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Review Article

Biopesticides: A Key to Sustainable Agriculture

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ABSTRACT

Various forms of life have existed in this universe ever since it was created. Many of them vanished in the changing environment and those which could adapt, survived. Among millions of life forms existing in this world, one species - human has got power to alter this world. They are always in search of things which led them to adapt to this changing environment. When pest population was increasing and farm production declining, they searched for ways and means through which these pests could be controlled and thus the synthetic pesticides came into being. Human never thought about the detrimental effects of these pesticides and used them indiscriminately for getting higher production. Later various detrimental effects on soil, environment, human and whole ecology were realized and search for an alternative to synthetic pesticide began and finally biopesticides came into existence. Biopesticides are those pesticides which are extracted from natural or biological means. They are non- toxic in nature giving ecofriendly system for pest control. Ensuring food and nutritional security to ever increasing population of the world is a prime concern, especially when factor productivity is declining, environmental pollution is increasing and natural resources are as always limited. Sustainable agriculture in such situations seems to be viable option. Sustainable agriculture systems are those systems which are economically viable and provide nutritious and safe food with maintaining natural resources for present as well as for future generations. There are various tools followed for attaining sustainability in agricultural production system among which biopesticides is the one.

Key words: *Sustainable agriculture, Biopesticides, Microbial pesticides, Semiochemicals.*

INTRODUCTION

Agriculture is critically important for ensuring food security, alleviating poverty and conserving the vital natural resource on which the world's present and future generation will be entirely dependent upon for their survival and wellbeing. Before 19th century most food in the world was organically produced using organic manure and human and animal power (horses in US and oxen in Asia)[14]. World population was 1.6 billion in 1900 which became 6 billion in 2000 and 6.8 at present. This rapid increase in the human population necessitated the use of modern technologies in agriculture production system.

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Modern Agriculture which largely depends on extensive use of external inputs like hybrid seeds, fertilizers and pesticides for better production has been of great help in alleviating hunger from the world in the last century. However, it has not gone well with the modern agriculture, and it has led to the emergence of several second generation problems like declining factor productivity, increasing multi nutrient deficiency in soil and increasing environmental pollution. Contamination of environment with dangerous and even lethal agrochemicals like synthetic pesticides needs to be stopped. Because this pollution is for the most part irrecoverable and the chain of evils initiated by it in the living world is irreversible. Over use of pesticide especially in vegetables and fruits has resulted in the residue much above the safety levels[1].

It took millennia for creation of life in this earth and time was one of the important ingredients in that process. For sustaining the present day ecology and environment, the time again must be considered the essential component. However, in modern world no one has time everyone wishes to get quick response. When farmers see their agricultural crops suffering with insect, pests and diseases and decrease in yield, they often expect a dramatic, magical treatment to make them lush, green and healthy again, so that higher production is ensured. As a result, they start using chemical pesticide, disregarding their future ill-effects. This indiscriminate use of chemical pesticide has resulted in insecticide resistance in pests, resurgence of minor pest and high level of pesticide residue in environment as well as food. High level of pesticide residue in food chain causes pesticide poisoning and death through organ malfunction, immune suppression, neurotoxicity, impairment of reproductive function, carcinogenicity, paralysis and harm to beneficial fauna and flora. These ill effects of chemical pesticides have forced people to search for the alternatives from where the concept of biopesticide came. In this paper, the concept of biopesticides and a review of literature on biopesticide are presented. The objective of this paper is to elaborate the concept of biopesticides, its types and their role in sustainable agriculture.

METHODOLOGY

During preparation of the manuscript, a number of sources have been used to collect the information. The consulted materials include agriculture journal, proceedings, technical bulletin, workshop paper, different books and websites of national and international institutes. Elaboration also includes author's academic experience and inputs from peer group discussions.

CONCEPT OF BIOPESTICIDE:

There are number of view and definition given by various national and international organizations on biopesticide all of which include reference to the natural or biological origin of the active ingredient.

According to Environment Protection Agency (EPA, 2003), USA "Biopesticides are certain types of pesticides derived from natural materials such as animals, plants, bacteria, and certain minerals". The EPA recognizes three categories of biopesticides: 1) Microbial pesticides, 2) Plant-incorporated protectants (PIP) and 3) Biochemical Pesticides. EPA has also included genetically modified (GM) plants within biopesticide definition. Despite considerable interest worldwide, there is no universal definition of biopesticides and in many countries including those of European Union biopesticides are regulated in the same way as conventional pesticides. The biopesticides in European Union have been divided into four categories: 1) Products based on pheromone and other semiochemical (for mass trapping or trap cropping), 2) Products containing a microorganism, 3) Products based on plant extracts, 4) other novel alternative products[6]. This scheme does not, however, cover GM plants[5].

Both OECD (Organization for Economic Co-operation and Development) and FAO (Food and Agriculture Organization) follow the theme of biological and natural origin of the agents and recognize the increasing importance of genetic modification of plant and microorganisms for ecological

pest management. FAO biopesticide manual second edition has included micro-organism (96 products), natural products (51 products), macro-organism (54 products), semiochemicals (53 products) and gene (19 products). In a practical sense, therefore, biopesticides are recognized by their sources and modes of action, and many are now commercialized, indicating that there's increasing interest in their use[3].

CATEGORIES OF BIOPESTICIDE:

Biopesticide can be considered as falling into three main categories:

1. **Microbial Pesticides:** These are naturally occurring organisms which include bacteria, fungi, protozoa or viruses. These are capable of controlling many different kinds of pest, although each active ingredient is specific for its target pest. For example*: Bacillus thuringinesis, Bacoloviruses, Metarhizium anisopliae, Verticillium leconi,* etc. *Baculoviruses* are promising agent for the control of order Lepidopteran (butterflies and moths), Hymenopteran (sawflies) and Coleopteran (beetles) pests. Some of the commonly available microbial biopesticides are listed in table 01:

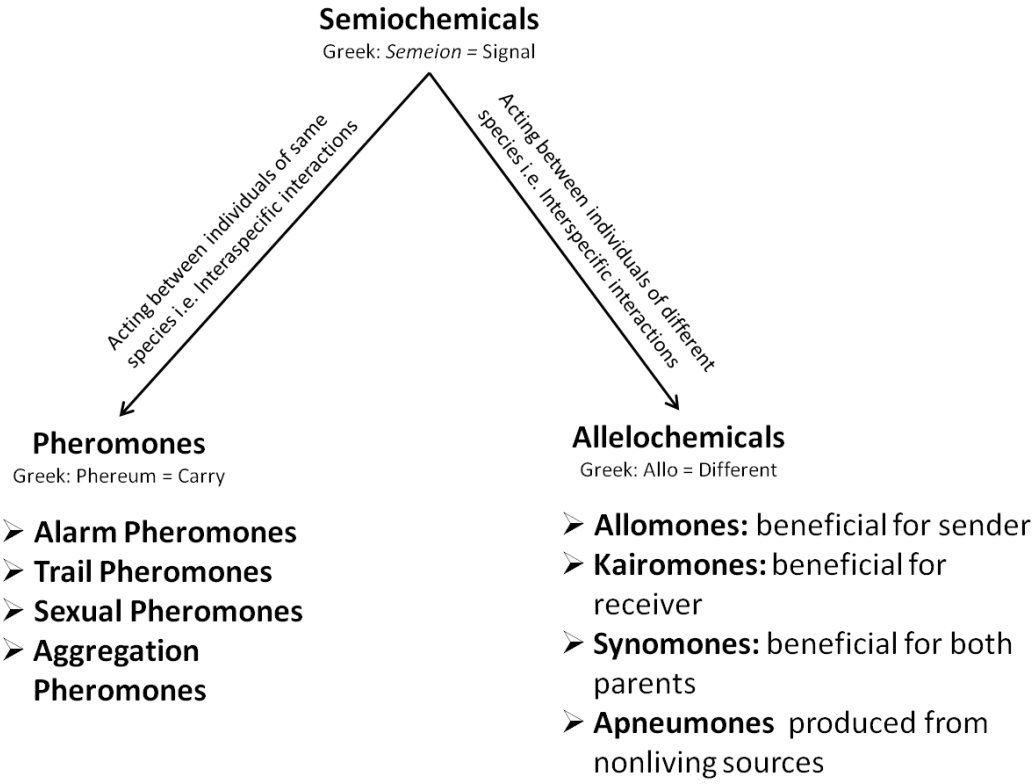
Table 01: List of Commonly Available Microbial Biopesticides

Microbial Biopesticides	**Product common name or Trade name**	**Target**
A. Fungal Biopesticides		
Trichoderma viride	NIPROT, Bioderma, Biovidi, EswinTricho, Biohit, Tricontrol, Ecoderm, Phalada 106TV, Sun Agro Derma, Defense SF	Soil -borne pathogen
Trichoderma harzianum	Phalada 105, Sun Agro Derma H, Biozim	Soil-borne pathogens
Beauveria spp.	Biosoft, ATEC Beauveria, Larvo-Guard, Biorin, Biolarvex, Biogrubex, Biowonder, Veera, Phalada 101B, Bioguard, Bio-power, Myco-Jaal	Coffee berry borer, diamondback moth, thrips, grasshoppers, whiteflies, aphids, codling moth
Metarhizium anisopliae	Meta-Guard, Biomet, Biomagic, Meta, Biomet, Sun Agro Meta, Bio-Magic,ABTEC, Verticillium	Coleoptera and lepidoptera, termites, mosquitoes, leafhoppers, beetles, grubs
Verticillium lecanii	Verisoft, ABTEC , Verticillium, Vert-Guard, Bioline, Biosappex,, Versitile, Ecocil, Phalada 107 V, Biovert Rich, ROM Verlac, ROM Gurbkill, Sun Agro Verti, Bio-Catch	Whitefly, coffee green bug, homopteran pests
Chaetomium globosum	Ketmium	Soil-borne pathogens
Gliocladium virens	WRC-GL-21, WRC-AP-1	Damping- off, root rot pathogens
Pythium oligandrum	Polyversum	Root rots
Verticillium dahlia	Dutch Trig	Dutch elm disease
Ampelomyces quisqualis	Bio-Dewcon	Powdery mildew
B. Bacterial Biopesticides		
Bacillus subtilis QST 713	Serenade	Fire blight, *Botrytis* spp.
Bacillus subtilis GB03	Companion , Kodiak	*Fusarium, Pythium, Rhizoctonia*
Bacillus subtilis MBI 600	Histick N/T , Pro-Mix with Biofungicide	Damping off
Serratia entomophila	Invade, Grandevo	Grass grub
Pseudomonas fluorescens	ABTEC Pseudo , Biomonas, Esvin Pseudo, Sudo, Phalada 104PF, Sun Agro Monus, Bio-cure-B	Plant soil-borne diseases
P. fumosoroseus	Nemato-Guard , Priority	Whitefly
Bacillus thuringiensis subsp. Kurstaki	Bio-Dart , Biolep, Halt, Taciobio-Btk	Lepidopteran pests
Bacillus thuringiensis subsp. israelensis	Tacibio, Technar	Lepidopteran pests
C. Viral Biopesticides		
Helicoverpa armigera NPV	Helicide, Virin-H, Helocide, Biovirus-H, Helicop, Heligard	*H. armigera*
Spodoptera litura NPV	Spodocide, Spodoterin, Spodi-cide, Biovirus-S	*S. litura*

Source: Kunimi[9] and Kabaluk *et al.*[7],

1. **Biochemical Pesticides:** Biochemical pesticides are naturally occurring substances that control pests by nontoxic mechanisms. These are used to modify

insect's behavior and physiology and even affect insect's control. These include semiochemicals, natural plant regulators, enzymes, etc. Among the botanical pesticides investigated, neem has received the maximum attention during the last two decade. More than 300 species of insects have been reported to be affected by the neem component[12].



(Source: Rathore and Nollet, 2012)

2. **Plant Incorporated- protectants (PIP):** These are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the Bt. pesticidal protein and introduced the gene into the plant's own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substances that destroys the pest.

BENEFITS OF BIOPESTICIDE:

At present, great emphasis is given on organically produced food, conservation of biodiversity, environment protection and sustainable agriculture. Biopesticides and biocontrol agents are the tools to meet to these challenges. These are the renewable alternative to conventional pesticides. Biopesticides are beneficial in view of their less toxicity, eco-safety, specificity, reduced number of application, no resistance in pests, increased yields and quality and higher value of produce for exports and suitability for rural masses[2]. It takes care of losses of crops, losses of exports, losses of man hours and lives and losses of beneficial, natural parasites and predators. When used as a component of IPM, efficacy of biopesticides can be equal to the conventional pesticides, especially for crops like fruits, vegetables, nuts and flowers[8]. By combining performance and environmental safety, biopesticides perform effectively with the flexibility of minimum application restrictions, and superior resistance management potential.

BIOPESTICIDE AND SUSTAINABLE AGRICULTURE:

Since the middle of 19th century to the present time, synthetic pesticides have been an agent for controlling the pests. There is no doubt that they have been promising agent for pest

control but within more than 7 decades of their use, the synthetic pesticides have so thoroughly been distributed throughout the animate and inanimate world that they occur virtually everywhere. The land which used to be productive 50 years back is now showing declining yield.

According to latest revision of the UN population prospects, the world population is projected to grow by 34 percent from 6.8 billion today to 9.1 billion in 2050. To feed this increasing population is a great challenge, especially when the productivity of land is declining day-by-day. Environmental pollution by agrochemical residues is increasing and eroding the natural resource base. Sustainability must be maintained in production system to feed the burgeoning population of the word. Sustainable agriculture systems are those which are economically viable and meet society's need for safe and nutritious food while maintaining or enhancing natural resources and the quality of the environment for future generation. It is in harmony with the environment while maintaining buoyancy and dynamism in agricultural growth for meeting basic human needs and conserving natural resources. It aims at producing food that is both nutritious and safe to human health. Since, all of the materials are of natural or biological origin, it is very safe to use biopesticides as potential source of pest control in sustainable agriculture.

FUTURE PROSPECTS:

Sustainability in agricultural production system is must to meet the growing demand of food with limited availability of resources. Plant protection is one of the key factors in agricultural production and biopesticides seems to be the best alternatives to synthetic chemicals. Though there is increasing use of biopesticides day-by-day but for sustaining the availability of food to increasing population, whole system of agriculture across the world should adopt biopesticides as control agent of pest. For this research regarding pest specificity of particular types of biopesticides, extension of knowledge and skill regarding use of biopesticides to the farmers, low cost availability of biopesticides and farmers acceptance are the primary task to be followed. Both private and governmental organization should make a joint effort in developing, manufacturing and sale of biopesticides. Regulation regarding registration of biopesticides needs to be made easy so that the commercialization and availability of biopesticides in the market is enhanced.

Various molecular and biotechnological tools and techniques are being used for producing biopesticides in a safe and sustainable manner. DNA recombinant technology is also being used for enhancing efficacy of biopesticides. Fusion protein is being designed to develop next-generation biopesticides. The technology allows selected toxins (not toxic to higher animals) to be combined with a carrier protein which makes them toxic to insect pests when consumed orally, while they were effective only when injected into a prey organism by a predator[4]. Likewise various innovative tasks are going on to increase the efficacy of biopesticides and make it acceptable globally.

Globally, there are 175 registered biopesticides active-ingredients and 700 products available in the market. The global market for biopesticides was valued at US $1.3 billion in 2011. However, in India, biopesticides represent only 4.2% of the overall pesticide market and is expected to exhibit an impressive annual growth rate ofabout 10% in the coming years. Neem-based pesticides, *Bacillus thuringiensis*, Nuclear Polyhedrosis Virus (NPV) and Trichoderma are some of the major biopesticides produced and used in India, while a total of 287 pesticides have been registered so far.

It is clear that the biopesticides are the key for sustainable agriculture and there is urgent need to put more and more scientific efforts to identify the thrust area of research for the development of eco-friendly production technology with the use of biopesticides as a pest control agent.

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