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BIOPESTICIDES: A SUSTAINABLE APPROACH FOR INSECT PEST MANAGEMENT

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ABSTRACT

Biopesticides are an important component of Integrated Pest Management (IPM) programs for insect pest control since they are more natural, environmentally friendly, safer than chemical pesticides and have relatively no or little effect on non-target organisms. They aid in improving crop health and yields while lowering production costs and eliminating the usage of toxic chemicals. They are effective tools for creating new sustainable agricultural products. Several botanicals and microbial biopesticides have been identified, isolated, processed, and used to eliminate hazards caused by Coleopteran, Hemipteran, Dipteran, Lepidopteran, Hymenopteran, and Thysanopteran insects. Several species of botanicals such as Neem (*Azadirachta indica* A.), Chili pepper (*Capsicum annuum*), Garlic (*Allium sativum*), Moringa (*Moringa oleifera*), Clove basil (*Ocimum gratissimum*), China berry (*Melia azedarach*), bitter leaf (*Vernonia amygdalina)* etc. and microbes such as *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, Baculovirus (*Nucleopolyhedrovirus (NPV)* and *Granulovirus (GV)*, *Steinernema carpocapsae*, *Nosema,* etc. have been used as biopesticides. Because biopesticides are successful in managing insect pests and diseases while also being safe to humans and the environment, they must be manufactured in the country and made available to farmers.

Keywords: Agriculture, Biopesticides, Botanicals, Crop productivity, Insect pests

INTRODUCTION

Biopesticides are non-toxic, ecologically friendly pesticides made from naturally occurring animals, plants, microbes, or minerals comprising living organisms (natural

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enemies), their products (phytochemicals, microbial products), or byproducts (semiochemicals) originating from animals (e.g., nematodes), plants (Chrysanthemum, Azadirachta), and microorganisms (e.g., *Bacillus thuringiensis*, Trichoderma, nucleopolyhedrosis virus) (Mazid et al., 2011). Biopesticides provide greater resistance control potential with minor application limits (Kumar, 2012; Nathan and Kalaivani, 2006) as compared to synthetic pesticide performance and environmental and ecological safety (Kumar, 2012; Nathan and Kalaivani, 2006). Biopesticides are a viable alternative to chemical pesticides in sustainable pest management strategies. Baculoviruses such as nucleopolyhedrovirus (NPV) and granulovirus (GV) have been utilized as biological pesticides in agriculture. Many studies have revealed that farmers utilize biopesticides to make organic food crops simpler to cultivate, and that the advent of "biologically based products" for pest management has helped farmers grow organic food crops more easily (Menn and Hall, 1999; Copping and Menn, 2000; Sengottayan, 2013). Pests that are resistant to both synthetic chemicals and biopesticide toxins can be reduced by biopesticide programs (Copping and Menn, 2000; Nathan and Kalaivani, 2006).

Microbial pesticides, entomopathogenic fungi, viruses, and protozoa are examples of biopesticides (Carlton, 1993*)*. Entomopathogenic fungi are among the first organisms to be used for the biological control of pests. Entomopathogenic fungi are a group of fungi living in the soil that infect insects by penetrating their cuticle to penetrate their bodies to eventually kill insects feeding on them (Dara, 2017). More than 700 species of these fungi from around 90 genera are pathogenic to insects (Sandhu et al., 2012). Several strains of *Metarhizium anisopliae* and *Beauveria bassiana* have been tested and developed as biopesticides. *Bacillus thuringiensis* subspecies *kurstaki* and *aizawai* have the best action against Lepidopteran larvae, *B. thuringiensis tenebrioni* has the best action against Coleopteran adults and larvae, particularly the Colorado potato beetle (*Leptinotarsa decemlineata*), and *B. thuringiensis japonensiss* strain Buibui has the best action against soil-inhabit. The entomopathogenic fungus *Metarhizium anisoplia*e var. *anisopliae* has long been recognized as a safe and environmentally friendly alternative to synthetic chemical pesticides (Domsch et al., 1980; Zimmermann, 1993). The entomopathogenic fungus *B. bassiana* was found effective for successful management of two-spotted spider mite, *Tetranychus urticae* (Ullah and Lim, 2015; Basak et al., 2021). The use of *B. bassiana* is effective against spider mites because it propagates their spores very easily between insect bodies (Wang and Xu 2012). Baculoviruses are double-stranded DNA viruses found in arthropods, particularly insects, and have been utilized as biocontrol agents against a variety of insect pests in their natural state (Moscardi, 1999). Baculovirus applications are still limited in agricultural businesses with low insect damage thresholds. The larval stage of Lepidoptera is the only one that is affected (Cory, 2000). Two nematode taxa, *Steinernema* and *Heterorhabditis* (Nematoda: Rhabditida), have been generally considered as insect pest biocontrol agents, according to Copping and Menn (2000). Some protozoa species have had some effectiveness as biopesticides (Solter and Becnel, 2000), notably *Nosema locustae* (the only species registered and commercially maintained) against grasshoppers (Henry and Oma, 1981). There are a few drawbacks to using biopesticides. Biopesticides take longer to work than conventional chemicals. As a result, biopesticides will fall short if a pest infestation is severe and needs to be handled fast. In nature, these decay quickly and are less stable. Their actions are influenced by unfavorable environmental conditions. The objective of this review is to gather information on the current status of knowledge on biopesticides and their role in sustainable agriculture. This information collected will be useful for researchers, farmers, extension agents, industries and others who are related to bio-pesticidal works.

MATERIALS AND METHODS

The study is primarily based on the number of literature reviews with plethora of materials regarding pesticide use status on global and Nepalese context. The sources of information include journal articles, conference proceedings, book sections, websites, report etc.

RESULT AND DISCUSSION

Status of bio-pesticides' application in Nepal

According to the pesticide registration and management organization, there are only 14 varieties of biological pesticides registered in Nepal, with 113 different trade names (Sharma 2019). Some of these pesticides are Azadirachtin, *Bacillus subtillis* 2% AS, *B. thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, *Nuclear Polyhedrosis* Virus of *Helicoverpa armigera* 0.43% AS, *Nuclear Polyhedrosis* Virus of *Spodoptera litura*, *Paecilomyces lilacinus* 2×10^9/g SP, *Pseudomonas fluorescens*, *Trichoderma harzianum*, *T. viride* and *Verticillium lecanii* (Adhikari et al., 2019). Nepal Agricultural Research Council (NARC) made collaboration with the International Institute for Crop Research for the Semi-Arid Tropics (ICRISAT) and Biopesticide Development in Western Nepal (for e.g., Dang, Banke, Bardia, Kailali and Kanchanpur) using *Helicoverpa* Nuclear Polyhedrose Virus (NPV) in chickpeas and pigeon peas, which developed in the successful reduction of chemical pesticide use and production costs (Ansari and Ghimire, 2008). There is a lack of standardized extraction and application methods, as well as enterprises involved in the development and marketing of biopesticides (Ansari et al., 2013).

Table 1: List of Biopesticides and their active ingredients in Nepal

Product Name	Active ingredient
Guard	*Pseudomonas fluorescens* $1x10^9$ CFU/g
BIOJEB	Biojeb is a botanical based fungicide. It contains a complex of physiologically active alkaloids isolated from selective Himalayan herbs
Maha-shakti	*Bacillus Thuingiensis* sub species *Kurstaki* $1x10^9$ CFU/g
Pecilo	*Paecilomyces fumosoroseus* $1x10^9$ CFU/g
Teer	*Ampelomyces quisqualis* $1x10^9$ CFU/g
AGRI GUARD	*Pongamia glabra*, Lantana, *Acorus calamus*, *Azadirachta*
AGRI-SAKTI	*Beauveria bassiana* $1x10^9$ CFU/g
BIOCIDE MANIC	*Metarhizum anisopliae*
Biocide trivi	*Trichoderma viride*
DHANUS	*Fusarium proliferatum* $1x10^9$ CFU/g

In the realm of bio-pesticide, there is a significant effort and research is going on. Government and non-government sectors in Nepal are producing bio-pesticides.

Table 2: Sectors in Nepal Government's involving in bio-pesticide production

A. Entomology Division, Nepal Agricultural Research Council (NARC)	
1	*Trichogramma chilonis*
2	*Trichogramma japonicum*
3	*Chrysoperla carnea*
4	*Cotesia plutellae*
5	*Curinus coeruleus*
6	*Coccinella sempempuntata*
7	Nuclear polyhedrosis virus of *Helicoverpa*
8	Nuclear polyhedrosis virus of *Plusia*
9	Granulovirus of potato tuber moth
10	*Metarhizium anisopliae*
11	*Beauvaria bassiana*
B. Regional plant protection laboratory, Hariharbhawan, Lalitpur, Nepal	
12	*Metharhizium anisopliae*
13	*Steinernema* sp.

14	*Heterorhabditi* spp.
C. Regional plant protection laboratory, Khajura, Banke, Nepal	
15	HNPV
D. Regional plant protection laboratory, Sundarpur, Kanchanpur, Nepal	
16	*Trichoderma viride*
E. Regional plant protection laboratory, Pokhara, Kaski, Nepal	
17	*Trichogramma chilonis*
18	*Trichogramma japonicum*
F. Regional plant protection laboratory, Biratnagar, Morang, Nepal	
19	*Acorus calamus*

Table 3: Community Resource Centers involved in bio-pesticide production in Nepal

A. Community Resource Centre, Kushadevi, Kavrepalanchowk	
1	*Trichoderm aviride*
2	*Steinernema* sp.
3	*Heterorhabditi* spp.
B. Community Resource Center, Kailali	
4	*Trichoderma viride*
C. Community Resource Center, Banke	
5	*Trichoderma viride*

Home-made botanical pesticides

Garlic (*Allium sativum)*

Garlic contains Diallyl disulphide and Diallyl trysulphide which are a powerful insecticide. Garlic extracts have been found effective against *Alternaria* spp., powdery mildew, black spot, *Phytopthera*, *Fusarium* spp., and bacterial infections such as *Pseudomonas* (Chakravarthy, 2007). Garlic has long been a popular ingredient in Nepalese cookery, with hundreds of tons of garlic imported each year from India. Garlic extract has been shown in lab studies to have acaricidal properties (Dabrowski and Seredynska, 2007). The extract possesses insecticidal properties against Dipteran, Coleopteran, Lepidopteran, and Hemipteran pests (Abdalla et al., 2017), implying that it could be a valuable botanical pesticide for a wide range of insect pests. Garlic aqueous extract was also used to suppress Lepidopteran pests, according to Baidoo and Mochiah (2016).

Neem (*Azadirachta indica*)

Neem contains Azadirachtin (Aza) which is a promisor biopesticide. In Nepalese vegetations, neem is a commonly used medicinal plant having the ability to act as a botanical insecticide. The Blattodean pest has been effectively inhibited using handcrafted aqueous preparations of neem plant materials (leaves, seeds, seed cake, and unformulated oil) (Ibrahim and Demisse, 2013). The leaves, bark, root, and seeds of the neem plant can be employed as botanical insecticides for a range of pests. Commercial neem-based treatments exhibit insecticidal and acaricidal properties, according to Morgan (2004). In the field, the same extracts have been used to control Hemipteran pests (Aziz et al., 2013), Lepidopteran pests (Abate, 2011), and Thysanopteran pests (Abate, 2011).

Chili peppers (*Capsicum* spp.)

Capsicum is a common and necessary component of almost every Nepalese farmer's field, and its bio-pesticidal activity can be employed to control a wide range of insect pests. Because it's insecticidal and repellent, it's used to manage Hemipteran pests, for example (Bergmann and Raupp, 2014; Dayan et al., 2009). Antonious et al. (2006) mentioned its insecticidal properties against Hemipteran pests, and Fening et al. (2014) mentioned its Thysanopteran pesticidal properties. According to Belmain et al. (1999), chili pepper was an effective deterrent and bio-pesticide for reducing the number of weevil species attacking stored grains.

Moringa (*Moringa oleifera*)

Moringa seeds contain lectins that have larvicidal activity against the flour moth *Anagasta kuehniella* (Agra-Neto et al., 2014), which can be a major issue in Nepalese flour storage, causing significant economic loss. Moringa seed oil offers antifeedant and insecticidal properties against the fall armyworm *Spodoptera frugiperda*, according to laboratory testing (Kamel, 2010). Ground Moringa leaves can be used to combat Coleopteran storage pests of food crops (Longe, 2016).

Chinaberry (*Melia azedarach*)

Insecticidal and antifeedant properties of limonoids found in chinaberry have been established in laboratory testing against Dipteran, Coleopteran, and Lepidopteran pests (Banchio et al., 2003). Aqueous extracts of chinaberry fruits and leaves help eliminate Lepidopteran pests in the field, according to Mckenna et al. (2013). The fruits and leaves can be used to fight mites in the field (Attia et al., 2011). Chinaberry aqueous extract can also be used to keep cabbage aphids at bay (Kibrom et al., 2012). Coleopteran storage pests were found to be reduced by using chinaberry ground plant material (Hafez et al., 2014).

Clove basil (*Ocimum gratissimum*)

The produced aqueous extract of clove basil has been used in field applications to control Hemipteran (Amoabeng et al., 2013; Oparaeke, 2006) and Lepidopteran pests

(Amoabeng et al., 2013). In lab tests, clove basil essential oil and some of its constituents were found to have insecticidal and repellent properties against Coleopteran pests, as well as repellant properties against houseflies (Singh and Singh, 1991). Ogendo et al. (2008) discovered that it has insecticidal and repellant biochemical activities against Coleopteran pests and houseflies, respectively, in laboratory testing. The production of such botanicals in a lab would expand the range of biopesticides for pest control.

Bitter leaf (*Vernonia amygdalina*)

The separation and utilization of sesquiterpene lactones from bitter leaf have been shown to be extremely successful in reducing Coleopteran pests due to their insecticidal and repellent activities against coleopteran pests and Lepidopteran pests (Green et al., 2017). Bitter leaf aqueous extracts have been utilized to suppress Coleopteran pests in field applications (Mkenda et al., 2015; Tembo et al., 2018), Hemipteran pests (Degri et al., 2012; Mkenda et al., 2015), and Lepidopteran pests (Degri et al., 2012; Mkenda et al., 2015).

Biopesticides and economic viability

Several studies and economic analyses on the use of biopesticides have found that their use should be encouraged. According to Gupta (2005) and Gupta and Pathak (2009), biopesticides are more cost-effective than synthetic pesticides, hence botanicals are preferable to synthetic pesticides. The use of Neem (*Azadirachta indica*) leaves, seed kernels, seed cake, or oil against the rice green leafhopper, *Nephotettix virescens*, resulted in a lucrative benefit-cost ratio, according to the research (Rajappan et al., 2000). A similar product containing Neem parts was found to have a high benefit-to-cost ratio for controlling aphid (*Sitobion aveanae*) in wheat (Aziz et al., 2013); whitefly (*Bemisia tabaci*) and pod borer (*Maruca testulalis*) in black gram (Gupta and Pathak, 2009); and pod bug (*Clavigralla gibbosa*) in pigeon pea (Gupta and Pathak, 2009; Narasimhamurthy and Ram, 2013). Amoabeng et al. (2014) discovered that controlling the Diamondback moth (*Plutella xylostella*) in cabbage with Siam weed or tobacco was cost-effective. Mkenda et al. (2015) found similar findings with aqueous extracts from Tephrosia, tree marigold, and bitter leaf in bean aphid (*Aphis fabae*), bean flower beetles (*Epicauta bovittata*) and (*E. limbatipennis*), and bean foliage beetles (*Ootheca mutabilis*) and (*O. bennigseni*). Chili pepper was discovered to have a lucrative benefit-cost ratio for controlling *Sesamia calamistis* stem borers in sorghum (Okrikata et al., 2016). In a country such as Nepal, where biopesticide manufacturing and use is common, they can be boosted for resource-poor and marginal farmers who use biopesticides seldom and are looking for more effective pest management approaches and procedures.

Biopesticides as health and environmental safety

Pesticide use that is haphazard, irrational, or unplanned hurts the environment by eroding soil surfaces, reducing agricultural productivity, and reducing micro and macro flora and fauna (Pimental, 2005). Loss of ecosystem resilience, biodiversity, insect rebound and resistance, bio-accumulation, and bio-magnification are some of the ecological consequences of injudicious and extended usage of synthetic pesticides. Comprehensive and systematic environmental safety studies have not been done because the majority of biopesticides are not heavily regulated. El-Wakeil et al. (2013) discovered that while Neem's toxicity is lower than synthetic pesticides, some non-target species may become sensitive. In a review on the ecological management of the cabbage diamondback moth, Parajuli and Paudel (2019) stressed the value of biopesticides in pest control. Amoabeng et al. (2013) discovered that aqueous extracts of Siam weed and tobacco have a lower impact on non-target ladybirds, hoverflies, and spiders than emamectin benzoate. On a trial, Mkenda et al. (2015) discovered that Tephrosia and tree marigold had no effect on ladybirds and had a limited or no effect on spiders.

Biopesticides in sustainable agriculture

Biopesticides could take the place of synthetic pesticides. Biopesticides are biodegradable, have multiple modes of action, are less costly, and have little toxicity to humans and non-target animals (Lengai and Muthomi, 2018). Because the pre-harvest intervals on fresh fruits and vegetables are so short, biopesticides are safe to employ (Khater, 2012). They're also target-specific, which means they don't harm beneficial creatures such as natural enemies (Shiberu and Getu, 2016). They work in very small dosages, and their use aids in long-term pest management and, as a result, agriculture (Nawaz et al., 2016). Natural pesticides do not build resistance to pests (Tadele and Emana, 2017). Their raw ingredients are inexpensive to obtain because they are found in the natural environment and some of them are used for other purposes such as food and feed (Srijita, 2015). Biopesticides are non-toxic, which means they are safe to use and eat (Damalas and Koutroubas, 2015). As a result, biopesticides can be easily integrated into integrated pest management (IPM), reducing the demand for chemical pesticides in crop pest control (Sesan et al., 2015). Natural items disintegrate quickly, which is good for the environment (Kawalekar, 2013). Short re-entry intervals are common with pesticides generated from natural sources, assuring the applicant's safety (Stoneman, 2010). Agricultural soil is also treated with biopesticides by introducing a high number of microbial species (Javaid et al., 2016).

CONCLUSION

Biopesticides are gaining popularity as they are potential alternatives to chemical pesticides in sustainable pest management programs. They are significant in IPM because they reduce the usage of harmful synthetic chemical pesticides that are hazardous to human and environmental health. In agriculture, baculoviruses such as nucleopolyhedrovirus and granulovirus have been used as effective biological insecticides. A group of botanicals either their parts or the whole as extract having pungent smell such as Neem (*Azadirachta indica* A.), Chili pepper (*Capsicum annuum*), Garlic (*Allium sativum*), Moringa (*Moringa oleifera*), Clove basil (*Ocimum gratissimum*), China berry (*Melia azedarach*), Biter leaf (*Vernonia amygdalina)* etc. can be used for pest control. A number of members of Hemipteran, Lepidopteran, Thysanopteran, Coleopteran and Dipteran insects have been successfully controlled by using bio-pesticides. Thus, the use of biopesticides enriched farming practices to promote food security and agricultural sustainability.

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