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Chapter

Biological Control of Insect Pest

Talha Nazir, Sehroon Khan and Dewen Qiu

Abstract

Among all the crops, the total loss due to the pests varied for each crop likely for wheat 50%, cotton 80%, maize 31%, rice 37%, potatoes 40%, and soybean 26%. Environmental stewardship and food security are the most important factors that involved in agriculture. In many cases by the misuse of insecticide led to population resurgence, pesticide residues, and pest resistance. The microorganisms like virus, fungus, protozoan or bacterium are the active ingredient in this type of pesticides. Safety of food alludes to the conditions and practices that save the quality of food to anticipate tainting and food borne sicknesses. Natural enemies and botanicals play a vital role to control pests with different mechanisms. Microbial, for example, microscopic organisms, growths, and infections are the major biopesticides being concentrated generally to create contrasting options to chemicals. The number and development rate of biopesticides demonstrate an expanding promoting pattern in recent decades. Biopesticides are host particular and biodegradable bringing about slightest persistency of leftover poisonous quality. Biopesticides make key commitments to IPM and can enormously lessen ordinary pesticides. Nowadays, the globe is working on protein-based biopesticide, and it is very effective method to control the insect pest.

Keywords: pests, biopesticide, food security, microorganism, natural enemies, protein

1. Introduction

1.1 Losses due to pests

Among all the crops, the total loss due to the pests varied for each crop likely for wheat 50%, cotton 80%, maize 31%, rice 37%, potatoes 40%, and soybean 26%. Weeds are the major problem in production, and its effects are almost 34% losses. Pathogens and animal pests are also problem in production, but its loss is less as compared to pests, loss due to pathogens is 16% and loss due to animal pests is 18% [1].

1.2 Use of pesticides

Agricultural pests like weeds, insects, pests, and plant pathogen are managed by using pesticide-insecticide. To control the pests, the cost of machinery, fuel, and labor is reduced [2–4]. The advantages of pesticides are production cost is lower, yield is high, and farmer's revenues become high [5]. For crop production, the pesticides are used worldwide and increased about 20 times from 1960 to 2000 [1], in 2002, the usage of pesticide becomes high and it was 1.0 billion tons, and in 2007, it reached to 1.7 billion tons. China is one of the major producer and also the most intensive insecticide-pesticide user in production of crops in the world [6, 7].

In China, the pesticide producers are more than 2800. There are more than 20 large industries which produce the pesticides with a capacity of 5000–10,000 tons per year. Registered active ingredients are more than 600, and up to 2005, the total products (or formulations) were 22,000. Last year, the total amount for production of pesticide was more than 1 million ton. In the sense of active ingredient, 0.28 million tons and almost 1.4 million tons of formulated products are used and every year 20 million hectares. Nearly 30–40% yield loss could be evaded. There are more than 400 million farmers and 200,000 distributions [8].

1.3 Safety of food in field and on agricultural practice

Pesticides are used to increase the crop production in agricultural farms. But the pesticide also has some sewer effects on human health even death because it contains poison. These residues are more effective on children as compared to adults. Different agricultural practices are used to keep the pest population below the economic threshold level. The use of pesticide application is the most adoptable technique used by farmers for the production of agricultural products. But these chemical pesticides caused many serious problems. Due to the indiscriminate use of pesticides for the better production of agricultural products, food residues remain in these products, which cause health problems in human after consumption of these products [9].

2. Threats of pesticides

2.1 Effect on humans and environment

Asthma, learning disabilities, diabetes, birth defects, autism, reproductive dysfunction, Parkinson's and Alzheimer's diseases, and many types of cancer are the most common diseases that affect the health of human in twenty-first century. The chronic diseases and death rate are about 1 million/year people due to the pesticides because they contain poison [10]. The residues of pesticide remain in or on the food after they applied on crops [11]. In many countries, it were seen that the levels of these residues in foods are often stipulated by regulatory bodies. Now, people are going to aware about the residues that occur in the edible food. Several pesticide residues especially exhibit bioaccumulation and derivatives of chlorinated pesticides which could develop harmful effect in human and animal body, also in environment [12]. Pesticides-insecticides can contaminate turf, soil, water, and other vegetation. For reducing or finishing the insects-pests or weeds, we use pesticides-insecticides but it will also be harmful for the other organism like beneficial insects, birds, and also nontarget crop or plants. Pesticides-insecticides contain acute toxic, but herbicides also pose risks to other plants or nontarget organisms [13]. One of the environmental science books is Silent Spring and the author of this book is Rachel Carson, which was published in 1962. In the book, the harmful effects on the environment, predominantly on birds of excessive use of pesticides, Rachel Carson accused the chemical industry for scattering half-truth and public officials of accepting industry claims without any question [14].

3. Types of insecticides

3.1 Transfer processes

Adsorption is the process in which insecticide fix (bind) with soil particle. According to the law, different charges can attract each other, this can be done because insecticides have positive charge and soil particles have negative charge, and moisture helps in absorption. Due to insistence of some insecticides, the insecticides keep on in the field soil for a long time and can be absorbed by plants grown in the field. Leaching is the process in which insecticide can move through soil instead of over the surface. An insecticide is dissolved with the irrigation water and then applied to the field plant. So, solubility is the mail factor. Volatilization is the process in which solid or liquid changes into gas. When volatilized, the insecticide can move away from treated area by the help of air. With the help of vapor pressure, we can determine that the insecticide will volatize or not. If the vapor pressure is high in the air then insecticide will be volatile. Spray drift is the process in which the droplets of spray move away from the application site during application. Runoff is the process in which the insecticide can move with water in the sloping surface. Insecticide may move as it is mixed with water or fasten to the soil particles of destroying soil. It relies on the slope of area; moisture content, rely and texture of soil [15].

4. Degradation or breakdown processes

It is the process in which the insecticide can break down with the help of light, microbes, and chemical reactions. This process may be done in hours or may take days or years; the breaking down of insecticide depends upon the chemical characteristics of the insecticide and environmental factors.

Microbial breakdown is the process in which the insecticide can break down with the help of microorganism's likely bacteria and fungi. When favorable conditions are available like warm temperature, appropriate soil moisture and oxygen, and favorable pH, the microbial breakdown increases. Chemical breakdown is the process in which the insecticide can break down with the help of chemical reactions in the soil. The type and also the rate of chemical reactions that happen are influenced by pH levels, soil temperature, and moisture and fixing of insecticide-pesticide to soil. Photodegradation is the process in which the insecticide can break down with the help of sunlight. Almost all the insecticides are break down in sunlight to some level. The breaking down of insecticide depends upon some factors like properties of the insecticide, intensity of light, and intensity of light [15].

5. Biopesticides: an alternate to traditional chemical pesticides

Environmental stewardship and food security are the most important factors that involved in agriculture. In many cases by the misuse of insecticide led to population resurgence, pesticide residues, and pest resistance. By using less opportunities once a legend idea, biopesticides are widely available, and this idea is working very rapidly. The biopesticide is an alternate way to control pests, and this method is environmentally friendly as well as effective [16].

6. Role of biopesticides in China

In 2008, the entire 97 varieties of biopesticides existed in China and cover the market with biopesticide with 6 billion yuan and it is the 10% of total sale of pesticide. At present, in China, some problems occur in commercializing biopesticides. The agricultural production is low that cannot fulfill the demand of farmers. The production technology of biopesticide is not good enough; less ability of innovation and concentration of industry are also low. They just encouraged the use of biopesticides in some varieties such as fruits, leafy vegetables, and melons. Chinese herbs and tea are also encouraged but on a small scale. The Chinese Government must implement hard policies of agricultural environmental and solid measure to promote biopesticide against pest in the production of agriculture [17].

7. Major classes of biopesticides

In biopesticide, there are certain of pesticide derived from natural materials as bacteria, certain minerals, animals, and plants. There are three types of major classes of biopesticides [18].

7.1 Biochemical pesticides

These are naturally occurring substances that control pests by nontoxic mechanisms. The conventional pesticides kill or disable the pest by contrast. Biochemical pesticides have some substance that interferes in mating, like sex pheromones, also different fragrance of plant extract attracts the pests to trap. Because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide, EPA has established a special committee to make such decisions [18].

7.2 Microbial pesticides

The microorganisms like virus, fungus, protozoan, or bacterium are the active ingredient in this type of pesticides. Each microorganism have specific active ingredient to control the specific pests, but microbial pesticides can control or kill many kinds of pests which damage the crop production. One fungus can control the weeds and other control or kill the insects-pests [18].

7.3 Plant-incorporated-protectants (PIPs)

These are pesticide substances produced by plants from genetic material which are inserted in plant. Scientists take the gene for BT pesticide protein and insert into plant's own genetic material. After inserting the gene of *Bt* bacterium in the plant, the plant prepared the substance that can destroy or kill the pest. The plant's genetic material and protein, but not plant itself, regulated by EPA [18]. An insect-toxic protein, Bb70p, was purified from *Beauveria bassiana* 70 using ammonium sulfate precipitation, ion exchange chromatography, and gel filtration. The protein caused high mortality by intra-hemocoelic injection into *Galleria mellonella*. Thus, Bb70p appears to be an insect toxin protein, demonstrating novelty. Identification of this insect-toxic protein presents potential to enhance the virulence of *B. bassiana* through genetic manipulation [19].

8. Biopesticide characteristics

Biopesticides have some characteristics:

1. Target range of biopesticides is narrow and used for specific problem.

2. Biopesticides work slowly.

3. Biopesticides suppress the pest population rather than eliminate.

4. Application time of biopesticides is somewhat critical.

5. There is limited field persistence and shelf life.

6. Biopesticides often used as amount of IPM programs.

7. They are much more suitable for human as well as for environment than conventional pesticides.

8. No residue problems commonly present by biopesticide.

9. Biopesticide application on food safety

Food safety requires wide application range of biopesticides which includes:

If one organism is feed on other organism, this is called its natural enemy. The beneficial insects are those insects that feed on pests. In order arthropods, for example, mites and spiders are beneficial [20]. Microbial pesticide exists naturally or by genetically changed fungi, protozoans, bacteria, algae, or fungi. This can be used as an alternate method to chemical insecticide, this is very effective. Biological toxin material is derived from microorganism, for example, fungus or bacterium, this is called microbial toxin. These types of microorganism may cause death or rupture the gut of the pest because these entomopathogens are highly toxic. Studies proved that pathogen develops insecticidal toxin that are very much important in pathogenesis [21]. Antibiotics are the substance that stops the growth or kills microorganism, including both fungi and bacteria. In "bactericidal", the antibiotics kill the bacteria, whereas in "bacteriostatic", the antibiotics stop the growth bacteria. It is the success of biotechnology that develops the transgenic crops which are resistance against the major pests and also commercialize the transgenic crops. In first generation, the products include plants with just single insecticidal *Bt* genes, which shows resistance against the major pests of cotton and corn [22]. In the search for alternative solutions to crop protection problems, the interest in plants and their chemobiodiversity as a source of bioactive substances has increased. Plants are capable of synthesizing an overwhelming variety of small organic molecules called secondary metabolites, usually with very complex and unique carbon skeleton structures [23]. For many years for the protection of crops, these substances are used for the benefit of mankind [24]. Plants release some chemicals in environment and when they are used as smother crops, green manures, intercrop, cover crop or mulch, or in rotational sequences grown than it can invade insect-pests and pathogenic diseases and shows the progress in the yield of crops [25]. Botanicals include crude or semi refined extracts and isolated or purified compounds from various plant species and commercial products [23].

10. Microbial pesticides

Entomopathogenic fungi are considered as essential natural regulators in population of different insects. These fungi have potential as mycoinsecticide agents alongside different agricultural insect pests. The mode of actions of these fungi mainly cause infection in body of their host through cuticle penetration, acquisition entrance to the host hemolymph, production of toxins, and grow by consuming nutrients which are existing in the hemocoel to avoid immune responses in insects [26]. A total of 1600 different types of viruses are involved in the infection of 1100 different species of insects and mites. Baculovirus is considered as a distinct group of viruses. About 100 species of insects are susceptible to this group of viruses. The main feature of this virus group is host specification [27]. Bacterial biopesticides are considered as the most common and inexpensive method of microbial pesticides. Different species of butterflies and moths as well as species of flies, beetles, and mosquitoes are generally controlled by these biopesticides. Bacteria which are used as bacterial pathogens to manage insect pest populations are mainly spore-forming and rod-shaped bacteria in the genus *Bacillus* [28]. The EPNsn introduces symbiotic, pathogenic bacteria of the genera *Xenorhabdus* (in the Steinernematidae) or *Photorhabdus* (Heterorhabditidae) into the hemocoel of their hosts following penetration. Subsequent multiplication of the bacteria leads to host death, which can occur within as little as 48 hours of infection. Nematodes infected insects usually have abnormal behavior than uninfected individuals. The nematode can kill its host without its associated bacterium but is unable to reproduce without it. They have also been used with commercial success against citrus root weevil, against turf pests and on mushroom crops (**Figure 1**) [29].

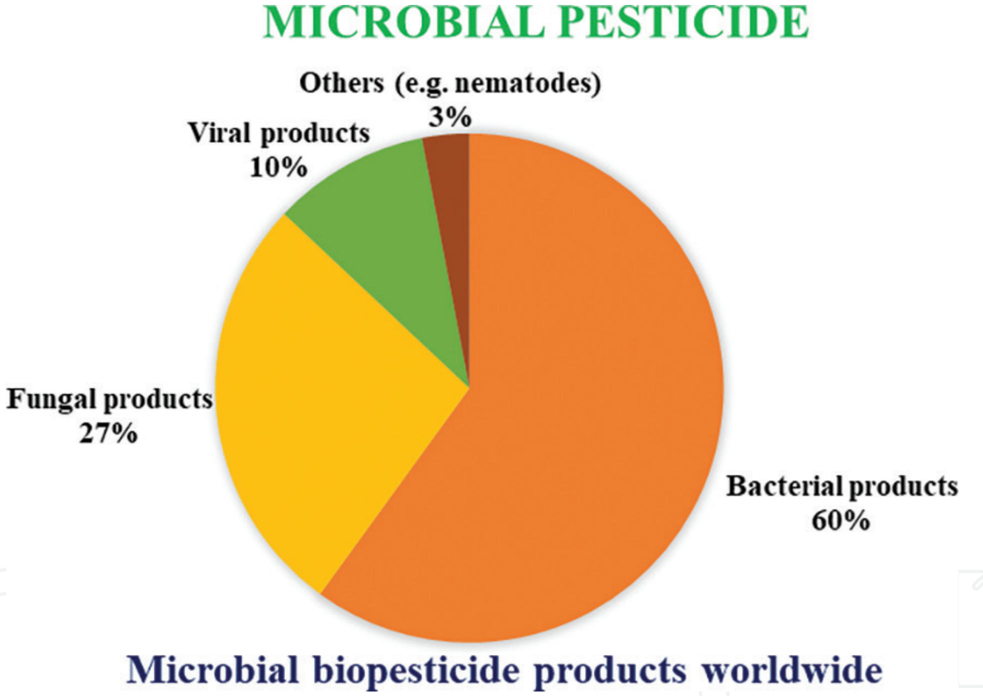

Figure 1.
Microbial biopesticide product worldwide active ingredient: microorganism (bacteria, fungi, virus, nematodes, etc.) (Source: Division of Agricultural Chemicals, 2011).

11. Botanicals

An extensive variety of secondary metabolites were produced by plants that prevent herbivores from feeding on them. These chemicals comprise phenolic compounds (e.g., tannins), glucosinolates (e.g., mustard oil), glucosinolates (e.g., mustard oil), and terpenoids (volatile oils, e.g., limonene). As a plant protection products about 50 different botanical active substances are registered in USA, nevertheless just 11 are registered in the EU. Pesticides are derived from plants and generally act in two ways: that is, stomach poison and contact poison. There are about 250,000 plant species that were evaluated from which 2121 are used in the management of pest, 1005 are demonstrated insecticidal activity, 384 are antifeedants, 297 are repellents, 27 are attractants, and 31 have growth inhibiting properties [30].

11.1 Characteristics of major traditional botanicals

There are some traditional botanical insecticides with their source, mode of action, toxicity, and uses [31] (**Table 1**).

Botanical insecticide	Source plant (s)	Mode of action	Toxicity	Uses
Pyrethrins	Flowers of pyrethrum daisy, *Tanacetum (Chrysanthemum) cinerariaefolium*	Interferes with Na and K ion movement in nerve axons	Mammalian oral LD_{50} > 1000, some allergic reactions can occur	On humans and pests to control lice, fleas, ticks. Rapidly breaks down
Rotenone	Roots of *Derris, Lonchocarpus, other tropical legumes*	Disrupts energy metabolism in mitochondria	Oral LD_{50} = 25–3000 Dermal > 1000	In orchards and gardens against several insects mainly beetles. Persists effectively for 4–5 days or more. Use as a fish poison
Sabadilla	Seeds of tropical European *Veratrum album* and lily *Schoenocaulon officinale*	Interferes with K and Na ion movement in nerve axons. Irritates mucous membranes and skin, potent inducer of sneezing	Oral LD_{50} near 4000	In fruits and vegetables against bugs and citrus thrips. Rapidly breaks down
Ryania	Wood stems of *Ryania speciosa*	Activate Ca++ ion release channels and causes paralysis in muscles of insects and vertebrates	Oral LD_{50} near 1000 Dermal near 4000	In fruit crops and fields against thrips and caterpillars. Frequently combine with pyrethrins and rotenone in commercial mixtures for use of garden

Botanical insecticide	Source plant (s)	Mode of action	Toxicity	Uses
Nicotine	Tobacco, *Nicotiana* sp., *Duboisia, Anabasis, Asclepias, Equisetum, Lycopodium*	Mimics acetylcholine and overstimulate receptor cells to cause convulsions and paralysis	Oral LD_{50} = 3–188 Dermal near 50 Very toxic to humans	Mostly in greenhouses and gardens. Nicotine fumigations target aphids, thrips and mites
Neem	Seeds, leaves, bark of chinaberry (*Melia azedarach*) and neem (*Azadirachta indica*)	Biochemical nature of feeding deterrence, repellence, growth regulation effects are not well described	Oral LD_{50} > 13,000	Medicinally use in humans. On landscape plants and many crops mainly against secondary pests and soft bodied. Very short persistence on treated plants
Limonene/Linalool	Citrus oils	Causes spontaneous stimulation of sensory nerves, biochemical mode of action	Limonene oral LD_{50} > 5000 Dermal > 3500	Mostly in pet shampoos, dip and sprays to kill ticks and fleas. Very short persistence on treated plants

Table 1.
Features of foremost traditional botanicals [31].

12. Natural enemies

If one organism is feed on other organism, this is called its natural enemy. The beneficial insects are those insects, which are feed on pests. In order arthropods, for example, mites and spiders are beneficial. Beneficial arthropods are of different types, parasitoids and predators. Predators like spiders and ladybug; they attach on many kinds of insects and will eat many preys in their life cycle. Parasitoids are flies or wasps that lay eggs inside or on the body of other arthropods, also called parasite. When the egg hatches inside or on the body of other arthropods, the immature parasitoid comes out and feeds on the victim, this is called host, finally killing it. Developing parasitoid, in his life cycle kills only one host. Diseases also affect the insects. Entomopathogens or insect diseases are microorganisms that attack insects and contain nematodes, viruses, fungi, and bacteria. There is some exception that warm-blooded animals cannot affect by the disease attacked by arthropods. To control weeds, sometime plant disease agents and insects are used [20].

There are few natural enemies that are very important from many beneficial insects.

Lacewings found the colonies of aphid to consume just like lady beetles. They feed on scales, mites, mealy bugs, insect eggs, and also on aphids. Stink bugs are called very severe pests and these bugs are useful predators because the eating behavior vary among different species. Searching behavior of lady beetles is frantic; they always bite quickly to eat that helps to understand lady beetles. They feed on many small insects, and no matter that prey is on which stage the aim is just killed. They mostly eat aphid due to his small size but many lady beetles also eat beetle grubs, small caterpillars, whiteflies, mealybugs, scales, mites, and all types of insect egg. From some mites, the spider mites are serious pest of plants but some are beneficial. From all the beneficial mites, the phytoseiid mites are mainly important, the reason is that it is the predator's plant feeding mites and also small organism like thrips or eggs of insect [20].

13. Antibiotics of agricultural

Antibiotics are the active biomolecules obtained from different microorganisms (bacteria, fungi, and actinomycetes). Few antibiotics are derived from plant origin also. Antibiotics kill the pathogens, disease causing harmful microorganisms by interfering with their molecular process like transcription translation, etc., or also by inhibiting the process which are very essential for the survival of pathogens like cell wall synthesis, etc. Antibiotics are further categorized into narrow range and broad spectrum antibiotics. Antibiotics are given orally as well as injected intravenous.

Different antibiotics are used in agriculture. Names of these antibiotics are as follows:

- Validamycin
- Avermectin
- Polyoxin
- Zhongshengmycin
- Wuyimycin
- Agricultural antibiotic 120

14. Insect sex pheromone

The sex pheromones are released by female to attract the male for mating, the female do this with for sexual reproduction. Sex pheromones are for breeding and for attraction of opposite sex and transferring information on their species, sex, age, and genotype after released by male. Volatile pheromones are called as defensive pheromones or sex pheromones, and they have a particular smell and focused on the sensitivity of alarm [32].

14.1 Application of insect sex pheromone

Pheromones are used in the following manners in pest management practical

- Pheromones are used for detecting by surveying and monitoring
- By using pheromones, it is easy to know the resistance of insecticide
- Pheromones are used to attract the pests to that area which is treated with poison or insecticide
- Population suppression by mass trapping
- Pheromones are also used to attract the pest to sterile them

15. Difference between chemical and biological pesticide

Chemical pesticide	Biological pesticide
Nontarget species are also harmed due to chemical pesticides	These do not harm nontarget species
These cause pollution, sometime serious	They do not pollute the environment
Harmful pesticide residues may often remain in food, fodder, and fibers	These have no harmful residues remaining in food, fodder, and fibers
These are relatively costlier	These are relatively cheaper
Insects may become resistant to pesticides, e.g., *Heliothis* has become resistant to most insecticides	Insects are expected not to develop resistance to biopesticides
They are nonspecific to target, so accurate identification of the pest is not necessary	Since they are highly specific, so correct identification of the pest is essential
High specificity often not required to make the use of pesticides	High specificity may often make the use of two or more biopesticides necessary
	Performance may be variable due to the influence of biotic and abiotic factors of the environment

16. Role of biopesticides in organic agriculture

Organic farming is a system used to produce agricultural products like food and fiber. The main aim of organic farming is that to develop biological diversity in the field to disturb the habitat for the organisms of pests, and the purposeful maintenance and replenishment of soil fertility. Biopesticides are used in organic agriculture for minimizing the pest population. To control harmful organisms or pests, different parts of plants are used like chili and garlic due to their strong smell against insects. Against mosquito sweet, basil is used as a repellent and so on. Biopesticides have bright future in the case of organic agriculture [33].

17. Future of biological control

In an environment, natural enemies are responsible for the regulation of 98% pest. From these 98%, only 5% pests have been controlled by the use of

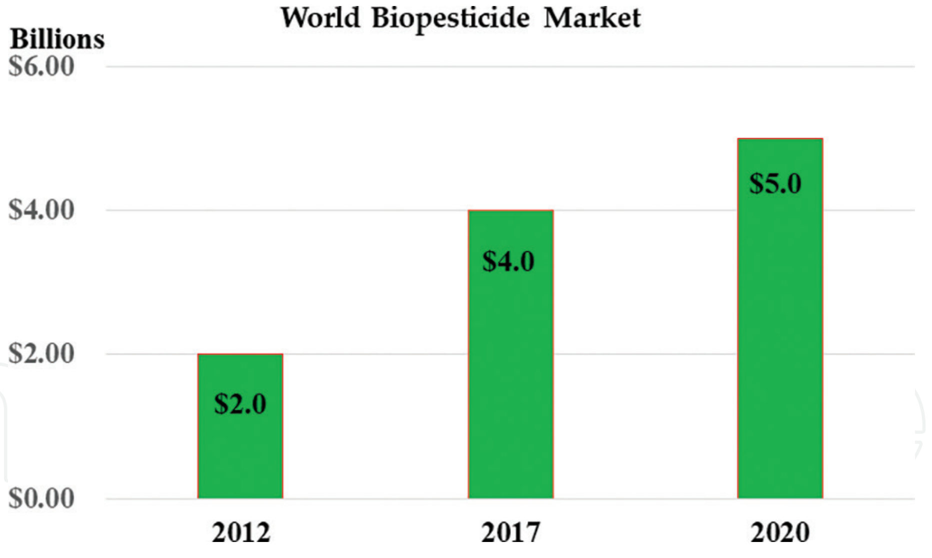

Figure 2.
World biopesticide market, fruit and vegetable crop represent 80% of usage (Source: Piper Jaffray Agricultural Note, August 2013).

entomopathogenic fungus. Reduction of insecticide use and exploitation of biocontrol agent can help in the population regulation of different pest and biocontrol agents. The importation of new predators and parasitoids in an environment is also a good source of biological control. The use of some new trends like strains, biotypes, and hybrids of parasites, fungal biopesticide, and use of different viruses also need attentions to be explored properly and can be used for the management of pests. The use of biocontrol agent has numerous advantages, but it is important to modify the other methods of control like the use of pesticides. The pesticides must not be very toxic to biocontrol agents, for example, endosulfan is less harmful to many natural enemies. Biocontrol helps in upholding 'Balance of Nature' as it is the phase of natural control [34].

Biopesticide, from a long time attracting the world consideration as safe and sound plan than chemical control of pest with less hazard to environment and the human. The collaboration between private and public sectors is compulsory to assist the growth, manufacturing, and sale of this environmentally friendly alternative. With research, new substances will be formulated and the delivery will also help in commercialization and usage of biopesticide. In developing countries, one of the most important factors is the availability and quality of the given product must be in low price. New products could help as promising choice against pest; further more research in field is necessary to confirm the efficacy on target pest in many cropping systems [35] (**Figure 2**).

18. Conclusion

Biocontrol is environmentally friendly and active means of decreasing or mitigating pests and pest effects through the use of natural enemies. The goal of b*iocontrol* is to promote the technology and science. Biological control is a technique of controlling pests, that is, mites, insects, weeds, and plant diseases by using other microorganisms.

Biopesticide is used for the modification of development of insect and behavior exerts unique approach for management of insect population. The application of biopesticide is based on the principle that is to provide safety to the human and environment. Wide research is going on, and it is required much more in future to achieve the improvement. The future of biopesticide would fully depend on adoption of application of biopesticide. Versatile use of biopesticide must meet the aims. They must able to control/suppress/kill the harmful insects pests and also prevent them, relatively in proper manner to conventional methods. Researchers, producers, and farmers should widely explore the use and find the safe environment and also maximum production of crops.

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Conflict of interest

Authors have declared no conflict of interest.

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