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Insight of botanical based biopesticides against economically important pest

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Abstract

This paper reviews the plant based biopesticidal product and its activity against the economically important pests. Other than identified botanicals like neem, neem gold etc., about 211 plant species were explained to have different types of pest management properties in laboratory conditions against defoliator pests. The term biopesticide embraced a wide diversity of both chemical and microbial active ingredients. Conventional insecticides possess inherent toxicities that endanger the health of the farm operators, consumers and the environment. Negative effects on human health led to a resurgence in interest in botanical insecticides because of their minimal costs and fewer ecological side effects. Botanicals have advantages over broad-spectrum conventional pesticides. They affect only target pest and closely related organisms, are effective in very small quantities, decomposed quickly and provide the residue free food and a safe environment to live. When incorporated into integrated pest management programs, botanical pesticides can greatly decrease the use of conventional pesticides or can be used in rotation or in combination with other insecticides, potentially lessening the overall quantities applied and possibly mitigating or delaying the development of resistance in pest populations.

Key-Words: Botanicals, Biopesticides, IPM strategies, Agricultural pest

Introduction

Most of the secondary metabolites such as terpenoids and alkaloids are reported as candidates for insecticidal compounds that could be an effective alternative for insect pest management. In fact, humans have used these for thousands of years as dyes (e.g. indigo, shikonin), flavours (e.g. vanillin, capsaicin), fragrances (e.g. essential oils of rose, lavender), stimulants (e.g. caffeine, nicotine), hallucinogens (e.g. morphine, tetrahydrocannabinol), poisons (e.g. strychnine, coniine) and medicines (e.g. quinine, atropine). The plants secondary metabolites (such as slavanoids, terpenes phenols, alkaloids, sterols, waxes, fats, tannins, sugars, gums, suberins, resin acids carotenoids etc.) defend them against microbial pathogens and invertebrate pests (Golob et al., 1999) and (Wink and Schimmer, 1999). The essential oils from various plants are toxic to different insect pests *viz. Artemisia judaica* has antifeedant activity against *Spodoptera littoralis* (Abdelgaleil *et al.*, 2008), *Nigella sativa* against *Callosobruchus chinensis* (Chaubey, 2008), ginger against *D. melanogaster* (Xu *et al.*, 2007)

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Pesticide Impact on Wildlife Ecology

Pesticides are substances or mixture of substances used to prevent, destroy, repel, attract, sterilize, or mitigate pests. Biopesticides are a type of pesticide derived from such natural materials as animals, plants, bacteria, and certain minerals (Nelson and William, 2004). The plant kingdom is recognized as the most efficient producer of chemical compounds, synthesizing many products that are used to defend plants against different pests (Isman and Akhtar, 2007).Wildlife ecologists and natural resource managers study the needs and habits of wildlife. An important goal of wildlife research is to discover and understand the critical factors that affect survival and sustainability of viable populations. Most wildlife will adapt and flourish, given sufficient quantity of quality habitat, even in the presence of people. While ecological studies may pinpoint very specific requirements for individual species, the lives of plants and animals and their habitats can be integrated collectively into a matrix (ecosystem) (Ritter, 2009). For instance, US EPA BRT 2002 act proposed about the knowledge of a biological and ecological relationships of any given plant or animal, and the role that species plays in the ecosystem, is required to evaluate the potential impact of a *specific* pesticide on a *specific* species. In addition, Moreira et al. (2007) described the impact of a specific pesticide may be negative, neutral, or positive to a species or its habitat as the chemical's residues move through the soil, water, food, or air. The interaction of wildlife, its habitat, and pesticides is evaluated by scientists trained in wildlife ecology, population dynamics, physiology, and environmental chemistry.

The production in agriculture is reduced by losses as high as 45% before or after harvesting due to attack of a variety of pests including insects, nematodes, virus and bacteria, induced diseases and competition by weeds (Vasanthraj David, 2008). An estimated one third of global agricultural production valued at several billion dollars is destroyed annually by over 20,000 species of insect pests in field and storage (Mariapackiam and Ignacimuthu, 2008)

Botanical pesticides and IPM strategies

Hundreds of native plant species have been evaluated against a range of insect pests on various crops. Botanical pesticides act as a synergistic component in several IPM Strategies. Among the botanical pesticides neem (*Azadiracta indica*) is being widely used and several formulations because of it containing the active component azadiractin are commercially available in market field. Later (Kumar *et al*., 2003; Anis Joseph *et al*., 2010) reported that the product with lower concentrations were not found to be useful under field conditions. There is evidence available for the synergistic action neem with microbial pesticides such as NPVs of tomato fruit worm (Reddy *et al*., 2012). Botanical insecticides have long been touted as attractive alternative to synthetic chemical insecticides for pest Management (Isman, 2006; Khaman *et al*., 2006). Hence botanical pesticides are ecofriendly, economic, target specific and biodegradable. But microbial insecticides offer effective alternatives for the control of many insect pests (Krischik and Davidson, 2007.). Their greatest strength is their specificity as most are essentially non-toxic and nonpathogenic to animals and humans. AVRDC has developed IPM strategies for vegetables involving neem as an integral component with botanical pesticides in managing phytophagous insects (Landolt *et al*., 2001) (Table-3).

Very recently, Reddy, 2012 published the extracts of *M. azadiracta* not only controlled the diamondback moth but also enhanced the activity of parasitoid against diamondback moth. Although, the potential of various plant botanicals in pest management has been demonstrated the plants have not been exploited commercially. From this reviews clearly showed that the developing a greater range of commercial botanical pesticides will enhance the IPM options. In the diversity of plant based biopesticides many new mwmbers have been discovered in the past to recent years reported insecticidal property of azadirachtin against *Eurema hecabe* on *Cassia fistula*, recommended neem seed oil against *Pemplia morosalis* on Jatropha nimbicidin against *Carryedon serratus* infesting seeds of many forest trees (Ramarethinam *et al*. 2002; Bakavathiappan *et al*., 2008; Arutselvi *et al*., 2012)

Effect of plant botanicals on stored grain pests

Syzygium lineare Wall (Myrtaceae) is a shrub or small tree with white flowers, linear leaves, thick bark and elongated, slender pedicles found in river banks of Tirunelveli hills of Western Ghats, Tamil Nadu, India (Manickam *et al*., 2004). The leaf powder is used for body cooling and the paste of the fruit is used for increasing stamina. In addition it is used to treat fungal and bacterial infection. The bark of the plant is having astringent, refrigerant and diuretic properties (Duraipandiyan *et al*., 2008). The antifeedant and growth inhibitory activities of various crude extracts and purified fractions of the plant were evaluated well against economically important polyphagous pest *Spodoptera litura* (Jeyasankar *et al*., 2010). Recently, characterization of novel crystal compound and their insecticidal activities against *Spodoptera litura* was also reported (Jeyasankar *et al*., 2011).

Callosobruchus chinensis L. (pulse beetle), *Tribolium castaneum* (Herbst) red flour beetle and *Oryzaephilus surinamensis* L. (Saw-Toothed grain beetle) are major and destructive stored grain pests of Pakistan. These are generally found in granaries, mills and warehouses. These pests not only cause economic loss, but are also responsible for 10% loss of world's cereal production (Wolpert, 1967). In Indo-Pak region, Farmers have Inherited knowledge of mixing leaves, barks, seeds, roots and oils of some traditional plants with the stored grains for protection against insect pests during storage (Saxena *et al.*, 1988). Research reveals that extracts prepared from plants have a variety of properties including insecticidal activity, repellency to pests, antifeedant effects, insect growth regulation, toxicity to nematodes, mites and other agricultural pests, also antifungal, antiviral and antibacterial properties against pathogens (Prakash and Rao, 1997). Abubakr *et al.*, (2000) also reported repellent and antifeedant properties of *Cyperus articulatus* against *T. castaneum.* Again *Jilani et al.*, (2003) tested neem seed oil from five localities of Pakistan against red flour beetle as growth inhibitor and found significant reduction in the progeny at 250 ppm or higher rate in all the samples.

Later, Sundararaj *et al.,* (2004) reported toxic and repellent properties of sugarcane bagasse-based lignin against some stored grain insect pests including *T. castaneum.* Kumar *et al.,* (2007) evaluated the long-term efficacy of the protein enriched flour of pea (*Pisum sativum* L. var. Bonneville) in its toxicity, progeny reduction and organoleptic properties by combining it with wheat flour and testing the admixture against the red flour beetle, *Tribolium castaneum.* Again, Moreira *et al.,* (2007) screened plants with insecticidal activity, in order to isolate, identify and assess the bioactivity of insecticide compounds present in plants, basil (*Ocimum selloi Benth.*), rue (*Ruta graveolens* L.), lion's ear (*Leonotis nepetifolia* (L.) R.Br.), jimson weed (*Datura stramonium* L.), baleeira herb (*Cordia verbenacea* L.), mint (*Mentha piperita* L.), wild balsam apple (*Mormodica charantia* L.), and billy goat weed or mentrasto (*Ageratum conyzoides* L.) against Coleoptera pests of stored products: *Oryzaephilus surinamensis* L. (Silvanidae), *Rhyzopertha dominica* F.

Applications of nanomaterials in agricultural production and crop

Recent manufacturing advancements have led to the fabrication of nanomaterials of different sizes and shapes. These advancements are the base for further engineering to create unique properties targeted toward specific applications. Historically, various fields such as medicine, environmental science, and food processing have employed the successful and safe use of nanomaterials. However, use in agriculture, especially for plant protection and production, is an under-explored area in the research community. Preliminary studies show the potential of nanomaterials in improving seed germination and growth, plant protection, pathogen detection, and pesticide/herbicide residue detection.

Secondary metabolites from plant origin and its insecticidal activity

Insecticides are the cornerstones upon which the pest management practices are based, and are likely to remain so as long as effective and inexpensive chemicals are available (Haynes, 1988). The pest management in agriculture is facing challenge in development of suitable agents to kill insect pests while ensuring the economic and ecological sustainability as majority of the pesticide chemicals are known to cause human and environmental hazards. In the recent past, a variety of new insect control agents have been developed, or are being developed, which may fit a variety of insect pest management needs (Hirashima, 2008). The growing demand for natural products has intensified in the past decades as they are extensively used as biologically active compounds and, are being considered an important alternative strategy for the sustainable insect pest management in agriculture, as they are biodegradable and potentially suitable for use in integrated management programs (Table-1). Pesticides of plant origin are gaining increased attention and interest among those concerned with environment friendly, safe and integrated crop management approaches (Bakavathiappan *et al*., 2012). In addition, they are playing a vital role in organic food production globally.

Insecticides extract a broad range of effects on insects and other arthropods *viz.* neuroexcitation resulting in hyperactivity, tremor and rigid paralysis due to energy depletion and neuromuscular fatigue, while neuroinhibition results in immobility and paralysis because of possible oxygen deprivation and/or reduced respiratory capacity that ultimately leads to mortality (Schmutterer, 1988). It is important to investigate behavioral patterns in insects to elucidate the mode of action of novel and conventional insecticides, and their response in the environment by minimizing their contact with the toxic material (von Keyserlingk *et al*., 1985). Multiple biological signals and mechanisms regulate the efficacy of the synaptic transmission, thus providing rich combinational possibilities for modifying neural communication. The bio-regulation and mechanisms has been studied by various workers, especially for synthetic pesticides, which provide a high degree of precision in modification of neural pathways (Ozoe and Huang, 2008). Crude extracts obtained from plants are usually composed of crude oil essential oils and miscellaneous compounds. The plant extracts as well as mineral oil have several benefits they selective to natural enemies and other non-target species suppress pests such as mites and pearl psylla are safe to the applicator and residues do not represent a food safety concern. (Stadler *et al*., 2001) (Table-2).

Potential perception

Sustainable growth in agriculture is crucial for most of the developing countries to sustain the growing populations. Synthetic crop protection chemicals are associated with pest resurgence, impact on non-target organisms, health and environment. Hence, there is need to develop safe alternative crop protectants (insecticides), which are more specific with wide range of activities. Identification of novel effective insecticidal compounds is essential to combat impacts of synthetic pesticides. An increasing number of researchers are reconsidering botanicals containing active phytochemicals in their efforts to address some of these problems. Consequently, more target-selective and biodegradable compounds are needed to replace the environmentally persistent chemicals having broad-spectrum toxicity, which may play an important role in sustainable pest management.

Conclusion

In conclusion synthetic insecticides have been used to contain insect populations since the inception of green revolution with the significant increase in crop production. However, the consequent pollution jeopardizes the agricultural as well as forestry business. In this context, plant products are preferred over synthetic chemicals. By utilizing Green Chemistry, and addressing the need for confidence in product efficacy and safety, by generating greater transparency about the products, and by moving markets to make way for the greenest solutions, biopesticides could be revolutionary. They could change how people conduct agriculture, how we understand and approach both pests and non-target species, including beneficial organisms. They could change how farm workers do their jobs and live their lives, and protect the health of consumers, communities and ecosystems. There is much to be done to help biopesticides play this transformative role in agriculture, and we as a society need to reflect upon and invest in making these changes happen. Linking Green Chemists and biopesticide producers are an essential first step in ensure these changes happen. Biopesticide formulations also include a broad range of other ingredients required to deliver the product and support performance, commonly referred to by the misleading term "inerts." Given the diversity in composition of biopesticide products, it is not surprising that the efficacy, cost, and impact of these products on human and environmental health also vary greatly from product to product. Understanding the complexity and breadth of the biopesticides industry is an essential foundation to an exploration of major trends, opportunities and challenges for broader adoption of biopesticides.

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Table 1: *Plant botanical (***secondary metabolites***)* sources and *its pesticidal as well as* insecticidal activity

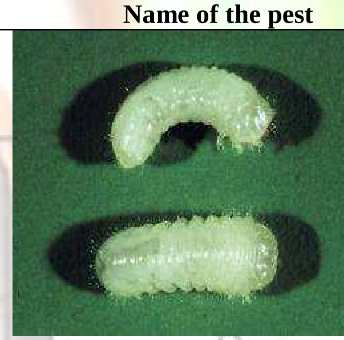
S.No:	**Name of the plants**	**Target pests**	**Secondary metabolites**	**References**
1.	Botanical extracts	Coleoptera: Elateridae	indigo, shikonin	Addor, 1994
2.	vanillin, capsaicin	microbial pathogens and invertebrate pests	slavanoids, terpenes phenols, alkaloids, sterols, waxes, fats, tannins, sugars, gums, suberins	Wink and Schimmer, 1999
3.	*Artemisia judaica*	*and Spodoptera littoralis*	essential oils	Abdelgaleil *et al*., 2008
4.	*Nigella sativa*	*Callosobruchus chinensis*	caffeine, nicotine	Chaubey, 2008
5.	ginger	*D. melanogaster*	morphine, tetrahydrocannabinol	Xu *et al*., 2007
6.	*Eucalyptus tereticornis, Eucalyptus tereticornis*	*Anopheles stephensi*	strychnine, coniine	Nathan et al., 2004
7.	*Litsea pungens* and *Listea cubeba*	*Trichoplusia ni*	quinine, atropine	Jiang *et al*., 2009
8.	*Cedrus* spp., *Pinus* spp., *Citronella* spp., *Eucalyptus* spp.	*Chloroxylon swietenia* against *Anopheles gambiae*, *Culex quinquefasciatus* and *Aedes aegypt*	tannins, sugars	Kiran and Devi, 2007
9.	*Calocedrus decurrens* and *Juniperus occidentalis*	*A. aegypti*, *Xenopsylla cheopis* and *Ixodes scapularis*	vanillin, capsaicin	Dolan *et al*., 2007
10.	*Chenopodium ambrosioides*	*Planococcus citri*, *Frankliniella occidentalis*	terpenoids, phenolics	Cloyd and Chiasson, 2007
11.	Rosemary	*Agriotes obscurus*	Alkaloids	Waliwitiya *et al*., 2005

Table 2: Categories different Biopesticide

Categories	**Examples**	**Advantages**	**References**
		Biochemical Pesticides (122**)**	
Insect Pheromones (36)	1). d-limonene, Macadamia Nut Borer 2). Tetradec-11-en-1-yl acetate	1). conventional by their non-toxic mode of action on target organisms (usually species specific), 2). mating disruption for several species of insects	Steinwand, 2008
Plant Extracts and Oils **(18)**	1). Lemongrass Oil 2). Thymol	1). Quickly paralyze and kill the pests and insects 2). More effectively from powdery mildew	Ware and Whitacre, 2004 Nguyen, 2008
Plant Growth Regulators **(6)**	1). IBA and Cycocel 2). Retain	1). enhance crop yield, crop shelf life, and the appearance of the crop 2). used in organic orchards	Fishel, 2006
Insect Growth Regulators (9)	1). Neem 2). *S-Methoprene*	1). disrupts molting by inhibiting biosynthesis or metabolism of ecdysone 2). which controls the growth, development, and maturation of insects .	Elahi, 2008 US EPA Fact Sheets, 2008
		Microbial Pesticides	
Bacterial Biopesticides (35)	1). *Bacillus subtilis* 2). *Pseudomonas fluorescens* Bactericide	effective they must come into contact with the target pest	Clemson HGIC, 2007
Fungal Biopesticides (15)	1). *Muscodor Albus* 2). *Aspergillus flavus*	**1).** used in fields, greenhouses, and warehouses 2). targeted for a specific insect species	US EPA Fact Sheets, 2008 Thakore, 2006

Viral Biopesticides (6)	1). *Cydia pomonella Granulosis Virus* 2). Bacteriophage:	1). protect against pest resistance to Spinosad for organic agriculture 2). Omnilitics to kill Xanthomonas, a pathogenic bacteria	Steinwand, 2008 Braverman, 2008
Other Microbial Biopesticides (11)	1). Protozoa 1 1 yeast, and 6 viruses	1). Nematodes are microscopic worms are used as insecticides 2). Biodegrade more quickly Limited field persistence	1). Sylvar, 2008 2). Millar, 2008

Table 3: Effect of some of the plants for various economically important pests in agricultural field

NO	Name of the plants	Name of the pest
1.	 *Calotrophis procera*	
2	 *Listea pungens*	
3.	 *Sygium linerae*	

4.	 Rose mary plant	 *Plagionotus floralis*
5.	 *listea cubeba*	 ***Acyrthosiphon pisum***
6.	 *Zingiber officinale*	 ***Nephotettix virescens***
7.	 *Cyprus articulates*	 ***Dicladispa armigera***

8.	 *polygonum hydropipes*	 ***Brevennia rehi***
9.	 *Datura stramonium*	 *Tribolium castaneum*
10.	 ***Melia azedarach***	 *Leptinotarsa decemlineata*