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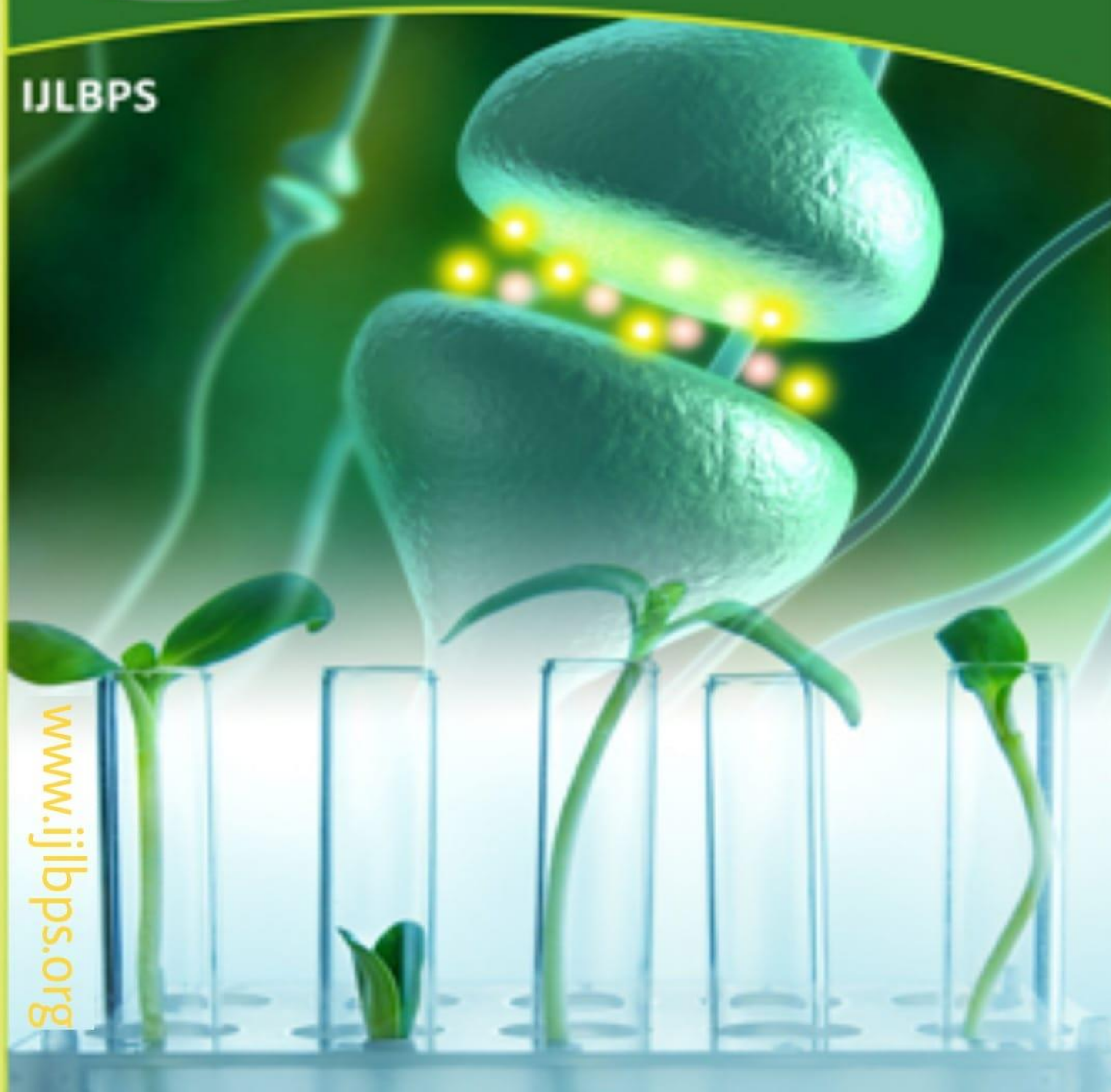

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Applications of Soil Microbe Biopesticides in Agricultural Settings

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Abstract

Alternatives to conventional pesticides, such as entomopathogenic viruses, bacteria, fungi, nematodes, and plant secondary metabolites, are becoming more important in pest management. Numerous biopesticides, including nuclear polyhedrosis virus (NPV), bacteria, and plant products, have been examined and shown to be very effective in the lab; those that have been chosen have also been assessed in the field with similar results. There are now commercially accessible bio pesticide products (including beneficial insects) for the management of pests and illnesses. Research on biopesticides is conducted with the ultimate goal of commercializing biopesticide products at the farm level at a price that is reasonable for farmers, therefore providing a new option for integrated pest control. Furthermore, bio pesticide research is ongoing, and more research is required in several areas, such as bio formulation and commercialization. A large number of partnerships between pesticide firms and bio product businesses that enable the production of successful bio pesticides on the market reflect a significant revival of economic interest in bio pesticides. Farmers always face the challenge of dealing with crop damage caused by pests and illnesses. Significant limits may be imposed onproduction that has an impact on human and environmental existence. Synthetic pesticides, which are harmful to both humans and wildlife, have replaced traditional means of plant protection in recent decades. The use of biological control, also known as biopesticides, is one of the ecologically benign strategies created to protect plants against plant infections. Microbial pesticides, biochemicals produced from microorganisms and other natural sources, and procedures involving the genetic integration of DNA into agricultural commodities are all included in the wide category of biopesticides. There are pros and cons of using bio pesticides on the environment, human health, and agricultural yields. The media are made from compostable materials. In addition to the microorganisms, several organic components such animal broth, organic materials, and organic waste product were used as carrier medium in the development of bio pesticides. Because they had no harmful effects on the environment, biopesticides helped maintain a stable and sustainable agricultural ecology. The greater value of organic crops means that farmers may earn more money from them.

Microorganisms in soil; natural pesticides; IPM

Introduction

Biopesticides, short for "biological pesticides," include a wide range of methods for controlling pest populations, such as those based on predation, parasitism, and chemical manipulation of pests. The phrase hasBiopesticides are "a sort of pesticide based on micro- organisms or natural materials," as defined by the European Union. have traditionally [biologically]command, and by extension, the tinkering with of living things

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Public opinion may have a role in shaping regulatory views, thusThe United States Environmental Protection Agency defines them as "pesticidal compounds generated by plants with additional genetic material" (plant-incorporated protect ants, or PIPs), "naturally occurring substances that control pests" (biochemical pesticides), and "microbial pesticides."Plants, microorganisms, fungus, nematodes, and other creatures are all sources [1, 2]. Many people have taken an interest in them as viable alternatives to synthetic chemical plant protection products (PPPs) since they are often used as part of integrated pest management (IPM) programs.Agrochemicals like inorganic fertilizers and insecticides are heavily used in today's farming. Pesticides, especially when used repeatedly or for extended periods of time, may have devastating effects on soil ecology, altering or even wiping out the beneficial or plant probiotic soil micro flora that is essential to plant health. Damaged soils can no longer support increased crop or grain yields on the same area of land. However, growing awareness of environmental contamination and the need to manage farmland sustainably has led to an increased focus on education and the adoption of practices, technologies, and goods that cause no or little environmental harm. This section discusses the many agrochemicals used, especially pesticides, and how they affect the soil microorganisms that are part of the soil's food web at different levels.In agroecosystems, invertebrate pests may be controlled with the help of a wide variety of microorganisms, including bacteria, fungus, baculoviruses, and nematode-associated bacteria. Many novel biopesticidal products are being created as a result of many discoveries, which is contributing to the expansion of the worldwide market. Recent academic and industrial efforts have led to the identification of novel microbial species and strains, as well as their unique toxins and virulence factors, after a few decades of effective usage of the entomopathogenic bacteria Bacillus thuringiensis and a few other microbial species. As a result, a great deal of thesehave progressed to the point of being sold in stores. A wide variety of bacterial entomopathogens exist, including multiple species of Bacillaceae, Serratia, Pseudomonas, Yersinia, Burkholderia, Chromobacterium, Streptomyces, and Saccharopolyspora; fungal entomopathogens include several Beauveria bassiana,saria species, as well as B. brongniartii, M. anisopliae, V. verticillatum, L. lecanicillatum, H. hirsutella, P. paecilomyces, and P. hirsutella. Baculoviruses are a kind of niche product that is effective against eating insects, particularly Lepidopteran caterpillars, but only those of a certain species. Species of Heterorhabditis and Steinernema are the most common types of entomopathogenic nematodes (EPNs), and they are both linked to mutualistic symbiotic bacteria of the Photorhabdus and Xenorhabdus genera. This study provides an up-to-date summary of what is known about microbial biopesticides and the availability of active compounds that may be employed in IPM programs in agro-ecosystems.In the conventional microbial management strategy, exotic microorganisms are imported and released to manage invasive pests for the long term, and several entomopathogens have been or are being utilized in this way. Exotic microbe releases are strictly controlled by government bodies and only occur after exhaustive testing. In contrast, farmers, government organizations, and homeowners often utilize commercially available entomopathogens that are discharged by inundative application as bio insecticides. Utilizing entomopathogen-based bio pesticides for pest management in agriculture, horticulture, orchard, landscape, turf grass, and urban environments requires an understanding of the mode of action, ecological adaptations, host range, and dynamics of pathogen-arthropod-plant interactions.With a global population that continues to grow, food safety and security have become urgent issues. Insect pests inflict billions of dollars in yearly damage to the agricultural industry due to their destructive habits. Production costs rise as a result of productivity losses and the use of expensive chemical pesticides. Chemical pesticides (including Benzene hexachloride, Endosulfan, Aldicarb, and Fenobucarb) have been used extensively in agricultural settings, and this has resulted in a number of different kinds of environmental problems. Furthermor prayable insecticides based on RNA interference are now being researched by many businesses, including Monsanto, Syngenta, and Bayer. The plant's DNA is not altered by these sprays. As resistance to the original RNA develops in the species being targeted, it may be possible to modify the RNA to keep it effective. RNA is a delicate molecule that usually degrades within a few days to a few weeks after being used. Monsanto predicted that prices will be about $5/acre [8].

Weeds resistant to the Roundup herbicide made by Monsanto have been the focus of RNAi research. A combination of RNA interference (RNAi) and a silicone surfactant allowed the RNA molecules to reach air-exchange pores on the plant's surface, where they damaged the tolerance gene and kept it down for long enough for the herbicide to do its job. This method would enable the ongoing use of glyphosate- based herbicides, but it wouldn't help a herbicide rotation plan that depended on alternating Roundup with other herbicides [8].

They may be built with enough accuracy to selectively eradicate some insect populations without affecting others. One difficulty in Monsanto's efforts to create an RNA spray to combat potato bugs is getting the spray to be effective for a whole week, rain or shine. More than 60 common pesticides no longer work on the potato beetle [8].

To avoid having its RNAi pesticide products tested for rodent toxicity, allergenicity, and residual environmental effects, Monsanto lobbied the U.S. Environmental Protection Agency (EPA). An EPA panel of experts concluded in 2014 that ingesting RNA poses no danger to human health [8].

While the RNA trigger was developed to alter wheat's starch content, the Australian Safe Food Foundation hypothesized in 2012 that it may potentially disrupt a gene for a human liver enzyme. However, proponents of the theory pointed out that RNA does not seem to survive in the stomach or saliva. Using RNAi would place natural systems at "the pinnacle of danger," according to the US National Honey Bee Advisory Board. Beekeepers raised concerns that unexpected consequences might harm pollinators, since many insect genomes remain undiscovered. Given the need for long-term presence for herbicide and other treatments, ecological concerns have not yet been well evaluated. Pests that have developed resistance to chemical pesticides are a direct result of the persistent use of these substances. This overuse of chemical pesticides leads to soil and water contamination. Therefore, the necessity of food safety and eco-friendliness elevates the role of biological management of insect pests in agricultural fields. When compared to chemical pesticides, bacterial insecticides are preferable. It not only protects crops from insect pests, but also helps build food security.

Subclasses of Biopesticides Biological pesticides may be broken down into the following categories:

• Microorganism-based insecticides, which may be broken down into:microorganisms such as bacteria, entomopathogenic fungi, or viruses, and even the metabolites that these organisms produce. Despite their multicellularity, entomopathogenic nematodes are often classified as microbial insecticidesOrganic compounds. Pests and microbiological illnesses may be managed using four classes of naturally occurring compounds now in use [5, 6]: pyrethrum, rotenone, neem oil, and different essential oils.Genetically modified (GM) crops, such those with plant-incorporated protect ants (PIPs), include DNA from other species. In several European nations, their usage is highly debated [7].

• RNAi insecticides, which may be applied topically or taken up by the plant.When it comes to photosynthesis, growth, and other fundamentals of plant physiology, biopesticides often don't play a role. They take a more proactive stance against biological pests. Antifeedants refer to the chemical substances found to be generated by plants as a means of defense against herbivores. These materials are renewable and biodegradable options that may be more cost-effective in the long run. This method of pest management is widely used in organic agriculture [6].RNA:Spossible for RNA drift across species boundaries[8].Monsanto has invested in multiple companies for their RNA expertise, including Beeologics (for RNA that kills a parasitic mite that infests hives and for manufacturing technology) and Preceres (nanoparticle lipidoid coatings) and licensed technology from Alnylam and Tekmira. In 2012 Syngenta acquired Devgen, a European RNA partner. Startup Forrest Innovations is investigating RNAi as a solution to citrus greening disease that in 2014 caused 22 percent of oranges in Florida to fall off the trees [8] .Examples: Bacillus thuringiensis, a bacteria capable of causing diseaseof Lepidoptera, Coleoptera and Diptera, is a well- known insecticide example. The toxin from B. thuringiensis (Bt toxin) has been incorporated directly into plants through the use of genetic engineering. The use of Bt Toxin is particularly controversial. Its manufacturers claim it has little effect on other organisms, and is more environmentally friendly than synthetic pesticides.Other microbial control agents include products based on:Entomopathogenic fungi (e.g. Beauveria bassiana, Isaria

fumosorosea, Lecanicillium and Metarhizium spp.),Plant disease control agents: include Trichoderma spp. and Ampelomyces quisqualis (a hyper-parasite of grape powdery mildew); Bacillus subtilis is also used to control plant pathogens [3]. Beneficial nematodes attacking insect (e.g. Steinernema feltiae) or slug (e.g. Phasmarhabditis hermaphrodita) pestsEntomopathogenic viruses (e.g.. Cydia pomonella granulovirus).Weeds and rodents havea also been controlled with microbial agents.Various naturally occurring materials, including fungal and plant extracts, have been described as biopesticides. Products in this category include: insect pheromones and other semiochemicals

chitosan: a plant in the presence of this product will naturally induce systemic resistance (ISR) to allow the plant to defend itself against disease, pathogens and pests Biopesticides may include natural plant- derived products which include alkaloids, terpenoids, phenolics and other secondary chemicals. Certain vegetable oils such as canola oil are known to have pesticidal properties.Products based on extracts of plants such as garlic have now been registered in the EU and elsewher

Applications Bio pesticides are biological or biologically- derived agents, that are usually applied in a manner similar to chemical pesticides, but achieve pest management in an environmentally friendly way. With all pest management products, but especially microbial agents, effective control requiresappropriate formulation[10] and application Bio pesticides for use against crop diseases have already established themselves on a variety of crops. For example, bio pesticides already play an important role in controlling downy mildew diseases. Their benefits include: a 0-Day Pre- Harvest Interval (see: maximum residue limit), 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 bio fungicides into grape 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 bio pesticides is in the area of seed treatments and soil amendments. Fungicidal and bio fungicidal seed treatments are used to control soil borne fungal pathogens that cause seed rots, damping-off, root rot and seedling blights. They 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 bio fungicidal products also show capacities to stimulate plant host defence and other physiological processes that can make treated crops more resistant to a variety of biotic and a biotic stresses.

Disadvantages:

- High specificity: which may require an exact identification of the pest/pathogen and the use of multiple products to be used; although this can also be an advantage in that the bio pesticide is less likely to harm species other than the target
- Often slow speed of action (thus making them unsuitable if a pest outbreak is an immediate threat to a crop)
- Often variable efficacy due to the influences of various biotic and abiotic factors (since some bio pesticides are living organisms, which bring about pest/pathogen control by multiplying within or nearby the target pest/pathogen)
- Living organisms evolve and increase their resistance to biological, chemical, physical or any other form of control. If the target population is not exterminated or rendered incapable of reproduction, the surviving population can acquire a toleranceof whatever pressures are brought o bear, resulting in an evolutionary arms ace.

Unintended consequences: Studies have found broad spectrum biopesticides have lethal and nonlethal risks for non-target native pollinators such as Melipona quadrifasciata in Brazil [13].

Generally, bio pesticides are made of living things, come from living things, or they are found in nature. They tend to pose fewer risks than conventional chemicals. Very small quantities can be effective and they tend to break down more quickly, which means less pollution.

Some bio pesticides are targeted in their activity, often working on a small number of species. However, users need more knowledge to use biopesticides effectively. This is because they are often most effectively used as part ofan Integrated Pest Management approach.

Types of Bio pesticides:

- **Microbes -** These are tiny organisms like bacteria and fungi. They tend to be more targeted in their activity than conventional chemicals. For example, a certain fungus might control certain weeds, and another

Microbial control agent	Tradenames of biopesticides	Target pests
Bacteria		
Bacillus thuringiensis subsp. *aizawai*	Agree WG and XenTari DF	Lepidoptera
B. thuringiensis subsp. *israelensis*	Mosquito Beater WSP	Diptera
B. thuringiensis subsp. *kurstaki*	CoStar, DiPel ES, Monterey B.t., and Thuricide	Lepidoptera
B. thuringiensis subsp. *tenebrionis*	Novodor FC	Coleoptera
Paenibacillus popilliae	Milky Spore Powder	Japanese beetle, *Popillia japonica*
Fungi		
Beauveria bassiana	BotaniGard ES, Mycotrol-ESO, Myco-Jaal, and Naturalis-L	One or more pests of Acarina,
Hirsutella thompsonii	ABTEC Hirsutella	Coleoptera, Diptera, Hemiptera,
Isaria fumosorosea	NoFly WP and Pfr-97 WDG	Hymenoptera, Lepidoptera,
Lecanicillium lecanii	Phule Bugicide	Orthoptera, Thysanoptera, and
L. longisporum	Vertalec	others
Metarhizium anisopliae	BioCane, Metarril and Ory-X	
M. brunneum	Met52 EC	
Paecilomyces lilacinus	MeloCon WG	Plant-parasitic nematodes
Nematodes		
Heterorhabditis bacteriophora	Nemasys and Terranem	Several orders of soilborne pests
Steinernema carpocapsae	Ecomask and NemAttack	
S. feltiae	Entonem, Fungus Gnat & Rootknot Exterminator, and Scanmask	
H. heliothidis and *S. carpocapsae*	Double-Death	
Viruses		
Granulovirus (GV)		Lepidoptera
Cydia pomonella GV	CYD-X and MADEX HP	
Nucelopolyhedrovirus (NPV)		
Helicoverpa zea NPV	Gemstar LC	
Spodoptera exigua NPV	Spod-X LC	

fungus might control certain insects. The most common microbial bio pesticide is Bacillus thuringiensis.

Substances Found in Nature – These include plant materials like corn gluten, garlic oil, and black pepper. These also include insect hormones that regulate mating, malting, and food-finding behaviours. They tend to control pests without killing them. For example, theymight repel pests, disrupt their mating, or stunt their growth. Some synthetic substances are allowed. However, they must be similar in shape and makeup to their natural counterparts. They must also work in the exact same way against pests.

Plant-Incorporated Protect ants (PIPs) – These are the genes and proteins, which are introduced into plants by genetic engineering. They allow the genetically modified plant to protect itself from pests, like certain insects or viruses. For example, some plants produce insect- killing proteins within their tissues. They can do this because genes from Bacillus thuringiensis were inserted into the plant's DNA. Different types of proteins target different types of insects. Microbial control and Integrated Pest Management:

There are several examples of entomopathogen-based bio pesticides that have played a critical role in pest management. Significant reduction in tomato leaf miner, *Tuta absoluta*, numbers and associated yield loss was achieved by *Bt* formulations in Spain [14]. *Bt* formulations are also recommended for managing a variety of lepidopteran pests on blueberry, grape, and strawberry [15-18].

Lecanicellium muscarium-based formulation reducedgreenhouse whitefly (*Trialeurodes vaporariorum*) populations by 76-96% in Mediterranean greenhouse tomato [19]. In other studies, *B. bassiana* applications resulted in a 93% control of twospotted spider mite (*Tetranychus urticae*) populations in greenhouse tomato [20] and 60-86% control on different vegetables [21]. The combination of *B. bassiana* and azadirachtin reduced rice root aphid (*Rhopalosiphum rufiabdominale*) and honeysuckle aphid (*Hyadaphis foeniculi*) populations by 62% inorganic celery in California [22]. *Chromobacterium subtsugae* and *B.rinojensis* caused a 29 and 24% reduction, respectively, in the same study. IPM studies in California strawberries also demonstrated the potential of entomopathogenic fungi for managing the western tarnished plant bug (*Lygus hesperus*) and other insect pests [23, 24]. Entomopathogenic fungi also have a positive effect on promoting drought tolerance or plant growth as seen in cabbage [25] and strawberry [26] and antagonizing plant pathogens [27].

Application of SeMNPV was as efficacious as methomyl and permithrin in reducing beet armyworms (*S. exigua*) in head lettuce in California [28]. Several studies demonstrated PhopGV as an important tool for managing the potato tubermoth (*Phthorimaea operculella*) [29]. The entomopathogenic nematode, *S. feltiae*,reduced raspberry crown borer (*Pennisetia marginata*) populations by 33-67% [30]. For managing the branch and twig borer (*Melagus confertus*) in California grapes, *S. carpocapsae* is one of the recommended options [18].

Entomopathogens can be important tools in IPM strategies in both organic and conventional production systems. Depending on the crop, pest,and environmental conditions, entomopathogens can be used alone or in combination with chemical, botanical pesticides or other entomopathogens.

Conclusion

Current problems with the use of chemical insecticides and emphasis on low inputs sustainable agriculture have pushed the microbial agents to the fore front for use in IPM systems. The microorganism provides certain distinct advantages over many other control agents and methods. The major advantage of exploiting microorganism for pest control is their environmental safety primarily due to the host specificity of these pathogens. Microorganisms have natural capability of causing disease at epizootic levels due to their persistence in soil and efficient transmission. Many insect pathogens are compatible with other control methods including chemical insecticides and parasitoids. The cost of development and registration of microbial insecticides is much less than that of chemical insecticides. There is a minimum effect on nontarget organism. There is a long term regulation of a pest population in most the cases whereas in others fairly a good check of pest population has been established. The large scale culture and application is relatively easy and inexpensive. The self-perpetuating nature of most of the pathogens in both space and time would certainly prove to be an asset in sustainable agriculture.

The availability of bio pesticides acting against diverse crop pests is essential to ensure the management of agro-ecosystems respecting the environment and human health. The growing demand from farmers is accompanied by an increasing market offer of newly introduced and improved products that can be used alone and in rotation or combination with conventional chemicals. Academic and industrial investments in the bio pesticide sector is experiencing a significant growth and many discoveries are being developed into new biopesticidal products that are enlarging the global market offer. This includes the development of novel solutions against new targets or the introduction of new technologies that enhance the efficacy of already available active substances. Advanced molecular studies on insect microbial community diversity are also opening new frontiers for the development of innovative pest management strategies [31, 32]. On the other hand, recent findings are contributing to foster a deeper understanding of the insect- microbial interactions within the plant ecosystem [33]. The modern legislative frameworks requiring following criteria and principles of integrated pest management (IPM) in agro-ecosystems, are further fuelling a significantly expanding market. Added to this are the efforts made by scientists working in the field of invertebrate pathology, whose studies aim to give light to new and increasingly effective microbial derived active substances.

In addition to the continuous search for new bio molecules and improving the efficiency of the known bio pesticides, recombinant DNA technology is also being used for enhancing the efficacy of bio pesticides. Better understanding of genes from microorganisms and crop plants has enabled the isolation of genes effective against particular pest. Fusion proteins are also being designed to develop next-generation bio pesticides. This technology allows selected toxins to be combined with a carrier protein which makes them toxic to insect pests when consumed orally. The fusion protein may be produced as a recombinant protein in substitutes. The human and environmental safety of the bio pesticides and compatibility with integrated pest management systems will drive continued expansion of this industry. The industry has recognized the need to work together and has formed the Bio pesticide Industry Alliance (BPIA), with a mission to improve the global market perception of bio pesticides as effective products. BPIA plans to develop industry standards for product quality and efficacy.

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