on different insects. The components of different botanical insecticides can be divided into six groups: attractants, growth inhibitors, feeding deterrents/antifeedants, toxicants, repellents and sterility/reproduction inhibitors.

Attractants

Insect attractants are botanical substances that cause insects to travel in a direction toward their source. They affect the sensilla that are responsible for taste and smell. For a variety of Cruciferaea insects and bark beetles, iso-thiocyanates from Crucifera seeds, sugar and molasses, and terpenes from bark combined with pheromones are natural attractants. Insect attractants are botanical substances that cause insects to travel in a direction toward their source. They affect the sensilla that are responsible for taste and smell. For a variety of Cruciferaea insects and bark beetles, iso-thiocyanates from Crucifera seeds, sugar and molasses, and terpenes from bark combined with pheromones are natural attractants.

Insects are lured to insecticide-coated traps or poisonous baits and distracted from their regular mating, aggregation eating, or ovipositional behavior during sampling or monitoring of insect populations to determine the level of infestation. They don't kill the insects; thus they don't disrupt the environment. They can be employed to lead the insects in the wrong directions for oviposition, causing them to lay unfertilized eggs or starve to death. They should not be employed as the lone control measure in an integrated control program (Arora *et al.,* 2012). Adapting the appropriate management technique, such as using insecticide-coated traps or poisonous baits on lusting insects, requires surveying or monitoring insect populations to determine the amount of infestation.

GROWTH RETARDANTS AND DEVELOPMENT INHIBITORS

Botanical pesticides had detrimental impacts on insect growth and development by shortening the developmental phases and reducing the weight of the larva, pupa, and adult stages (Talukder 2006). Plant derivatives also lower the survival rates of larvae, pupae, and adults as well as their emergence (Koul *et al.,* 2008). According to studies, azadirachtin and neem seed oil both significantly increased aphid nymphal mortality, at rates of 80 and 77%, respectively, while also lengthening the time it took for those who survived to reach adulthood (Kraiss & Cullen, 2008). Many botanical pesticides are known to have a significant impact on the growth stage, developmental phase, and adult emergence (Shaalan *et al.,* 2005).

Feeding Deterents/Antifeedants

These are natural insecticides that make the treated stored crops unpleasant to look at or taste (Rajashekar *et al.,* 2012) in order to prevent or disrupt insect eating. The treated stored food crops are stayed on by the insects indefinitely, and they eventually starve to death. For instance steroids, alkaloids, and other compounds may have contributed to the death of Dinoderus porcellus which showed that oil from *M. alternifolia* and its chemical constituents had obvious antifeedant activity against Helicoverpa armigera Hubner (Loko *et al.,* 2017). An important component of neem known as azadirachtin has been proven to be an effective insecticide (Ghoneim and Hamadah 2017). By blocking oviposition and halting males' sperm production, it promotes sterility in insects and functions as an antifeedant, repulsant, and unpleasant agent. It was also discovered that 1,8-cineol, a component of galangal essential oil, has antifeedant, repellant, and toxic effects in termites (Abdullah *et al.*2017). The methanol extracts of Gliricidium sepium contained terpenoids, coumarin, and phenols that demonstrated substantial antifeedant activity (Jose and Sujatha2017). This showed that the plant's active substances reduce larval eating behavior, while others mess with hormone balance or make the food taste bad. These active ingredients may directly affect the larvae's chemosensilla, preventing eating for insects.

Toxicants

Some plant-based pesticides are poisonous and kill insects found in stored goods (Padin *et al.,* 2013). Since rotenone is a mitochondrial toxin that disrupts the electron transport chain and prevents energy production, it is regarded as a hazardous substance (Hollingworth *et al.,* 1994). Since it must be consumed to be effective as an insecticide, it is a stomach toxin (Isman, 2006). Granary weevil adults were successfully fumigated and killed by Lavandula angustifolia essential oil. Furthermore, it was found that a potent repellent action can alter granary weevil orientation away from a desirable host substrate (Germinara *et al.,* 2017). The stored grain pest Callosobruchus chinensis was shown to be toxic to fumigants (Trivedi *et al.,* 2017). In order to suppress the pulse beetle, it may be able to make natural fumigants or repellents using the essential oils of cinnamon, clove, rosemary, bergamot, and Japanese mint.

Repellents

A botanical pesticide has a repellent property that keeps insects away from treated materials by stimulating olfactory or other receptors (Isman, 2006). This protects crops while having little impact on the ecosystem.

Botanical pesticides are regarded safe in pest control since they leave little to no pesticide residue and are therefore safe for people, the environment, and ecosystems (Talukder *et al.,* 2006).

The various anti-insect mechanisms and various non-persistent volatility of the essential oil sample could be the causes of the distinct repellent effects on the two insects (Kimutai *et al.,*2017) .The type of repellent (active ingredients), formulation, mode of application, environmental factors (temperature, humidity, and wind), the attractiveness of particular people to insects, loss due to removal by perspiration and abrasion, the sensitivity of the insects to repellents, and the biting density are all factors that affect repellent effectiveness.

Sterility/Reproduction Inhibitors

Sterility can be created using the sterile insect technique (SIT) or a chemosterilant, a substance that prevents sexually reproducing organisms from ovulating (Morrison *et al.*, 2010). Chemosterilants are substances that cause temporary or permanent sterility of one or both sexes or inhibit the development of young into sexually mature adults in order to control economically destructive or disease-causing pests which are typically insects (Navarro-Llopis, *et al.,* 2011). According to studies, plant components, oils, extract, and powder mixed with grain decreased insect oviposition, egg hatchability, postembryonic development, and progeny development. (Asawalam & Adesiyan, 2001)

Some natural insecticides are used as chemosterilants. For instance, azadirachtin physiologically prevents the prothoracic gland from producing and releasing molting hormones, causing incomplete ecdysis in immature insects and sterility in adult insects (Isman, 2006).

Also, essential oils have neurotoxic effects on insects, which are characterized by hyperactivity, hyperextension of the legs and abdomen, and a quick knock-down or immobility. (Prowse, *et al.,* 2006)

The respiration rate of Tenebrio molitor was harmed by garlic essential oil as well. Low respiration rates are therefore a sign of physiological stress, and essential oils can impair insect respiration by inhibiting muscle activity, which can result in paralysis (Correa *et al.,* 2015).

Conclusion,Challenges of Application of Botanical Pesticides And Recommendation

Botanical insecticides are natural chemicals derived from plants with insecticidal properties and used as an excellent alternative to synthetic or chemical pesticides for crop protection to avoid negative or side effects of synthetic insecticides. Botanical pesticides (essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids) have various chemical properties and modes of action and its effect on insects in different ways namely; repellents, feeding deterrents/antifeedants, toxicants, growth retardants, chemosterilants and attractants. More awareness should be created, so that the use of botanical pesticides can be encouraged, since botanical pesticides focus their actions against a target species, they leave fewer residues in food, they are biodegradable, they are unlikely to contaminate the environment and poise no danger to the final consumers as their toxic level is very minimal.

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