MICROORGANISMS AND PLANTS AS A TOOL IN INTEGRATED PEST MANAGEMENT

Dr. V. Agatha Christy
Assistant Professor
Department of Zoology
Pope's College, Sawyerpuram, Thoothukudi District, Tamil Nadu, India.

Abstract: Bio-pesticides are considered to be the best alternative to synthetic pesticides that are highly effective, target specific and reduce environmental risks. These factors led to its application in pest management program instead of chemical pesticides throughout the world. Bio-pesticides are derived from animals, plants and other natural materials such as fungi, bacteria, algae, viruses, nematodes and protozoa. The advance research and development in the field of bio-pesticide applications greatly reduce the environmental pollution caused by the chemical synthetic insecticides residues and promotes sustainable development of agriculture. Since the advent of bio-pesticides, a large number of products have been registered and released, some of which have played a leading role in the agro-market. The development of bio-pesticide has prompted to replace the chemical pesticide in pest management. The current status and advancement of bio-pesticides focusing mainly on improving action spectra, replacing of chemical pesticides, its role in integrated pest management, proper application of botanical and semio chemical in pest management have been discussed in this review.

Keywords: Bio-pesticides, IPM, Semiochemical, Microbial pesticides, Botanical pesticides, Baculoviruses.

INTRODUCTION

The global population will grow to 10.12 billion by 2100. In order to fulfil the food demand of growing population; higher and advance productive agricultural materials are required [1].The highest yield of crops is based on the improved variety, the appropriate pest and disease management, and recommended fertilization. Proper pest management is an important factorfor healthy and high yielding crop that can provide food to the increasing population. The adequate pest management is pivotal need for today to produce maximum food for increasing population from less. The multiple approaches that would be suitable in organic farming reduce the human and environmental exposure to synthetic chemical pesticides, and may also reduce the overall costs of pesticide applications. To date, only 15% of natural enemies of insect pests have been identified. In all successful bio control programs; most importantparasitoids are Hymenoptera and predators (Neuroptera, Hemiptera and Coleoptera). Globallymore than 125 species of natural enemies are commercially available for biological controlprograms such as *Trichogramma* spp.; *Encarsia formosa* Gahan, and *Phytoseiulus persimilis*Athias- Henriot [2]. Although, chemical pesticides play a vital role in insect pest management, however, they have accelerated land, air and water contamination. Similarly, they have been the main cause of insect resistance as well as adverse impacts on natural enemies and humans[3]. Due to these factors, farmers adopted bio-pesticides which are environmentally friendly and reduced frequently application of synthetic insecticides for pest management [4].Nowadays, a lot of bio-pesticides have been developed from microorganisms (bacteria, fungi, viruses, etc.), plant, animal derived products (pheromones, hormones, insect-specific toxins, etc.) and genetically modified organisms and used worldwide for insect pest management [5, 6].This review summarizes the current development and improvement of all aspects related to bio-pesticides in insect pest management including spectra improvement, challenges and role of bio-pesticides in integrated pest management.

CURRENT STATUS OF BIO-PESTICIDES

In this case the current status of different categories of bio-pesticides such as microbial pesticides based on microorganisms, botanical pesticides derived from plants, semi chemicals will be discussed. Microbial bio-pesticides So far, in the global agriculture system the most widely used pesticides have synthetic origin such as halogenated, carbonate and organo phosphorus compounds. Excessive use led to the creation of new strains of pests resistant to synthetic insecticides. The resistance development often related to receptors modification that involved the mechanisms and targets of action [7, 8]. Due to the results of resistance, researchers have synthesized many new organic molecules with this target of action, having adverse effect on the non target organisms. Acute or chronic poisoning caused by pesticides is a problem in many countries in the world, especially in developing countries [9]. Bio-pesticides derived from fungi, bacteria, algae, viruses, nematodes and protozoa and also some other compounds produced directly from these microbes such as metabolites are main microbial pest control agents [10]. Up to now, there are more than 3000 kinds of microbes that cause diseases in insects. Some biopesticides are given in Table 1. However, a lot of research should be conducted to find remaining undiscovered or unidentified microorganisms that are useful in insect pest management.

Over 100 bacteria have been identified as insect pathogens, among which Bacillus thuringiensis Berliner (Bt) has got the maximum importance as microbial control agent. So far, more than 1000 insect species viruses have been isolated such as nuclear polyhedrosis virus (NPV) infested 525 insects worldwide. Over 800 species of endomopathogenic fungi and 1000 species of protozoa pathogenic have been described and identified. The two major groups of entomopathogenic nematodes are Steinernema (55 species) and Heterorhabditis (12 species).

Table 1: Some important biopesticides list and their references

	Common name and references
Entomopathogenic viruses	
Helicoverpa zea: corn earworm, tomato fruitworm, tobacco budworm, *Helioth virescens*	Corn earworm NPV (HezeSNPV)
Helicoverpa armigera, cotton bollworm, pod borer	Cotton bollworm NPV (HearNPV)
Plutella xylostella	Diamond back moth GV
Anticarsia gemmatalis	Velvetbean caterpillar, NPV (AngeMNPV)
Noctuidae	Alfalfa looper NPV (AucaMNPV)
Buzura suppressaria	Tea moth (BuzuNPV)
Entomopathogenic bacteria	
Lepidoptera	*Bacillus thuringiensis* sub species kurstakia
Lepidoptera	*B. thuringiensis* sub-species aizawaia
Coleoptera: Scarabaeidae	*B. thuringiensis* sub-species japonensis
Coleoptera: Scarabaeidae, *Popillia japonica*	*Paenibacillus popilliae*
Entomopathogenic fungi	
Hemiptera	*Aschersonia aleyrodis*
Coleoptera (Scarabaeidae)	*Beauveria brongniartii*
Hemiptera, Thysanoptera	*Conidiobolus thromboides* Acari
Hemiptera	*Lecanicillium longisporum*
Coleoptera, Diptera, Hemiptera, Isoptera	*Metarhizium anisopliae sensu* lato
Lepidoptera	*Nomuraea rileyi* .

POSITIVE ASPECTS OF MICROBIAL PESTICIDES

Generally, the beneficial characteristics of microbial insecticides are given below as described by Jindal [12].

- The bioactive agents are basically non-toxic and non-pathogenic to non-target organisms, communities and humans.
- They have narrow area of toxic action, mostly specific to a single group or species of insect pests and do not directly affect beneficial insects (predators, parasites, parasitoids, pollinators) in treated areas.
- They can be used in combination with synthetic chemical insecticides because in most cases the microbial product is not deactivated.
- Their residues have no adverse effects on humans or other animals, therefore, microbial insecticides can be used in near harvesting time.

- Sometime, the pathogenic microorganisms can become established in a pest population or its habitat and provide control pest generation to generations or season afterseasons.
- They improve the root and plant growth by encouraging the beneficial soil microflora and also increase yield.

MAIN CHALLENGES TO MICROBIAL PESTICIDES.

The rapid biopesticide success is due to its effectiveness and safety as compared to chemical insecticides. Still, there are a lot of challenges facing to microbial pesticides to replace chemical pesticides in the future.

- The utilization of microbial pesticides in IPM model requires high scientific study such as systematic surveys on properties, mode of action, pathogenicity, etc.
- Ecological studies are necessary on the dynamics of diseases in insect populations because the environmental factors play a vital role in disease outbreaks to control the pests.
- In order to improve mass production technologies;contamination should be reduced with the improvement of formulation potency and increase in shelf-life of microbial biopesticides.
- Dry formulations should be commercially focused than the liquid formulations with the improvement of slow speed with which microbial pathogens kill their host. Genetic and biotechnological tools would lead to theproduction of strains with improved pathogenesis and virulence.
- Due to narrow specificity mostly forces biopesticide application with common conventional insecticides. However, this practice can also lead to incompatibility problems such as inhibition or death of the living organism.
- All aspects study should be done especially; persistence, resistance, dispersal potential, the range of non-target organisms affected directly and/or indirectly in order to solve the problem of regarding the regulatory and registration.

BACULOVIRUSES BIOPESTICIDE IMPORTANCE AND FUTURE ASPECTS

Baculovirus biopesticide has many advantages as a tool in the insect pest management program, including the highly specificity, no adverse effect on vertebrates and plants and ease of genetic manipulation. However, the baculovirus, like other biopesticides have some difficulties for commercial use, such as the current requirements for killing speed, short field stability, high production costs, and biological control agents. The wild type baculoviruses have slow killing rate that Journal of Entomology and Zoology Studies reduce their practical application. To overcome this problem ulti strategy has been developed to use the recombinant DNA technology to enhance their killing action including the insertion of genes encoding insect hormones or enzymes, or insect specific toxins [13]. However, only the expression of juvenile hormone esterase showed a significant improvement in insecticidal activity of the parent wild-type baculovirus . Because of juvenile hormone esterase regulates juvenile hormone, its over expression the hormone concentrations were decreased and leads to prevent insect feeding and pupation. Short half-life in the hemolymph of juvenile hormone esterase is a serious restriction to the effective use of recombinant baculovirus to express this enzyme. Still, many efforts have been made to improve in vivo stability, making it more effective. Anticarsia gemmatalis is a very important soybean insect pest in Brazil, before an IPM program implementation, frequent insecticide were applied for their control and AgMNPV used to threaten about 2000 hectares of soybeans treatment area increased to two million ha by 2002-2003 [14]. The application of AgMNPV to control A. gemmatalis in Brazil was a very successful program has been considered as the most important in the world. The codling moth, Cydia pomonella is well known pest of fruits such as apple, pears and walnuts throughout the world [15]. In 1964, the isolation of the C. pomonella granulovirus (CpGV) provided a highly effective pathogen for control of important insect pests worldwide that are responsible for huge economic loss every year. Cotton Bollworm, H. armigera is the resistant noctuid species to a wide range of insecticides [16, 17] resistance to transgenic Bt cotton as well [18, 19]. It has also been found that the combination of HaMNPV with endosulfan has provided significant results [20, 21, 22]. In China HaSNPV is one of the most important commercial baculovirus. Many NPVs are used on over 100,000 ha annually]. Nowadays, the commercial baculoviruses production is occur in vivo, using the baculovirus in the open field and collecting infected larvae (dead) or reared larvae feed with baculovirus contaminated food in the laboratory [23].

BOTANICAL BIOPESTICIDES

Botanical pesticides derived from some parts or whole plants having ability of insect killing, sterilization, weed control and plant growth regulating activities. The application of botanical pesticides for the crop and stored products protection from insect pests has been become a part of traditional agriculture for generations. The development of bio-pesticides has promoted the modernization of agriculture and will, no doubt, and gradually replace chemical pesticides. A large number of products have been released, some of which have played a leading role in the market. Over 6000 plant species have been identified that possessing insecticidal properties. In insect pest management, a number of plant products derived from neem, custard apple, tobacco, pyrethrum, etc. have been used as safer insecticides. Botanical pesticides have environmentally friendly characteristics such as volatile nature, low environmental risk compared to current synthetic pesticides. Due to minimal residual activity; predation, parasitism, and the number of pollination insects would affect smaller and compatible with IPM programs. Azadirachtin compounds derived from the neem tree is sold under various trade names, can use on several food crops and ornamental plants for controlling whitefly, thrips, scale and other pests [24, 25]. Some important botanical bio-pesticides are shown in Table 2.

Table 2: Some plant products used as bio-pesticides

Plant product used as bio-pesticide	Target Pest
Limonene and Linalool	Fleas, aphids and mites, also kill fire ants,several types of flies, paper wasps and house crickets
Neem	A variety of sucking and chewing insect
Pyrethrum /Pyrethrins	Ants, aphids, roaches, fleas, flies, and ticks
Rotenone	Leaf-feeding insects, such as aphids, certain beetles (asparagus beetle, bean leaf beetle, Colorado potato beetle, cucumber beetle, flea beetle, strawberry leaf beetle, and others) and caterpillars, as well as fleas and lice on animals
Ryania	Caterpillars (European corn borer, corn earworm, and others) and thrips
Sabadilla	Squash bugs, harlequin bugs, thrips, caterpillars, leaf hoppers, and stink bugs

A number of problems have been encountered while commercializing the botanical pesticides such as quality control and product standardization. As synthetic pesticides, the improper and excessive use of botanical pesticides may also develop pest resistance. The phytotoxicity is also a matter of botanical pesticides such as neem oil based is often phytotoxic to tomato, brinjal and ornamental plants at high oil levels. Although plant extracts are considered to be relatively safe to humans, still, this is not yet confirmed for all plant species such as Aconitum spp. and Ricinus communis have notoriously high toxicity to man and Tephrosia vogelii having well-known adverse effects against fish [26].

SEMIOCHEMICALS

From the 1970's to 1980's in the last century, about 1000 kind of insect's pheromones were identified and discovered. The first experiment that involved pheromones for pest control was conducted in 1980's. Since then, a lot of pheromones have been identified and used in pest management programs. More than 30 target species have been controlled successfully by sex pheromones. Based on the use of these semiochemicals, producers rely on the deployment of air permeation to attract and kill techniques for pest control. Current research has found that herbivore-induced plant volatiles from arthropod herbivores interaction. Then it has synthesized and used in slow release dispensers to attract predators and parasitoids. Under field conditions, they lead to a high capture of natural enemies. It is worth noting that application of compounds such as jasmonic acid to plants can also induce the production of a natural blend of HIPVs. The results of this study indicate that the application of synthetic HIPVs crops may attract - direct and indirect effects that can protect crops from pests such as sodium alginate as a biological control to attract natural enemies and the natural enemies of aphids.

SEMIOCHEMICALS IMPROVEMENT AND DEVELOPMENT

- For improvement of semiochemicals, understanding the mechanisms of communication systems of insects, behavior and mating systems among target insects and non-target organisms is important. At the same time the effects of different meteorological and physiochemical characteristics of insects and plants should be understood.
- Proper protection and controlled release formulations should be developed to prolong its efficacy after their application on crop and reduce its rapid photodegradable.
- The best successes of semiochemicals have been achieved where large, contiguous areas have been treated with these compounds. Farmers should be used a very proper insect control methodology to get best result from semiochemical application.
- Cost of registration, size of the potential market and product's price are very important for development. Therefore should be improved.

REPLACEMENT OF CHEMICAL PESTICIDES TO BIOPESTICIDES

Chemical pesticides play an important role in the green revolution, which can realize high yield varieties and the most effective pest management tool. Synthetic pesticides are very effective, affordable and rapid in action in the case of the pest populations reached to economic threshold levels (ETLs). Problems such as pest resistance development, resurgence, pesticide residues in the food commodities and environmental effects to non-target organisms and direct hazards to human beings have evolved due to repeated and excessive use of pesticides. Many species of insects and mites have developed resistance to different groups of pesticides. Environmentally friendly alternative to chemical pesticides is biopesticides. The development and improvement of biopesticides are based on the negative effects of chemical pesticides. More than 3000 tons/year biopesticide is produced in the worldwide; its market share is only 2.5%. The rapid increasing rate of biopesticides is due to its target specificity and ecologically friendly.

ROLE OF BIOPESTICIDES IN IPM

Crop protection has relied basically on synthetic chemical pesticides in past, but their availability is now declining as a result of new laws and legislations and the evolution in the process of insect resistance. Therefore, it is necessary to replace the pest management strategy. Bio-pesticide is the best alternative to synthetic chemical pesticides based on living micro-organisms or natural products. Bio-pesticides include a broad array of microbial pesticides, bio-chemicals derived from microorganisms and other natural sources, and processes involving the genetic modification of plants to express genes encoding insecticidal toxins. Bio-pesticides have demonstrated the potential of pest management and used worldwide. In the European Union, there are new opportunities for development of biological pesticides in combination with integrated pest management, ecological science and post genomic technologies . In this regard, the use of bio-pesticides and bio-agents has assumed significance as an important component of IPM due to their economic viability and eco-friendly nature instead of chemical synthetic pesticides. Bio-pesticide application as a component of IPM programs can play important role in overcoming disadvantage of chemical insecticides that have some important characteristics such as biodegradable and self- perpetuating, less harmful on beneficial pests, mostly host specific and less shelf life. Baculovirus bio-pesticides are an alternative to chemical pesticides in integrated pest management; however, they have a wide range of difficulties for commercial uses such as slow killing, short life time, high production costs and current laws and regulations of biological control agents. To overcome many problems of wild-type baculoviruses, many strategies have been developed to improve their killing action by recombinant DNA technology, including the insertion of genes encoding insect hormones or enzymes, or insect-specific toxins.

IMPROVEMENT IN ACTION SPECTRA OF BIOPESTICIDES

Bio-pesticide is commercially available for a single main pest that reduce their market value due to their formulations, e.g, Mycotal® the fungus Verticillium lecanii) against cereal aphids. Some bio-pesticides are highly targeted specific hence generally concern as a disadvantage because accessible bio-pesticide markets are smaller than those for products with broad spectrum activity. Some bio-pesticides are only effective in specific stages of pests to reduce their population below threshold level. In addition, some of the pesticides have important advantages in favour of their application in modern legislation, such as new behavioural modes of action, which enable them to overcome the increased resistance to conventional pesticides with valuable tools as well as to reduce he impact on non-target organisms. It must also be pay attention to a number of biological pesticide has relatively wide range of activities (such as Bacillus thuringiensis and active bioextracts from natural products such as azadirachtin), which encourages their widespread application and market size. In the development of biological pesticide, it is important to overcome the problem of improper preparation or formulations, low shelf life, slow pest control and the highest market costs as well as other marketing registration related issues.

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