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Biopesticides and their mode of action against insect pests: A review

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Abstract
Biopesticides including entomopathogenic viruses, bacteria, fungi, nematodes, and plant secondary metabolites, are gaining increasing importance as they are alternatives to chemical pesticides and are a major component of many pest control programs. The virulence of various biopesticides such as nuclear polyhedrosis virus (NPV), bacteria, and plant product were tested under laboratory conditions very successfully and the selected ones were also evaluated under field conditions with major success. Biopesticide products (including beneficial insects) are now available commercially for the control of pest and diseases. The overall aim of biopesticide research is to make these biopesticide products available at farm level at an affordable price, and this would become a possible tool in the integrated pest management strategy. Moreover, biopesticide research is still going on and further research is needed in many aspects including bioformulation and areas such as commercialization. There has been a substantial renewal of commercial interest in biopesticides as demon- strated by the considerable number of agreements between pesticide com- panies and bioproduct companies which allow the development of effective biopesticides in the market. This paper has reviewed the important and basic defection of major biopesticides in the past. The future prospects for the development of new biopesticides are also discussed.

Keywords: Biopesticides, mode, action against insect pests

1. Introduction
1.1 Biopesticides
Biopesticides are developed from naturally occur- ring living organisms such as animals, plants, and microorganisms (e.g., bacteria, fungi, and viruses) that can control serious plant-damaging insect pests by their nontoxic eco-friendly mode of actions, therefore reaching importance all over the world. Biopesticides and their by-products are mainly utilized for the management of pests injurious to plants (Mazid *et al.* 2011) [44].

Biopesticides are classified into three different categories: (1) plant-incorporated protectants, (2) microbial pesticides, and (3) biochemical pesticides. They do not have any residue problem, which is a matter of substantial concern for con- summers, specifically for edible fruits and vegetables. When they are used as a constituent of insect pest management, the efficacy of biopesticides can be equal to that of conventional pesticides, particularly for crops like fruits, vegetables, nuts, and flowers. By combining synthetic pesticide performance and environmental safety, biopesticides execute efficaciously with the tractability of minimum application limitations and with superior resistance management potential (Kumar 2012) [38]

Copping and Menn (2000) [15] reported that biopesticides have been gaining attention and interest among those concerned with developing environmentally friendly and safe integrated crop management (ICM)-compatible approaches and tactics for pest management. In particular, farm- ers' adoption of biopesticides may follow the recent trend of "organically produced food" and the more effective introduction of "biologically based products" with a wide spectrum of biologi- cal activities against key target organisms, as well as the developing recognition that these agents can be utilized to replace synthetic chemical pes- ticides (Menn and Hall 1999; Copping and Menn 2000; Chandrasekaran *et al.* 2012) [46, 15, 12]. Insecticides from microorganisms extend a unique chance to developing countries to research, and they have possessed to develop natural biopesticide resources in protecting crops. The utilization of biopesticide programs would be required to prevent the development of resis- tance in target

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insect pests to synthetic chemical pesticides and toxins from biopesticides (Copping and Menn 2000; Senthil-Nathan 2006) [15, 62, 65].

Compared with chemical pesticides, biopesti- cides do not present the same regulatory prob-

lems seen with chemical pesticides. Biopesticides are frequently target specific, are benign to beneficial insects, and do not cause air and water quality problems in the environment, and also agricultural crops can be reentered soon after treatment. Microorganisms from nature can also be used in organic production, and risks to human health are low. In addition, the usage of biopesti- cides has other several advantages; e.g., many target pests are not resistant to their effects (Goettel et al. 2001; EPA 2006) [27, 21].

Biopesticides derived from bacteria like *Bacillus thuringiensis* (Bt), a large array of fungi, viruses, protozoa, and some beneficial nematodes have been formulated for greenhouse, turf, field crop, orchard, and garden use (Hom 1996; Butt et al. 2001a, b; Grewal et al. 2005; EPA 2006) [33, 8, 31, 21]. Biocontrol microbials, their insecticidal meta- bolic products, and other pesticides based on living organisms are sorted as biopesticides by the EPA. There are hundreds of registered products enlisted in EPA (2013) [21].

2. Microbial pesticides
2.1 Bacteria
2.1.1 *Bacillus thuringiensis*
Beginning in the 1980s and continuing to the present, a different molecular approach has been employed to develop market acceptance of biopesticides. Earlier, several efforts were aimed at establishing microbial insecticides, like *Bt*, which has been used commercially over 40 years (Gelernter and Schwab 1993) [24]. Later, some *Bacillus* species such as *Bacillus thuringi- ensis israelensis Bti* and *Bacillus sphaericus* 2362 (*Bs*) were found particularly effective against mosquito (Revathi et al. 2013) [57] and other dipteran larvae. *Bti* was first discovered to have increased toxicity against mosquito larvae in 1975 (Goldberg and Margalit 1977) [28].

Various bacterial species and subspecies, especially *Bacillus*, *Pseudomonas*, etc., have been established as biopesticides and are primar- ily used to control insect and plant diseases. Most salient among these are insecticides based on several subspecies of *Bacillus thuringiensis* Berliner. These include *B. thuringiensis* ssp. *kurstaki* and *aizawai*, with the highest activity against lepidopteran larval species; *B. thuringi- ensis israelensis*, with activity against mosquito larvae, black fly (simuliid), and fungus gnats; *B. thuringiensis tenebrionis*, with activity against coleopteran adults and larvae, most notably the Colorado potato beetle (*Leptinotarsa decemlin- eata*); and *B. thuringiensis japonensis* strain Buibui, with activity against soil-inhabiting beetles (Carlton 1993; Copping and Menn 2000) [9, 15]. *Bt* produces crystalline proteins and kills few target insect pest species like lepidopteran species. The binding of the *Bt* crystalline proteins to insect gut receptor determines the target insect pest (Kumar 2012) [38].

Toxicity of *Bti* and some other toxic strains is commonly imputed to the parasporal inclusion bodies (δ-endotoxins) which are produced during sporulation time. These endotoxins must be assimilated by the larvae to accomplish toxicity. *Bt* and their subspecies produce different insecti- cidal crystal proteins (δ-endotoxins), and their toxicity was determined (Chilcott et al. 1983) [14]. These toxins, when ingested by the larvae, can damage the gut tis- sues, leading to gut paralysis. After that, the infected larvae stop feeding and

finally they die from the combined effects of starvation and mid- gut epithelium impairment (Betz et al. 2000) [7].

Some other microbial pesticides act by out- competing insect pest organisms. Microbial pesticides need to be continuously supervised to ensure that they do not become capable of injur- ing nontarget organisms, including humans (Mazid et al. 2011) [44]. In previous studies, the microbial pesticide advance has resulted in a sig- nificant decrease of synthetic chemical insecti- cide usage (James 2009) [35].

Gray et al. (2006) [29] reported *Bt* toxins produced by plant growth-promoting rhizobacteria, which also develop bacteriocin compounds of insecti- cidal attributes. *Bt* is marketed worldwide for the control of different important plant pests, mainly caterpillars, mosquito larvae, and black flies. Commercial *Bt*-based products include powders containing a combination of dried spores and crystal toxins. They are applied on leaves or other environments where the insect larvae feed. Toxin genes from *Bt* have been genetically engineered into several crops.

3. Fungi
3.1 *Metarihizium anisopliae*
M. anisopliae Sorokin var. *anisopliae* is an essential entomopathogenic fungus. It propa- gates worldwide in the soil, demonstrating a wide range of insect host species. This subspe- cies was first described in 1879 by Metschnikoff, under the term *Entomophthora anisopliae*, as a pathogen of the wheat cockchafer, and later it was termed *M. anisopliae* by Sorokin in 1883 (Tulloch 1976) [70].

Several entomopathogenic fungi and their derivatives are also used as microbial pesticides. *M. anisopliae* are hyphomycete entomopathogenic fungi most widely used for insect pest control and are ubiquitous worldwide. This species comprises a huge number of different strains and isolates of various geographical origins and from different types of hosts (Roberts and St. Leger 2004) [59].

Under natural conditions, *Metarhizium* are found in the soil, where the moist conditions per- mit filamentous growth and production of infec- tious spores, called conidia, which infect soil-dwelling insects upon contact. *M. anisopliae* has the potential to be used as a bio- control agent, particularly for malaria vector spe- cies, and is also a suitable candidate for further research and development Driver et al. (2000) [19] reevaluated the taxonomy of the genus *Metarhizium* using sequence data from ITS and 28S rDNA D3 regions and also using RAPD patterns, revealing ten distinguishable clades. *M. anisopliae* var. *anisopliae* represents clade 9. These entomopathogenic fungi have been viewed as safe and regarded as an environmentally satisfactory alternative to synthetic chemical pesti- cides (Domsch et al. 1980) [18]. Recently, these entomopathogenic fungi have been registered as microbial agents and are also under commercial development for the biological control of several pests (Butt et al. 2001a, b) [8].

M. anisopliae strains are obtained from different geographical localities (Fegan et al. 1993) [23], as sug- gested, among others, by extremely variable toxici- ties (Goettel and Jaronski 1997) [26]. *M. anisopliae* have been used on a large scale in countries like Brazil, where 100,000 ha of sugarcanes are treated every year (Faria and Magalhães 2001) [22]. They are released in the field after thorough assessment of strains. Consorting to Goettel et al. (2001) [27] have reported that the growth and application of fungi as micro- bial agents for biocontrol of insect pest involve tests with mammalian models to evaluate possible human and animal health risks.

4. Virus
4.1 Baculovirus
Baculoviruses are double-stranded DNA viruses present in arthropods, mainly insects. Baculoviruses are usually highly pathogenic and have been used efficaciously in their natural form as biocontrol agents against numerous serious insect pests (Moscardi 1999) [50]. Even so, the application of baculoviruses is still limited in the field of agricul- ture and horticulture where the thresholds for pest damage tend to be minimized. In Lepidoptera, i.e., the primary group where baculoviruses have been isolated, they only cause mortality in the larval stage (Cory 2000) [16].

Baculoviruses need to be ingested by the lar- vae to initiate infection. After ingestion, they enter the insect's body through the midgut and from there they spread throughout the body, although in some insects, infection can be limited to the insect midgut or the fat body. Two groups of baculoviruses exist: the nucleopoly- hedroviruses (NPVs) and granuloviruses (GVs). In NPVs, occlusion bodies comprise numerous virus particles, but in GVs, occlusion bodies ordinarily contain just one virus particle. A common feature of baculoviruses is that they are occluded, i.e., the virus particles are embedded in a protein matrix. The presence of occlusion bodies plays an essential role in baculovirus biology as it allows the virus to survive outside the host (Cory 2000) [16].

Recently, it has been substantially demonstrated that baculoviruses are not infectious to vertebrates and plants. Also within the insects, their host range is restricted to the order from which they were iso- lated. Genetic engineering of baculoviruses has so far been restricted to isolates from Lepidoptera (Kolodny-Hirsch *et al.* 1997) [37]. Baculoviruses vary in the number of hosts that they can infect; some seem to be particular to one species and hence are very unlikely to be a hazard when genetically mod- ified, whereas others infect a range of hosts (Barber *et al.* 1993) [5]. The majority of new baculovirus recombi- nants now employ insect-selective toxins. Genetic modification has been mostly carried out on the alfalfa looper, *Autographa califor- nica* NPV (AcNPV)- the virus for which most molecular information is available, including the complete DNA sequence, which permits precise insertion of foreign genes. Recently, the development of genetically modified baculovi- ruses has expanded to other strains of commer- cial or regional interest (Cory 2000) [16].

Baculovirus-infected insect larvae have pri- marily initiated a cascade of molecular and cel- lular appendages finally the larva enters into the death and the development of huge amounts of polyhedral occlusion bodies comprising rod-shaped virions (Miller 1997) [47]. Lately, a naturally occurring baculovirus (*Agrotis ipsilon* multiple nucleopolyhedrovirus, family Baculoviridae, AgipMNPV) was indicated to have hope as a microbial insecticide for controlling *A. ipsilon* in turf (Prater *et al.* 2006) [56].

Numerous viral formulations are available pri- marily for the control of caterpillar pests. For instance, Certis has recently registered Madex™, an increased-potency codling moth granulosis virus (GV) that also affects oriental fruit moth (OFM). Certis also deals Cyd-X™, which also contains the codling moth GV and which can be an efficient tool for codling moth management (Arthurs and Lacey 2004) [2]. Aside from Madex and Cyd-X, Certis markets Gemstar™, which contains *Heliothis zea* NPV, and Spod-X™, which contains beet armyworm NPV. Gemstar is also registered for the control of lepidopteran pests, like the cotton bollworm and budworm, caterpillars that are mainly dangerous insect pests of corn, soybean, and other vegeta- bles. Furthermore, Certis

has registered a celery looper (*Syngrapha fal- cifera*) NPV and an alfalfa looper (*Autographa californica*) NPV (EPA 2006) [21].

5. Nematodes
5.1 *Steinernema* (Rhabditida)
One of the new hot products in biopesticide is nematodes. Pest nematodes can be supervised with cover crops, crop rotation, and internaliza- tion of organic material into the soil (McSorely 1999) [45]. In the early 1990s, various effective ento- mopathogenic nematodes from two genera, namely, *Steinernema* and *Heterorhabditis* (Nematoda: Rhabditida), were discovered and established as a biocontrol agent against insects (Copping and Menn 2000) [15].

Insect-parasitic nematodes may encroach upon soil-dwelling stages of insects and kill them within 48 h through the expulsion of pathogenic bacteria. After the host dies, the infectious stages of the nematodes become adults and a modern generation of infective juveniles (IJs) develops. Entomopathogenic nematodes are com- monly available for plant protection from serious insect pests and diseases, and also there have been various efforts to biocontrol insect pest pop- ulations in the field by employing IJs via spray- ing. Nevertheless, little is known about the ability of indigenous nematodes to influence insect pest populations (Peters 1996) [53].

In nematodes, the parasitic cycle is initiated by the third-stage IJs. These nonfeeding juveniles infest suitable insect host and enter through the insect's natural body openings like the anus, mouth, and spiracles (Grewal *et al.* 1997) [30]. Once they have entered inside the host, nematodes infest the hemocoel and then release their symbi- otic bacteria into the intestine. After that, the bac- teria cause septicemia, killing the host within 24–48 h. The uptake of IJs is rapidly manipulating by the bacteria and decomposed the host tissues. Almost two to three generations of the nematodes are finished within the host cadaver (Pomar and Leutenegger 1968) [54].

In previous research studies, it has been clearly indicated that entomopathogenic nema- todes can be effective biocontrol agents against some of the major insect pest families found in stored goods like Pyralidae (Shannag and Capinera 2000) [66] and Curculionidae (Duncan and McCoy 1996) [20]. demonstrated the susceptibil- ity of insect pests found in stored products, including *Ephestia kuehniella* Zeller and *Tenebrio molitor* L., to an increased concentra- tion of nematodes. Georgis (1990) [25] had also advo- cated a field concentration of >2.5 billion nematodes/ha against some of the major insect pests of row crops, but concentrations few times higher (7–15 billion/ha) are demanded to accom- plish the control of pest population (Loya and Hower 2002) [41].

6. Protozoa
6.1 *Nosema*
In previous studies, protozoan diseases of insects are ubiquitous in nature and constitute an essential regulatory role in insect populations (Maddox 1987) [42]. Microsporidia, such as *Nosema* spp., are generally host specific and slow acting, most frequently producing chronic infections. The biological activities of most entomopathogenic protozoa are complex. They grow only in living hosts and some spe- cies necessitate an intermediate host. Microsporidia species are among the most commonly observed, and their main benefits are persistence and recycling in host popula- tions and their debilitating effect on reproduc- tion and overall fitness of target insects. As inundatively utilized microbial control

agents, some species have been moderately successful (Solter and Becnel 2000) [68].

Some protozoan species are pathogenic like *Nosema locustae* for grasshoppers, which is the only species that has been registered and estab- lished commercially (Henry and Oma 1981) [32]. *N. bombycis*, the first reported microsporidium, is a pathogen of silkworm pébrine, which persisted in Europe, North America, and Asia during the mid-nineteenth century (Becnel and Andreadis 1999) [6]. Pébrine is still an epidemic and causes heavy economic losses in silk-producing coun- tries such as China (Cai *et al.* 2012).

Almost 1,000 protozoan species, mainly micro- sporidia, attack invertebrates, including numerous insect species like grasshoppers and heliothine moths. Virtually renowned insect-pathogenic pro- tozoan species are *Nosema* spp. and *Vairimorpha necatrix*. Protozoans produce spores, which are the infectious phase in several susceptible insects. *Nosema* spp. spores are assimilated by the host and develop in the midgut. Germinating spores are released from the sporoplasm and invade host tar- get cells, inducing massive infection and demol- ishing organs and tissues. Sporulation process begins again from the infected tissues and, upon expulsion and ingestion by a susceptible host, induces an epizootic infection. Naturally, parasit- oids and insect predators commonly act as vectors distributing the disease.

7. Botanicals
Since ancient times, natural compounds from plants were used, more or less efficaciously to give security from insect pests. In the nineteenth century, these compounds became scientifically established and widely utilized in the earlier period of the twentieth century (Morgan 2004) [49]. Plants and some insects have coexisted on the earth for almost three and a half million years, which has allowed lots of time for both to develop offensive and defensive strategies. Plants have developed many strategies to assist themselves from being assaulted by predators. An example of such plant strategy is developing compounds that are highly toxic to insects (Nisha *et al.* 2012) [52].

7.1 Neem
In Asia, neem has an extensive history of use mainly against household and storage pests and, to some extent, against insect pests of crops. Nevertheless, a breakthrough in the insecticidal application of neem was attained by Pradhan *et al.* (1962) who successfully protected the crops from insects by applying them with low concen- tration of 0.1% neem seed kernel suspension during a locust invasion. The Indian neem tree (*Azadirachta indica*) is one of the most important limonoid-producing plants from the Meliaceae family. Several components of its leaves and seeds show marked insect control potential, and due to their relative selectivity, neem products can be recommended for many programs on crop pest management (Schmutterer 1990) [60]. Neem product activity has been assessed against 450–500 insect pest species in different countries around the world, and from that, 413 insect pest species are reportedly susceptible at various con- centrations (Schmutterer and Singh 1995) [61].

In India alone, neem activity has been assessed against 103 species of insect pests, 12 nematodes, and several pathogenic fungi (Arora and Dhaliwal 1994) [1]. Some recent reviews on the potential of neem in pest manage- ment include those of Singh and Raheja (1996) [67], Naqvi (1996) [51], and Dhaliwal and Arora (2001) [17]. Most works have focused on azadirachtin richly from neem seed extracts which act as both

strong antifeed- ants and insect growth regulators. Azadirachtin affects the physiological activities of insects (Mordue (Luntz) and Blackwell 1993) [48] and does not affect other biocontrol agents. Further, neem products are biodegradable and nontoxic to non- target organisms (Senthil-Nathan 2013).

In several Asian countries, numerous studies have measured neem activity alone or in combi- nation with established insecticides and other biocontrol agents of damaging insect pests in agricultural crop system. In Indian field trials carried out, neem treatments were determined to be effective against some insect species like green leafhopper, yellow stem borer, rice gall midge, rice leaffolder, and grass- hopper (Senthil-Nathan et al. 2009).

7.2 Melia azedarach
The promotion of botanicals as eco-friendly pes- ticides, microbial sprays, and insect growth regu- lators has been a major concern amid the presence of other control measures like beneficial insects, all of which demand an integration of supervised insect pest control (Ascher *et al.* 1995) [3]. Plant-based insecticides are developed naturally from plant chemicals extracted for use against serious insect pests. As a result of concerns about the ecological continuity of synthetic pesticides and their potential toxicity to humans, nontarget ben- eficial insects, and some domestic animals, there is a regenerated interest in natural products to control insect pests. From this conclusion, the development of biopesticides seems to be a logi- cal choice for further investigation. Meliaceae and Rutaceae species have received much atten- tion due to the fact that they are a rich source of triterpenes known as limonoids (Connolly 1983).

The Meliaceae plant family is known to hold an assortment of compounds with insecticidal, antifeedant, growth-regulating, insect-deforming, and growth-modifying properties (Champagne *et al.* 1989; Schmutterer 1990; Mordue (Luntz) and Blackwell 1993; Senthil-Nathan and Kalaivani 2005) [11, 60, 48, 64]. *M. azedarach*, otherwise known as chinaberry or Persian lilac tree, is a deciduous tree that origi- nates from northwestern India, and it has been recognized for its insecticidal properties, which are still to be entirely analyzed. This tree grows in the tropical and subtropical parts of Asia, but nowadays it is also cultivated in other warm places of the world because of its considerable climatic tolerance. The leaves of *M. azedarach* are used for their insecticidal activity, whereas the fruit extracts of *M. azedarach* produce a vari- ety of effects in insects, such as growth retarda- tion, reduced fecundity, molting disorders, and behavior changes (Ascher *et al.* 1995) [3]. The antifeedant and insect growth-regulating effects of *M. azedarach* extracts are known for many insects (Carpinella *et al.* 2003, Senthil-Nathan and Sehoon 2006) [62, 65], the latter effect being the most essential physiological effect of *M. azedarach* on insects (Ascher et al. 1995) [3].

As previously mentioned, the Meliaceae plant family has been known as a potential source for insecticide properties. Also, several extracts from neem and other plant seeds and leaves have excel- lent insecticidal properties against vectors and are at the same time very eco-friendly (Schmutterer 1990) [60]. The effi- caciousness of these neem products on mosqui- toes was also demonstrated (Chavan 1984; Schmutterer 1990; Su and Mulla 1999; Senthil-Nathan et al. 2005d) [13, 60, 64]. Without a doubt, plant-derived toxicants are a valuable source of potential insecticides. Plants and other natural insecticides may play a vital role in mosquito control programs as well as

in other major insect control programs (Mordue (Luntz) and Blackwell 1993) [48].

8. Biochemicals
8.1 Pheromones
Insects produce chemicals called pheromones to stimulate a certain behavioral reaction from other individuals. These pheromones have numerous effects and are named according to their evoked response, for example, sex pheromones, aggrega- tion pheromones, alarm pheromones, etc. A few pheromones function as sex attractants, permit- ting individuals to detect and locate mates, whereas others induce trail following, oviposi- tion, and aggregation in other congeners. Pheromones have become essential tools for monitoring and controlling agricultural pest pop- ulations, and as such, a huge collection of over 1,600 pheromones and sex attractants has been reported (Witzgall et al. 2004).

In the past decades, there has been a significant volume of literature on insect pheromones and new opportunities have arisen to explore the use of semiochemicals in managing insect pest prob- lems. Insect control by pheromones alone has pre- cincts, but they can be applied in integrated control in combination with other practices (Howse et al. 1998; Reddy and Guerrero 2004) [34, 57]. Plant volatiles are recognized as an integral part of the pheromone system of various Coleopteran species studied so far. How the combinations of pheromones and plant volatiles are incorporated into the insects' olfactory systems so that they can discriminate pheromone molecules alone and pheromone plus odor plume strands and react behaviorally to these signals is a question of increasing importance (Baker and Heath 2004) [4].

Recently, the pest management system has undergone an intentional shift from calendar- based, broad-spectrum insecticide applications to more holistic, integrated, and high-efficacy approaches. Furthermore, environmental conser- vation, food safety, and resistance management are a few of the key components guiding current pest management policies in commercial agricul- ture (Witzgall *et al.* 2010) [72].

Kogan and Jepson (2007) [36] had reported that meeting the necessities of the quickly expanding global population while incorporating sustain- ability and ecological stewardship is a major challenge facing modern agriculture. In agricul- tural fields, the application of pheromones and/or allelochemicals as behavioral manipulation tools can replace or complement existing pest manage- ment programs (Witzgall et al. 2008) [71], resulting in a decreased rate of broad-spectrum use.Nowadays, pheromones and other semio- chemicals are applied to monitor and control pests in millions of hectares. There are several advantages of utilizing pheromones for monitor- ing pests, including lower costs, specificity, ease of use, and high sensitivity (Laurent and Frérot 2007; Witzgall et al. 2010) [39, 72]. Insect pest monitoring by using pheromone lures can profit management conclusions such as insecticide application timing (Leskey *et al.* 2012; Peng *et al.* 2012) [40].

Pheromones produced by insects are highly species specific. Virgin female insects are devel- oping sex pheromones when expecting for a mate and males along the concentration slope for the female producer. Aggregation pheromones are released by insects such as wood-invading bee- tles to show to others the presence of a good food source (Copping and Menn 2000) [15].

Some of the alarm pheromones are developed by insects that are beneath approach from a pred- ator and this contributes to a movement of the insect pest aside from the production source and, therefore it becomes dangerous. Plants and its derived attractants are also known that interact with the insects to a valuable food source and, while combine with insect-derived attractants will be developed a potent attraction to some insect pests (Copping and Menn 2000) [15].

In previous studies, Mayer and McLaughlin (1991) [43] proposed that all insects produce approxi- mate form of pheromone and companies subsist that synthesize a pheromone for any customer. Recently, 30 mating-disruption pheromone- based products are registered by the US EPA as biocontrol agents of lepidopteran pest species that can cause agricultural damage (Copping and Menn 2000) [15].

9. Conclusion
The utilization of natural products with commercial value is directly manifested by the numerous compounds present in the market and that have remained there in many cases after many years. These values of natural products are considered as a source of new mechanisms and their consequent incorporation into high-output screens is hard to evaluate. Recently, several works have been exercised and extend to be undertaken to enhance the shelf life, immediate death, the biological scheme, efficient in the field and dependability, and the effect of cost of living systems and there have been some notable successes in situations where some disruption to the crop is acceptable.

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