Biopesticides: An Effective and Environmental Friendly Insect-Pests Inhibitor Line of Action

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Abstract— **From immemorial time, agriculture has been fronting the damage happenings of abundant pests including insects, which is results an essential reduction in crop yield. Pest management approach, method and discipline have experienced over time developments and advancements to minimize environmental impact. For that reason, there is a necessity to progress biopesticides, which are efficient, ecofriendly and do not consent any destructive consequence on atmosphere. This review exemplifies some of selected illustrations of case studies on the current deployment of biopesticides in pest management package. Biopesticides are contraction of biological pesticides, which include several types of pest management interventions through predatory, parasitic, or chemical relationships. The term biopesticides has been historically associated with biological control by implication and the manipulation of living organisms. But, regulatory positions can be influenced by public perceptions wherein *b*iopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria and certain minerals. Frequently, biopesticides have no harmful residues detected, can be cheaper than chemical pesticides when locally produced and may be more effective than chemical pesticides in the long-term and are biodegradable. Three major classes of biopesticides are available such as microbial pesticides consisting of entomopathogenic bacteria (e.g., *Bacillus thuringiensis*), fungi (e.g., Trichoderma spp.), or viruses (e.g., Baculovirus) including their metabolites sometimes, entomopathogenic nematodes and protozoa. Bioal pesticides i.e., herbal pesticides (intrinsic unique and diverse array of chemical complex structure in different plant species) provide efficient protection from the pests and microbial diseases, and plant incorporated protectants (i.e., genetically modified crops like transgenic Bt cotton) though their use as food items is debatable. Biopesticides can be applied through introductions, augmentative releases, inundatively, or through conserving existing field populations of natural pest control agents. Optimistically, further sensible tactic can be progressively implemented towards biopesticides in the nearby upcoming time and temporary incomes from chemical pesticides should not limit the destiny of biopesticides. Biopesticides can be used as part of an overall integrated pest management suite to reduce the legal, environmental and public safety hazards of chemical residues, and inexpensive alternative to some insecticides.**

Index Terms− **Bioherbicide, Biological Pest Control, Plant Defense to Herbivory, Antagonism, Biopesticide.**

I. INTRODUCTION

Within all countries of the world, chemical pest control agents are expansively used, but they are watched as environmentally objectionable. Consequently, there is an amplified societal burden to substitute them progressively with biopesticides which are harmless to humans and non-target organisms. The injurious ecological consequences of the synthetic chemicals have forced for exploration of some unusual approaches. This leads to increased development of compounds based on the recreations of naturally occurring toxins of biological derivation having numerous biological actions. Biopesticides include a broad array of microbial pesticides, biochemicals derived from micro-organisms and other natural sources. Biopesticides can be as a form of pesticide based on micro-organisms or natural products and these include naturally occurring substances that control pests (biochemical pesticides), microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material (plant incorporated protectants) [1], [2], [3], [4].

Biopesticides are biochemical pesticides that are naturally occurring substances that control pests by nontoxic mechanisms. Biopesticides are living organisms (natural enemies) or their products (phytochemicals, microbial products) or byproducts (semiochemicals) which can be used for the management of pests that are injurious to plants. Biopesticides have an important role in crop protection, although most commonly in combination with other tools including chemical pesticides as part of bio-intensive integrated pest management [5]. These are typically created by growing and concentrating naturally occurring organisms and their metabolites including bacteria and other microbes, fungi, nematodes, proteins, etc. These are often considered to be important components of integrated pest management (IPM) programs, and have received much practical attention as substitutes to synthetic chemical plant protection products [6].

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II. CATEGORIES AND USE OF BIOPESTICIDES

Biopesticides used in insect pests control broadly fall into three major types as illustrated in the subsequent section:-

1. Biochemical Pesticides

Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones that interfere with mating as well as various scented plant extracts that attract insect pests to traps. Because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide, a special committee can be established to make such decisions to determine whether a pesticide meets the criteria for a biochemical pesticide. Actually, these are naturally occurring substances such as plant extracts, fatty acids or pheromones that manage pests through non-toxic contrivances. Biochemical pesticides include substances that interfere with growth or mating, such as plant growth regulators, or substances that repel or attract pests, such as pheromones [7], [8], [9].

1.1. Plant Products

Botanical insecticides are promising alternatives for use in insect management, however, like conventional synthetic insecticides; botanicals have advantages and disadvantages that should be judged accordingly. Use of botanicals is now emerging as one of the important means to be used in protection of crop produce and the environment from pesticidal pollution, which is a global problem. Neem tops the list of 2,400 plant species that are reported to have pesticidal properties and is regarded as the most reliable source of eco-friendly biopesticidal property. Neem products are effective against more than 350 species of arthropods, 12 species of nematodes, 15 species of fungi, 3 viruses, 2 species of snails and 1 crustacean species. Azadirachtin, a tetranortritarpinoid, is a major active ingredient isolated from neem, which is known to disrupt the metamorphosis of insects. Two tetracyclic triterpenoids- meliantetyraolenone and odoratone isolated from neem exhibited insecticidal activity against *Anopheles stephensi*. Neem seed kernel extract is found most effective in reducing the larval population of *Helicoverpa armigera* in chickpea and pod damage. Neem formulations also have a significant effect against eggs of peach fruit fly *Bactrocera zonata* (Saunders). Over 195 species of insects are affected by neem extracts and insects that have become resistant to synthetic pesticides are also controlled with these extracts. Neem bio-pesticides are systemic in nature and provide long term protection to plants against pests. Pollinator insects, bees and other useful organisms are not affected by neem based pesticides. Botanical insecticides are processed into various forms which include preparations of crude plant material, plant extracts or resins and pure chemicals isolated from plants [10], [11].

1.2. Use of Pheromone in Insect Pest Management

Pheromones are chemicals emitted by living organisms and used to send messages to individuals usually of the opposite sex within the same species. Pheromones of hundreds of insect species have been chemically elucidated, including the sex pheromone of the codling moth. When used in combination with traps, sex pheromones can be used to determine what insect pests are present in a crop and what plant protection measures or further actions might be necessary to assure minimal crop damage. If the synthetic attractant is exceptionally effective and the population level is very low, some control can be achieved with pheromone traps or with the attract and kill technique. Generally, however, mating disruption is more effective. Synthetic pheromone that is identical to the natural version is released from numerous sources placed throughout the crop to be protected [12], [13].

Mating disruption has been successful in controlling a number of insect pests and more growers use this technique and produce crops without using insecticides. Ii has been proven effective in codling moth, navel orangeworm, pink bollworm, fruit moth, grape moth, and grapevine moth, to name a few. More percent of the fruit tree acres are treated with mating disruption for caterpillar control in some states. Efforts to control the pink bollworm *Pectinophora gossypiella* (Saunders), by mating disruption began with the sex attractant 'hexalure'. The discovery of the pink bollworm sex pheromone led to the first successful commercial formulation. An inhibitor-based tactic has demonstrated to suppress infestations of the southern pine beetle *Dendroctonus frontalis* Zimmermann. The southern pine beetle uses a variety of semiochemicals to mediate mass attack on host pine trees. Two aggregation pheromones, frontalin and trans-verbenol, function in directing other beetles to join in the mass attack of a host tree that is necessary for successful colonization. Once the tree is overcome, no further beetles are needed and two anti-aggregation pheromones, endobrevicomin and verbenone are released to divert beetles to other trees [14].

1.3. Use of Peptidomimetics in Insect Pest Management

Conformationally constrained peptides have been pursued as valuable tools in drug discovery and development, and could be applied in insecticide design. The non-peptidic analog has the potential to be used as a leading compound in the development of novel insecticides, overcoming the bioavailability issues of peptides penetrating the insect cuticle or gut mucosa. However, for rational insecticide design, one needs to know both the three-dimensional structure and spatial position of the insectophore, which is information that is unfortunately lacking with most of the insecticidal toxins characterized to date. Nevertheless the concept has received limited validation following attempts to 'clone' the functional residues of peptide toxins that block vertebrate calcium or potassium channels. The development of a peptidomimetic insecticide is likely to be challenging since noncritical residues determined in insect toxicity bioassays may be vital for averting vertebrate toxicity, via steric hindrance. In addition, these non-critical residues maybe important for providing insect target subtype selectivity [15].

2. Microbial Pesticides

Microbial pesticides consist of a microorganism (e.g., a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest, for example, there are fungi that control certain weeds, and other fungi that kill specific insects [16]. The most widely known microbial pesticides are varieties of the bacterium *Bacillus thuringiensis*, or Bt, which can control certain insects in cabbage, potato and other crops. The Bt produces a protein that is harmful to specific insect pest. Certain other microbial pesticides act by out-competing pest organisms. Each strain of this bacterium produces a different mix of proteins, and specifically kills one or a few related species of insect larvae. While some Bts control moth larvae found on plants, other are specific for larvae of flies and mosquitoes. The target insect species are determined by whether the particular Bt produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve. Microbial pesticides need to be continuously monitored to ensure that these do not become capable of harming non-target organisms, including humans [17], [18], [19].

2.1. Prospective Benefits of Entomopathogenic Fungi

Entomopathogenic fungi are important natural regulators of insect populations and have potential as mycoinsecticide agents against diverse insect pests in agriculture. These fungi infect their hosts by penetrating through the cuticle, gaining access to the hemolymph, producing toxins, and grow by utilizing nutrients present in the haemocoel to avoid insect immune responses. Entomopathogenic fungi may be applied in the form of conidia or mycelium which sporulates after application. The use of fungal entomopathogens as alternative to insecticide or combined application of insecticide with fungal entomopathogens could be very useful for insecticide resistant management [20]. The commercial mycoinsecticide based on *Beauveria bassiana* (Balsamo) Vuillemin with reduced doses of trichlorophon have been used to suppress the second-generation outbreaks of *Cydia pomonella* L. The higher insect mortality has been detected when *B. bassiana* and sublethal concentrations of insecticides have been applied to control potato beetle (*Leptinotarsa decemlineata*), attributing higher rates of synergism between two agents. A long term example of a classical biological control project using fungi is the program targeting the cassava green mite *Mononychellus tanajoa* (Bondar). The exploration for potential natural enemies revealed that the entomophthoralean *Neozygites floridana* is one of the most important natural enemies of cassava green mite *M. tanajoa*. The impact of the fungus *N. floridana* on the tomato red spider mite *Tetranychus evansi* Baker & Pritchard has been demonstrated in the field and under screen house during four crop cycles of tomato and nightshade [21], [22].

The effectiveness of seven strains of entomopathogenic fungi against fruit fly *Ceratitis capitata* adults has been evaluated, aqueous suspensions of conidia from *Metarhizium anisopliae* is the most toxic, resulting in about 90% mortality. The compatibility of the entomopathogenic fungus *B. bassiana* with neem has been conducted against sweetpotato whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on eggplant [23]. The combination of *B. bassiana* and neem yielded the highest *B. tabaci* egg and nymph mortalities and the lowest LT50 value. Therefore, neem is used along with *B. bassiana* suspension as an integrated pest management program against *B. tabaci*. The use of the insect-pathogenic fungus *M. anisopliae* against adult *Aedes aegypti* and *A. albopictus* mosquitoes has also been reported [24]. The life span of fungus-contaminated mosquitoes of both species is significantly reduced compared to uninfected mosquitoes. The results indicated that both mosquito species are highly susceptible to infection with this entomopathogen. Fungal biocontrol agents, including 10 isolates of *B. bassiana*, *M. anisopliae*, and *Paecilomyces fumosoroseus* have been bioassayed for their lethal effects on the eggs of the carmine spider mite *Tetranychus cinnabarinus*. Results confirmed the ovicidal activity of the three fungal species and suggested the feasibility to search for more ovicidal isolates from fungal species that may serve as biocontrol agents against spider mites such as *T. cinnabarinus* [25]. Several insect-killing fungi are included as biopesticides, such as entomopathogenic fungi Hypocreales have been used for the control of potato psyllid; *B. bassiana* for whiteflies, thrips and other pests; *Isaria fumosoroseus* Apopka strain or *P. fumosoroseus* for whiteflies and others; and *M. anisopliae* for black vine weevil, thrips and others. It has been observed that all fungal treatments significantly resulted in effective suppression of pests and reduced plant damage symptoms [26].

2.2. Use of Bacterial Bio-Pesticides

Bacterial bio-pesticides are probably the most widely used and cheaper than the other methods of pest bioregulation. Insects can be infected with many species of bacteria, but those belonging to the genus Bacillus are most widely used as pesticides. One of the Bacillus species *Bacillus thuringiensis* has developed many molecular mechanisms to produce pesticidal toxins; most of toxins are coded for by several cry genes [27]. Since the discovery as a microbial insecticide, *B. thuringiensis* has been widely used to control insect pests important in agriculture, forestry and health. Its principal characteristic is the synthesis, during sporulation of a crystalline inclusion containing proteins known as endotoxins or Cry proteins, which have insecticidal properties. To date, over one hundred *B. thuringiensis* based bioinsecticides have been developed, which are mostly used against lepidopteran, dipteran and coleopteran larvae. In addition, the genes that code for the insecticidal crystal proteins have been successfully transferred into different crop plants, which have led to significant economic benefits. Because of their high specificity and the safety in the environment, *B. thuringiensis* and Cry proteins are efficient, safe and sustainable alternatives to chemical pesticides for the control of insect pests. The toxicity of the Cry proteins have traditionally been explained by the formation of transmembrane pores or ion channels that lead to osmotic cell lysis [28]. In addition to this, Cry toxin monomers also seem to promote cell death in insect cells through a mechanism involving an adenylyl cyclase/ PKA signalling pathway. However, despite of this entomopathogenic potential, controversy has arisen regarding the pathogenic lifestyle of *B. thuringiensis*. Recent reports claim that *B. thuringiensis* requires the co-operation of commensal bacteria within the insect gut to be fully pathogenic [29], [30].

2.3. Success of Baculovirus Pesticides

First well-documented introduction of baculovirus into the environment which resulted in effective suppression of a pest occurred accidentally before the World War II. Along with a parasitoid imported to Canada to suppress spruce sawfly *Diprion hercyniae*, a nucleopolyhedrosis specific for spruce sawfly was introduced and since then no control measures have been required against this hymenopteran species. In the past, the application of baculoviruses for the protection of agricultural annual crops, fruit orchards and forests has negligibly matched their potential. The number of registered pesticides based on baculovirus, though slowly, increases steadily distributed under different trade names in different countries. Nucleopolyhedrosis viruses and granulosis viruses are used as pesticides but the group based on nucleopolyhedrosis is much larger. The first viral insecticide is a preparation of *Heliothis zea* nucleopolyhedrosis which is relatively broad range baculovirus and infects many species belonging to genera Helicoverpa or Heliothis. These provided control of not only cotton bollworm, but also of pests belonging to these genera attacking soybean, sorghum, maize, tomato and beans. The resistance to many chemical insecticides including pyrethroids revived the interest in viruses and the registered under the name a s product of choice for biocontrol of *Helicoverpa armigera*. Countries with large areas of such crops like cotton, pigeonpea, tomato, pepper and maize have introduced special programs for the reduction of this pest by biological means [31].

3. Plant Incorporated Protectants

One approach, to reduce destruction of crops by phytophagous arthropod pests, is to genetically modify plants to express genes encoding insecticidal toxins. The adoption of genetically modified crops has increased dramatically and the genetically modified plants possess a gene or genes that have been transferred from a different species. Plant-incorporated protectants are pesticidal substances produced by plants and the genetic material necessary for the plant to produce the substance. For example, scientists can take the gene for a specific Bt pesticidal protein, and introduce the gene into the plant's genetic material. Then the plant manufactures the pesticidal protein that controls the pest when it feeds on the plant. Genetically engineered crops are often broken down into two categories, herbicide tolerant and plant-incorporated protectants. In addition, crops are also engineered or ‘stacked’ to express multiple traits, such as crops that are resistant to multiple herbicides or are resistant to herbicides and incorporate insecticides. In all these cases, the characteristics are achieved through the manipulation of genetic composition of the organism by adding specific genes. The first *B. thuringiensis* (Bt) plant-incorporated protectant for use has registered 11 Bt plants, although five of these registrations are no longer active. Corn and cotton Bt incorporated varieties are introduced and a Bt variety of soy is registered. Despite industry claims that these plants would lessen pesticide dependency, insects have exhibited resistance to the engineered crops. This raises concerns about the efficacy of natural Bt used in organic food production and the loss of an important tool [32], [33].

The production of transgenic plants that express insecticidal δ-endotoxins derived from the soil bacterium (Bt plants) and the expression of these toxins confers protection against insect crop destruction. The lethality of Bt endotoxins is highly dependent upon the alkaline environment of the insect gut, a feature that assures these toxins are not active in vertebrates, especially in humans. These proteins have been commercially produced, targeting the major pests of cotton, tobacco, tomato, potato, corn, maize and rice, notably allowing greater coverage by reaching locations on plants which are inaccessible to foliar sprays. There are numerous strains of Bt, each with different Cry proteins, and more than 60 Cry proteins have been identified. Most Bt maize hybrids express the Cry1Ab protein, and a few express the Cry1Ac or the Cry9C protein, all of which are targeted against the corn borer (*Ostrinia nubilalis* Hubner) (Lepidoptera). Some recent maize hybrids express the Cry3Bb1 protein, which is targeted against the corn rootworm complex (Diabrotica spp.) (Coleoptera), also a major pest of maize, and cotton expressing the Cry1Ac protein is targeted against the cotton bollworm (*Helicoverpa zea* Boddie) (Lepidoptera), which is a major pest of cotton; potato expressing the Cry3A or Cry3C is targeted against the potato beetle (*Leptinotarsa decemlineata* Say) (Coleoptera), which is a major pest of potato; and Cry4 proteins are targeted against some Diptera, such as certain flies (*Lycoriella castanescens* Lengersdorf) and mosquitoes (*Culex pipiens* L.,) [34], [35].

III. Applications of Microbial Pesticides

Biopesticides are biological or biologically derived agents that are usually applied in a manner similar to chemical pesticides, but achieve pest management in an environmental friendly way. With all pest management products, but especially microbial agents, an effective control requires appropriate formulation and application. Biopesticides for use against crop diseases have already established themselves on a variety of crops, for example, biopesticides already play an important role in controlling of downy mildew diseases. Their benefits include the ability to use under moderate to severe disease pressure, and the ability to use as a tank mix or in a rotational program with other registered fungicides. Because some market studies estimate that as much as 20% of global fungicide sales are directed at downy mildew diseases, the integration of biofungicides into production has substantial benefits in terms of extending the useful life of other fungicides, especially those in the reduced-risk category. A major growth area for biopesticides is in the area of seed treatments and soil amendments. Fungicidal and biofungicidal seed treatments are used to control soil borne fungal pathogens that cause seed rots, damping-off, root rot and seedling blights. These can also be used to control internal seed-borne fungal pathogens as well as fungal pathogens that are on the surface of the seed. Many biofungicidal products also show capacities to stimulate plant host defense and other physiological processes that can make to treated crops more resistant to a variety of biotic and abiotic stresses [36], [37]. There is less danger of impact on the environment and water quality and they offer a more environmentally friendly alternative to chemical insecticides. These could also be used where pests have developed resistance to conventional pesticides [38], [39], [40], [41], [42].

IV. CONCLUSION

There are three key features of commercial difficulties instigated by insects. One is concerning to the damage of crop production and other relates to the health of human and pets. The third concerns to the cost of attempt to prevent or control such production losses and health hazards. The chemical pesticides used to control them have created serious ecological problems such as pest evolved resistance, destroying of beneficial insects and natural predators, and pollution of environment has increased worldwide. As a result, increasing attention has been directed toward creation of biological agents, making them highly toxic to the target organism, possessing the desirable properties of a chemical pesticide, can be mass produced on an industrial scale and has a long shelf and minimal environmental impacts. Fortunately, many of insect are associated with pathogenic microbes that have been suggested as controlling agents of pests and developed as commercial products. Entomopathogens microorganisms that cause disease in arthropods, particularly insects and mites are naturally widespread in the environment and include bacteria, fungi, viruses, nematodes and protozoa. Most are host specific, and some cause natural epidemics in insect populations, which can be mass-produced and applied against pests in a way that is similar to a pesticide, using sprays, dusts and drenches. Biocontrol agents can be used successfully against a complete range of high threshold pests including aphids, whiteflies, stem borers, leaf miners, locusts and grasshoppers. The efficiency of a biocontrol agent depends on two factors; such like its capacity to kill and to reproduce on pests, and currently based on ecological terms, and its functional and numerical responses. Hence, there are specific opportunities for use of biological control agents, but as a group these do not provide a remedy, as alternatives to chemical pesticides. Growers can adopt biological agents that may provide efficacy comparable with standard chemical insecticides. Technological advances in biological agents production formulations, quality control, application timing and delivery, and particularly in selecting optimal target habitats and target pests, have might widen the efficacy gap between chemical and biocontrol agents. Biopesticides clearly have a potential role to play in the development of future integrated pest management strategies, and it is very likely that in future their role will be more significant in agriculture and forestry.

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Author's Profile

1. Dr. Muhammad Sarwar, Principal Scientist, is going through 25th years of Service experience in Research orientated Department of Agriculture (16-05-1991 to 31-05-2001, Government of Punjab), and Pakistan Atomic Energy Commission (01-06-2001 to date).
2. Have 172 publications in National (60) and Foreign (112) Journals with suitable Impact Factor.
3. Award of Higher Education Commission of Pakistan "Post-Doctoral Scholarship-2006" for Post Doc., research work at Chinese Academy of Agricultural Sciences, Beijing, China.
4. Shield award, Letters of Appreciation, and Certificates of performance and honor granted from Chinese Academy of Agricultural Sciences, Beijing, China.
5. Awarded Gold Medal-2010 by Zoological Society of Pakistan (International) in recognition of research contributions in the field of Insect Science.
6. Granted Research Productivity Award-2011, by Pakistan Council for Science and Technology.
7. Included in Panel of approved Supervisor of Higher Education Commission (HEC), Pakistan.
8. Completed "Basic Management Course" organized by Pakistan Institute of Engineering & Applied Sciences (PIEAS), Islamabad, held from 31 January to 18 February, 2011.