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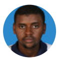
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BIOPESTICIDES FOR PESTS CONTROL: A REVIEW

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ABSTRACT

Despite the harmful implications involved in the use of synthetic chemicals to control pests, still they are extensively used in all countries all over the world. The increased social pressure to replace them gradually with other alternatives that are safe to humans and non-target organisms has led to increased development of compounds based on the models of naturally occurring active ingredients of biological origin, having various biological activities known as "biopesticides". Biopesticides are broad array of microbial pesticides, biochemicals derived from micro-organisms, phytochemicals and other natural sources, and processes involves the genetic modification of plants to express genes encoding insecticidal toxins. The use of biopesticides for pest control today is an evolving field in pest management. This paper reviewed the current state of knowledge on the potential use of biopesticides for pests control globally, highlighting the concept of biopesticides, their categories, utilisation in pest management, formulations, application technology/method at different stages of advancement in both delivery and efficiency with their classical/key examples of successful use in commercial control of pests for agricultural crops and finally with empherical information on mechanisms of actions of biopesticides on pests control.

Keywords: Biopesticides, control, formulations, pests, phytochemicals.

1. INTRODUCTION

Destructive activities of numerous pests like plant pathogens (fungi, bacteria, nematodes etc), insects and weeds have plagued agriculture and this leads to a drastic decrease in yields (Saima and Jogen, 2011). Crop losses caused by pests coupled with other problems like inclement weather, farmers' limited access to technical know-how and poor soil conditions undermine food security. About 40 per cent reduction in the worlds crop yield due to pests has been estimated (Oerke *et al.*, 1994).Management of these pests to increase food security in order to meet the needs of increasing human populace is imperative and this should be done in such a way that no damage is done to human health, public goods and environment that farming brings (David *et al.*, 2011; Bastianns *et al.*, 2008). Over the past half of the decade, crop protection against pests depend solemnly on chemical pesticides and new legislations on chemical usage and the evolution of resistance in pest populations has resulted in their declining usage. Besides this, the use of synthetic pesticides is significantly becoming more difficult due to a number of factors notably among them are:

a) Management failure as a result of excessive prophylactic use of pesticides through pest resurgence and the development of heritable resistance (Van Emden *et al.*, 2004).It was estimated that there are close to 200 species of weeds that are resistant to herbicides (Heap, 2010) and over 500 species of arthropods have developed resistance to some insecticides (Hajek, 2004).

b) Not feasible to peasant or local farmers because of their expensive costs and also their effect on target organisms.

Having these incessant problems or drawbacks associated with the use of synthetic chemicals to control pests, it is imperative to look for eco-friendly method that will serve as an alternative to chemicals (biopesticides). Biopesticides are effective, biodegradable with no residuals in the environment. Due to the adverse effects of chemicals, biopesticides development is increasing and that their efficiency against pests is significant (Salma and Jogen, 2011). The aim of this review is to critically highlight the potentials of biopesticides for pest control.

2. CONCEPT OF BIOPESTICIDES

Bio-pesticides are naturally occurring substances from living organisms (natural enemies) or their products (microbial products, phytochemicals) or their by-products (semiochemicals) that can control pest by nontoxic mechanisms (Salma and Jogen, 2011). Organization for Economic Co-operation and Devlopment (2009), viewed biopesticides as manufactured mass produced agents derived from natural sources living micro-organisms and sold for use to control pests. According to Suman and Dikshit (2010), biopesticides encompass a abroad array of microbial pesticides, biochemicals obtained from micro-organisms and natural sources. Historically, biopesticides has been associated with the biological control and by implication, the manipulation of living organisms as indicated in Table 1.

3. CATEGORIES OF BIOPESTICIDES

Biopesticides fall into four (4) major categories:

(1) Microbial pesticides (3) Plant-Incorporated-Protectants (PIPs)
(2) Biochemical pesticides (4) Semiochemicals

3.1 Microbial Pesticides: These consist of microorganisms such as bacterium, virus, fungus, protozoan as active ingredients which are used for the biological control of plant pathogens, pestiferous insects and weed. The most widely used microorganism in the development of biopesticide is the insect pathogenic bacterium *Bacillus thuringiensis*(Bt). This bacterium serves as an insecticide for most Lepidoptera, coleopteran anddiptera (Gill *et al.*,1992). *B. thuringiensis* produces protein crystals or toxin during spore formation of the bacterium that is capable of lysis of gut cells when consumed by a specific or susceptible insects (Chandler *et al.*, 2011).

3.2 Biochemical Pesticides: They are also known as herbal pesticides (Pal and Kumar, 2013) are naturally occurring substances used for controlling pests through a non-toxic mechanism and because it is difficult sometimes to assessed whether a natural pesticide can control the pest by a non-toxic mode of action, Environmental Protection Agency (EPA) has established a committee to determine whether a pesticide meets the specified criteria for a biochemical pesticide (Salma and Jogen, 2011). Plants that produced secondary metabolites are also considered as biopesticides (Schumutterer, 1990).

3.3 Plant-Incorporated-Protectants (PIP): PIPs, also known as Genetically Modified Crops, are biopesticidal substances produced by plants from genetic material that have been added or incorporated into their genetic makeup. A typical example of this is the use of Bt protein to develop PIP in a process called genetic engineering. The Bt toxin is host specific and is capable of causing death within a short time, usually 48 hours (Siejel, 2001). Safe to beneficial organisms, human, environment and it does not harm vertebrates (Lacey and Siegel, 2000).

3.4 Semiochemicals: A semiochemical by definition is a chemical signal produced by one organism, usually insects which caused a behavioural change in an individual of the same or different species. For crop protection, the most widely used semiochemicals are the insect pheromones which serve as a signal to communicate with others in their species for a number of reasons and synthesized for pest control by mating disruption, Lure-and-Kill systems and mass trapping (Preddy *et al.*, 2009).

4. BIOPESTICIDES FORMULATIONS

In most cases, the active ingredients of biopesticides are formulated in the same way as the synthetic pesticides and most convenient for farmers to use the same equipment for application (Slavica and Brankica, 2013).The basis for most of the biopesticides is living organisms and their viability have to be maintained during the formulation process and stored at acceptable levels. The organisms must revive from their dormant state in order to be active at the application time (Boyetenko, 1998). Final product is maintained by mixing the microbial component with different carriers and adjuvants during formulation process for better protection from environmental factors, controlled rates, improved bioactivity and storage stability. To achieve the most important function of the developed biopesticides formulation such as easy handling and application of the product, stabilization of the microbial agent during distribution and storage, protection of the bioagent from adverse environmental conditions, enhancement of the bioagents activity by increasing contact and interaction with the target pest is necessary to ensure these, Biopesticides are formulated in various ways (Mollet and Grubenmann, 2001).

Depending on the physical states of the biopesticide formulation as dry or liquid forms, the active ingredients are produced by addition of stabilizers, synergist, spreads, stickers, surfactants, colouring agents, anti-freezing compounds, additional nutrients, dispersants and melting agents (Brar *et al.,* 2006; Knowles, 2008) as presented in Table 2. In general, biopesticides are usually formulated as dry formulation (for direct applications) and liquid formulations.

4.1 DRY FORMULATION FOR DIRECT APPLICATIONS:

4.1.1 Dustable Powders (DP): Active ingredient concentration for dust formulations is usually 10% and is formulated by sorption of active ingredient on finely ground, solid mineral powder (talc, clay etc.) with particle size ranging from 50-100 mm. The inert ingredients for dust formulations are UV protectants, adhesive materials (i.e. stickers) to enhance adsorption and anticaking agent (Slavica and Brankica, 2013).

4.1.2 Granules (GR): Active ingredient concentration for granules ranges from 2-20% and the active ingredients either coat the outside of the granule or are absorbed into the granules. To control the rate of effectiveness of active ingredients after application, granules can be coated with resins or polymers. Granules are mostly applied to control insects living in soils,weeds and nematodes for uptake by roots. Granules with coarse size particles range from 100-600 microns made from such materials such as kaoline, silica, starch, polymers, groundnut plant residue, dry fertilizers etc. (Slavica and Brankica, 2013; Tadros, 2005). Some granules release their active ingredients after exposure to soil moisture.

4.1.3 Seed Dressing(SD): A kind of biopesticide formulation obtained by mixing active ingredient carrier in form of powder and accompanying inert to facilitate end product adherence to seed coats. Powders for seed dressing are applied to seed by tumbling seeds with the product designed to adhere to them and they also contain colouring agents inform of red pigment as a safety maker for treated seed (Woods, 2003).

4.1.4 Wettable Powders (WP): These are also dry formulation ground finely and applied after suspension in water. Wettable Powders are obtained by blending active ingredients with melting and dispersing agents, synergist, surfactants, and inert fillers. Strict safety measures are usually taken because of their dustiness that can cause serious health problems to manufacturers and during application. Besides, WPs have long stability during storage, good miscibility with water and can be applied with conventional spraying equipments (Brar *et al.,* 2006; Knowles, 2008).

4.1.5 Water Dispersible Granules (WDG): It is designed to be suspended in water and to overcome problems associated with WPs, dust free and with good storage stability (Knowles, 2008; Slavica and Brankica, 2013).

4.2 LIQUID FORMULATIONS:

4.2.1 Emulsion: Emulsion formulations are designed to be mixed with water and it could be normal emulsion which is oil in water (O/W) or an inert emulsion which is water in oil (W/O). Most importantly, the proper choice of emulsifiers for stabilization to avoid instability is necessary. But in the case of water in oil emulsion due to oil in the external phase of the formulation, losses as a result of evaporation and spray drift are minimal (Brar *et al.,* 2006; Slvica and Brankica, 2013).

4.2.2 Suspension Concentrate (SC): Formulated by mixing finely ground, solid active ingredient dispersed in liquid phase, usually water. Agitation is always a requisite before application to keep particles evenly distributed because the solid particles are not dissolved in liquid phase. The particle size distribution is 1-10 µm and these small particles size offers easier access of the active ingredients to plant tissue and improved bioefficiency. It is a popular type of formulation because of safety to operator and environment (Knowles, 2005; Woods, 2003).

4.2.3 Suspo-Emulsion (SE): Is a mixture of emulsion and suspension concentrate and highly demanding formulation, because it is necessary to develop a homogenous emulsion component with a particle suspension component so that the final product will remain stable. In addition, it is necessary to be carried out using storage stability resting (Knowles, 2008).

4.2.4 Oil Dispersion (OD): The product of the formulation is produced in the same ways as suspension concentrate. Instability problems could be avoided by proper selection of inert ingredients (Vernner and Bauer, 2007).

4.2.5 Capsule Suspension (CS): Active ingredients are formulated in micro-encapsulated stable suspension intended for dilution with water before use. Capsules made from gelation, starch, cellulose and other polymers are used to encapsulate the bioagents and in this way the bioagents are protected from the harsh environmental conditions. Interfacial polymerization principle is the most frequent applied method of encapsulation which is used to give smaller size and highly efficient formulations typically fungal biopesticides (Winder *et al,* 2005).

4.2.6 Ultra Low Volume Liquids (ULV): Formulations not intended to be diluted in water before use and have concentration of active ingredients. It is easy to transport and can be formulated using a suspended biocontrol agent as an active ingredient (Woods, 2003).

5. BIOPESTICIDES APPLICATION TECHNOLOGY/METHODS

Effective control of pests can be achieved by good selection of application techniques/methods and an appropriate time and/or frequency of biopesticides application. The following are some of the methods of biopesticides application:

5.1 Seed Treatment: One way to apply biopesticides is by seed treatment and is the most effective method or technique. Powder formulations are applied on seeds by tumbling seed with the product that is designed to adhere to the seed (Matthew *et al.*, 2014; Wood, 2003).

5.2 Foliar Application: Simply means biopesticides application on leaves surface as sprays. For example application of *B. subtillis* to bean leaves reduced the incidence of bean rust caused by *Uromyces phaseoli*.

5.3 Seedling Dipping: This involves dipping roots of the seedlings in biopesticides suspension for some minutes or hours prior to transplanting. For example *Trichoderma spp.* are applied in this way.

6. MECHANISMS OF ACTION OF BIOPESTICIDES FOR PEST CONTROL:

They include the following:

1) Antibiosis 2) Competition 3)Hyperparasitism 4) Synergism

6.1 Antibiosis: This occurs as a result of an interaction with other microbes (microorganisms) mediated by specific metabolite of microbial origin, by volatile compounds, lytic enzymes or other toxic substances (Rikita and Utpal, 2014). The microorganisms produce antibiotics, bacteriocin, volatile compound and metabolite production.

6.2 Competition: Another mechanism of control by biopesticides is their ability to compete aggressively, that they grow rapidly and colonize substrate to exclude pathogens. For example *T. spp.* are aggressive competitors of *Fusarium spp.*

6.3 Hyperparasitism: Hyperparasitism is the lysis of the death by other microorganisms or direct parasitism. For e.g *T. lignorum* is found to be parasitizing the hyphae of *R. solani* and therefore soil inoculation with *Trichoderma* spores help to control damping off disease in citrus seedlings (Rikita and Utpal, 2014).

6.4 Synergism: The ability of some bioagent to combine actions of hydrolytic enzymes and antibiotic secondary metabolites. For example the effectiveness *T. spp.* as a biocontrol agent and its fitness in the environment is as a result of synergistic effects of antimicrobial compounds. Example includes pyrones, coumarins etc.

7.1 GENERAL ADVANTAGES OF BIOPESTICIDES

The interest in biopesticides is based on the benefits or advantages associated with such products. They include:

1) Biopesticides are usually inherently less harmful/toxic and cause less environmental load or pollutions.
2) Designed to only one specific pest or, in some cases, a few target pests as opposed to chemical that have a broad spectrum activity.
3) Cost of developing biopesticides is significantly lower than those of synthetic chemical pesticides.
4) Their nature of control is preventive not curative and their effects on flower is less.

7.2 DISADVANTAGES OF BIOPESTICIDES

1) Speficity is high which may require an exact identification of the target pest/ pathogen.
2) Because of their slow speed of action, biopesticides are often unsuitable if a pest outbreak is an immediate and becames a threat to crops.
3) Biopesticides are not suited for a stand-alone treatment rather they have to be with a compartible method for high efficacy.
4) Living organisms evolve and increase their resistance to biological, chemical, physical and any other form of control.

8. CONCLUSION

The increasing concern of consumers at one hand, and government on the other hand about the problems associated with synthetic chemicals for pest control, and on food safety has led growers to find new eco-friendly methods to replace the current chemical-based practices. The use of biopesticides as supplement has emerged as promising alternative to chemical pesticides and their demand is rising steadily in all parts of the world.Therefore, this report has provided some information about the potentials of “biopesticides for pest control” and if fully exploited, could serve as a very effective alternative method for pest control as well as good component of integrated pest management.

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TABLE 1: Some successful experimental use of bio-pesticides against various diseases

Bioagent	Pathogen	Host(Crop)	Reference
Trichoderma viride, T. harzianum	*Macrophomina phaseolina*	Sunflower	
T. viride	*Fusarium oxysforum* f. spudum	Pigeon pea	Kapoor *et al.*, 2010
T. harzianum	*Phytophthoracapsici, Fusariumoxysporum*f. Sp*lycopersici*	Chilli and Tomato	Sriram *et al.*, 2010
Bacillus subtilis	*M. fructicola, M. laxa*	Peaches	Casals *et al.*, 2010
T. harzianum	*Fusariummoniliforme*	Maize	Harleen and Chandler , 2011
T. vride	*Colletotrichumtruncatum*	*In vitro*	Pandit and Kaushal, 2011
T. viride	*Colletotrichumcapsici*	Chilli	Sangeetha *et al.*, 2011
T. viride	*Phytophthoracapsici*	Black pepper	Mathew *et al.*, 2011
Tricihoderma spp.	*Botrytis cinera*	Tomato	Tucci *et al.*, 2011
B. subtilis	*Peronosclerosporasorghi*	Maize	Sadoma *et. al.*, 2011
Trichodermaspp	*Rhizoctoniasolani*	*In vitro*	Kalita *et al.*, 2012
Pseudomonas aeruginosa	*Sclerotiniasclerotiorum*	Tomato	Deshwal, 2012
B. subtilis	*Ralstoniasolanacearum*	Tomato	Chen *et al.*, 2013
Streptomyces spp	*Xanthomonasoryzae*pv.*Oryzae*	Rice	Hastuti *et al.*, 2012
T. harzianum	*Alternariaalternata*	Tobacco	Gveroska and Ziberoski, 2012
T. harzianum	*Pucciniasorghi*	Rice	Dey *et al.*, 2013
T. viride	*Colletotrichumcapsici*	Chilli	Jagtap *et al.*, 2013
T. viride	*Alternariaporri*	Invitro	Yadav *et al.*, 2013
T. harzianum	*Pyriculariaoryzae*	Rice	Dey *et al.*, 2013

TABLE 2: Some bio-pesticides formulations available in commercial quantity

Product name	Active ingredient (Bio agent)	Targets	References
Antagon*	*Trichodermaviridae*	*Rhizoctonia solani* and *Macrophomina phaseolina*	Rikita and Utpal, 2014
Biocon*	*T. viridae*	Root and stem diseases of tea	Rikita and Utpal, 2014
Bioderma*	*T. viridae and T. harzianum*	Pathogens of vegetables, pulse and cereals.	Rikita and Utpal, 2014
Defence-SF*	*T. viridae*	Soil-borne diseases of crops.	Rikita and Utpal, 2014
Biogaurd*	*T. viridae*	Soil-borne diseases of vegetables and pulses.	Rikita and Utpal, 2014
Biotok*	*Bacillus subtilis*	*Corticium invisum* and *C. theae*	Rikita and Utpal, 2014
Biosheld	*Pseudomonas fluorescens*	Fungal pathogens of cereals pulses and vegetables.	Rikita and Utpal, 2014
Regalia*	*Reynoutriasachalinensis*	*Botrytis sp*., Downy mildew, Powdery mildew,*Phytophthora infestans*	Chandler et al., 2011
Contans WG*	*Coniothyriumminitans*	*Sclerotia spp.*	Chandler *et al.*, 2011
Serenade ASO*	*Bacillus subtilis* QST713	*Botrytis spp.*	Chandler *et al.*, 2011
Nema-Q**	*Quillajasaponaria*	Plant parasitic nematodes	Chandler *et al.*, 2011
MeleCon WG**	*Paecilonmyceslilacinus*	Plant parasitic nematodes in soils	Chandler *et al.*, 2011
*Pasteuria usage***	*Pasteuria usage*	Sting nematodes	Chandler *et al.*, 2011
Curbit ***	Zucchini yellow mosaic virus, weak strain.	Zucchini yellow mosaic virus	Chandler *et al.*, 2011
Chontrol****	*Chosondrtereumpupureum*	Cut stumps of hardwoods trees shrubs	Chandler *et al.*, 2011
DeVine****	*Phytophthorapalmivora*	*Morenia orderata*	Chandler *et al.*, 2011
Biomite*****	Citronellol	Tetranychid mites	Chandler *et al.*, 2011
Exosex CM******	(E,E)-8,10dodecadien-1o1	Codling moth	Chandler *et al.*, 2011
Cyd-X [7]	*Cydiapomonella* GV	Codling moth	Chandler *et al.*, 2011
Azatin XL[7]	Azadrachtin	Aphids,scale,thrips,weevil, Leafhoppers	Chandler *et al.*, 2011

Key:*=fungicides,**=nematicides,***=antiviral,****=herbicides,*****=attractants,******=semiochemical,[7]=insecticides.