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Role of bio-pesticide in vegetables pest management: A review

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Abstract
Bio-pesticides are considered as an alternative to chemical pesticide in modern vegetable production. We had to increase the vegetables yield in any way that's why we used chemical insecticide blindly. Obviously the chemical pesticide are not environment friendly and they are responsible for water, air and soil pollution as well as can spread cancer causing agents also. In view of these reasons, the scientist has found the option of chemical pesticide through bio-pesticide. There are different types of microorganisms Which are used in the Bio-pesticide. The role of Bio-pesticide in vegetables production assumes special significance, particularly in the present context of increased cost of chemical pesticide and their hazardous effects on environment. This review outlines the current state of knowledge on the potential use of biopesticides in global control of pests in vegetables.

Keywords: Pest, biopesticides, toxins, vegetables

Introduction
Vegetables are most important component of a balanced diet and act as a protective food. India occupies a prime position in the world in vegetable production and 2nd largest producer of vegetable next to china. India produces about 7905000 million tons of vegetables from an area 465000 million hectares, and productivity 17t/h [1] which are far below to the desired requirement (300g/capita/day) to fulfil the need of the growing population [2]. It is widely accepted that vegetables are important component of a healthy diet, and that their consumption could help prevent a wide range of diseases. Epidemiological data support that protective effect of vegetables against several types of cancers and cardiovascular disease [3]. No field of human endeavour is entirely free of risk. All aspects of our daily life are surrounded by some degree of risk. Even to do nothing can incur a risk. In every case, we have to consider all risks of any activity in the light of all its benefits. This applies equally to the safe and effective pesticide use. For decades, discussions among scientists and the public have focused on the real, predicted, and perceived risks that pesticides pose to people and the environment. It is evident that wide-spread use of pesticides in modern agriculture has been an accepted part of the industry for many years. At the same time, there is evidence of both direct and indirect dangers involved in the use of these chemicals [4-8]. Pesticide use has certainly contributed towards improving agricultural production, in terms of both yield and quality, thus increasing agricultural income, particularly in developed countries. However, careless use of pesticides without adhering to the safety norms and recommended practices has posed serious health risks to humans, other living organisms, and the environment, from on-farm workers ‘exposure and release of chemicals into the air and water, to commodities containing pesticide residues [9-10]. 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 [11].
Therefore, there has been a growing demand for food safety and quality in recent decades, as reflected in the tight safety regulations on imports of products and strict regulations on the amount of pesticide residues on commodities. Moreover, increasingly high standards regarding product quality are continuously being set. Public awareness about the adverse effects of pesticides on the safety of foods and on the environment has increased in recent years, and the search for alternatives to widely used chemical pesticides, including biopesticides, has become a priority. In this regard, the conventional pesticide industry and market have undergone major changes over recent decades [12], which have entailed greater efficiency of pesticide use than in the past through major improvements to pest management technology and practices in the context of Integrated Pest Management (IPM) programs.

These developments have significantly improved pest management practices, reduced, in some cases, pesticide use, and have also impeded the growth in demand for chemical pesticides [13]. Biopesticides are natural materials derived from animals, plants, and bacteria, as well as certain minerals, that are used for pest control [14]. Almost 90% of the microbial biopesticides currently available on the market are derived from only one entomopathogenic bacterium, i.e., Bacillus thuringiensis or Bt [15]. Currently, biopesticides comprise a small share of the total crop protection market globally, with a value of about $3 billion worldwide, accounting for just 5% of the total crop protection market. Growth of biopesticides is projected to outpace that of chemical pesticides, with compounded annual growth rates of more than 15% [16, 17]. The aim of this review is to critically highlight the potentials of biopesticides for vegetable pest control.

Bio-Pesticides

According to the United States Environmental Protection Agency (EPA), biopesticides are pesticides derived from natural materials, such as animals, plants, bacteria, and certain minerals (www.epa.gov). Biopesticides are biochemical pesticides that are naturally occurring substances that control pests by nontoxic mechanisms. Biopesticides are living organisms (natural enemies) or their products (phytochemicals, microbial products) or by products (semiochemicals) which can be used for the management of pests that are injurious to plants. Biopesticides have an important role in crop protection, although most commonly in combination with other tools including chemical pesticides as part of Bio-intensive Integrated Pest Management Biopesticides or biological pesticides based on pathogenic microorganisms specific to a target pest offer an ecologically sound and effective solution to pest problems. They pose less threat to the environment and to human health. The most commonly used biopesticides are living organisms, which are pathogenic for the pest of interest. These include biofungicides (Trichoderma), bioherbicides (Phytopthora) and bioinsecticides (*Bacillus thuringiensis*). The potential benefits to agriculture and public health programmes through the use of biopesticides are considerable [18]. Organization for Economic Co-operation and Development (2009), viewed biopesticides as manufactured mass produced agents derived from natural sources living micro-organisms and sold for use to control pests [19].

Biopesticides Registered under Insecticides Act, 1968 [20].

1. Bacillus thuringiensis var. israelensis
2. Bacillus thuringiensis var. Kurstaki
3. Bacillus thuringiensis var. galleriae
4. Bacillus sphaericus
5. Trichoderma viride
6. Trichoderma harzianum
7. Pseudomonas fluoresens
8. Beauveria bassiana
9. NPV of Helicoverpa armigera
10. NPV of Spodoptera litura
11. Neem based pesticides
12. Cymbopogan

Categories of Biopesticides

Biopesticides fall into four major categories:

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

Use of Biopesticides in Vegetables Pests Management

Mostly the vegetables are harvested frequently and the picked vegetables are marketed for human consumption immediately without any analysis for residual effects of the pesticides. However, toxic effects of synthetic pesticides are a real threat to human health. The bio-pesticides are safe and their application not only suppresses the insect pests effectively, but there is no risk of residual effects for the consumers [21].

Vegetables Insect Management

Effect of Neem based pesticides against white fly and jassid was higher than other treatments and Achook and NSKE (3%) were the most effective in controlling the white fly and jassid [22]. It was found that different Neem products (botanical pesticides) proved to be effective to control Jassid under field conditions [23]. Neem based products gave significant control of jassids (Amrasca devastans) [24]. It is also in agreement with who used Neem oil at 2% and Neem seed water extract at 3% which significantly reduced the population of jassids and white fly [25]. Neem and dhatura controlled the sucking insect pests effectively [26]. The effect of bio-pesticides and their efficacy was to control insect pests of tomato. The bio-pesticides appear to be a promising biological control agent against whiteflies. The use of these products in a context of integrated protection of tomato requires that their efficacy is not altered when applied together [27]. Neem oil, Tobacco leaves, Neem powder, Neem oil + B.M. Beneficial micro-organism were sprayed twice. The pre-treatment counts of the pest were recorded one day before spray. The post treatment observations were taken after 48, 72 hours one week two weeks. In first spray against jassid Neem oil was most effective bio-pesticides and showed highest mortality (71.97%) followed by Neem oil + B.M. Beneficial micro-organism (65.48%) Neem powder (61.56%) and Tobacco leaves (54.75%). In the first spray against Jassid Tobacco leave has showed highest reduction percentage (85.90%) and followed by Neem oil (80.00%) Neem oil + B.M. Beneficial microorganism (75.70%) and Neem powder (70.70%). In second spray against jassid Neem oil has showed good highest mortality (72.30%) followed by Neem oil + B.M. Beneficial micro-organism (63.68%) [28]. The treatment of Neem formulation with azadirachtin-endosulfan at 15 days interval brought down the Jassids population up to 0.68/5 plants [29]. The effect of six plants extracts (sweetsop, chilli pepper, garlic, ginger, Neem and Tobacco) against the insect pests of cowpea. All the plant extract treatments were significantly better than control treatments. Results of the present finding therefore, suggest the use of all the tested plant extracts particularly Tobacco, sweetsop and garlic as they have been found to be very promising bio-pesticides in the control of insect pests [30]. Tobacco extract resulted highest mortality (98.60%) of mealy bug, Neem oil was most effective after Tobacco extract causing 89.32% pest mortality, Neem extract ranked third in relation to efficacy against mealy bug with insect mortality of 80.37%, while garlic extract was least effective against mealy bug with mortality of 75.82% after 72 hours treatment [31]. Among the plant material, best antifungal activity was achieved by extracts of *Azadirachta indica* (Neem), and *Allium sativum* (garlic) at the concentration of 0.015% [32]. Only plants sprayed with Neem (31.1 mg a.i./l) showed symptoms of phytotoxicity. Lime sulphur and Neem based products, applied in appropriate concentrations and formulations, bear out as a viable alternative to control *Trypanosoma evansi* on tomato plants [33]. The toxic effect of the insecticides and bio-pesticides decreased after 7 days of treatment application [34]. Three bio-pesticides (Bt, NeemAzal and Spinosad) as alternatives to manage important tomatoes insect pests, and reported that Neem Azal was effective against all test insects pests. The chemical pesticides demonstrated the highest effects in controlling the tested insects but they reduced significantly the population of the beneficial insects. The bio-pesticides seem to be less hazardous to the beneficial insects [35].

Adults were susceptible to five of seven aqueous suspensions of conidia. The extract from *M. anisopliae* was the most toxic, resulting in about 90% mortality. The compatibility of the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin with neem was conducted against sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (*Hemiptera: Aleyrodidae*), on eggplant. The combination of *B. bassiana* and neem yielded the highest *B. tabaci* egg and nymph mortalities and the lowest LT50 value. Therefore, neem was used along with *B. bassiana* suspension as an integrated pest management program against *B. tabaci* [36].

Fungal biocontrol agents, including 10 isolates of *Beauveria bassiana*, *Metarhizium anisopliae*, and *Paecilomyces fumosoroseus* were bio assayed for their lethal effects on the eggs of the carmine spider mite, *Tetranychus cinnabarinus* [37]. The ovicidal activity of the three fungal species and suggested the feasibility to search for more ovicidal isolates from fungal species that may serve as biocontrol agents against spider mites such as *T. cinnabarinus*. Two isolates of entomopathogenic fungi, *Beauveria bassiana* SG8702 and *Paecilomyces fumosoroseus* Pfr153, were also bio assayed against *T. cinnabarinus* eggs [38]. Entomopathogenic fungi (Hypocreales) have been used for the control of potato psyllid, *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae) in an area endemic for zebra chip disease of potato. Entomopathogenic fungi could provide a viable component for an integrated pest management strategy for control of B. cockerelli and other potato pest insects. Commercial formulations of *Metarhizium anisopliae* and *Isaria fumosorosea* and *abamectin* were conducted. It was observed that all fungal treatments significantly reduced plant damage and zebra chip symptoms [39].

Table 1: Some of the plant products registered as bio-pesticides [40].

Plant Product used as Biopesticides	Target Pests
Limonene and Linalool	Fleas, aphids and mites also kill fire ants, several types of flies, paper wasps and house crickets
Neem	A variety of sucking and chewing insect
Pyrethrum/Pyrethrins	Ants, aphids, roaches, fleas, flies, and ticks
Rotenone	Leaf-feeding insects, such as aphids, certain beetles (asparagus beetle, bean leaf beetle, Colorado potato beetle, cucumber beetle, flea beetle, strawberry leaf beetle, and others) and caterpillars, as well as fleas and lice on animals
Ryania	Caterpillars (European corn borer, corn earworm, and others) and thrips
Sabadilla	Squash bugs, harlequin bugs, thrips, caterpillars, leaf hoppers, and stink bugs

Neem tops the list of 2,400 plant species that are reported to have pesticidal properties and is regarded as the most reliable source of eco-friendly biopesticidal property. Neem products are effective against more than 350 species of arthropods, 12 species of nematodes, 15 species of fungi, three viruses, two species of snails and one crustacean species [41]. Azadirachtin, a tetranortritarpinoid, is a major active ingredient isolated from neem, which is known to disrupt the metamorphosis of insects [42]. One of the most successful examples of microbial biopesticide use is in the management of diamondback moth (Plutella xylostella) in tropical Asia and Africa. Diamondback moth is the most destructive insect pest on vegetable brassicas in the world, sometimes causing more than 90 percent crop losses [43]. Unlike the diamondback moth, they do not have any effective biocontrol agents. However, B. thuringiensis-based biopesticides are an effective tool against secondary lepidopterans. For instance, the cabbage head caterpillar is quite susceptible to most of the Cry1A toxins such as Cry1Aa, Cry1Ab, and Cry1Ac [44]. Entomopathogenic viruses, especially nucleopolyhedrovirus (NPV) and granulovirus (GV), also are known to be effective against various insect pests on vegetables. Helicoverpa armigera NPV (HaNPV), Spodoptera litura NPV (SlNPV), and S. exigua NPV (SeNPV) already have been commercialized and are widely used against tomato fruit worm (Helicoverpa armigera), common army worm (Spodoptera litura) and beet army worm (S. exigua), respectively [45]. Several reports have confirmed the effectiveness of entomopathogenic fungi against various pests on vegetables. For instance, some of the entomopathogenic fungi isolates were known to possess ovicidal and larvicidal effects against legume pod borer [46], larvicidal effects against diamondback moth on cabbage, larvicidal effects against web worms (*Hymenia recurvalis* and *Psara basalis*) on amaranth [47-48] and pupicidal effects against tomato fruit worm [49]. Additive effects were found on the mortality of diamondback moth when entomopathogenic fungi were combined with the parasitoid, Oomyzus sokolowskii [50]. However, the parasitism was reduced when the diamondback moth was treated with entomopathogenic fungi 24 h before the exposure to the parasitoid. The entomopathogenic fungi caused 9-21 percent confirmed mortality of the parasitoid and S. litura [51-52]. AVRDC has developed and promoted an IPM strategy based on sex pheromones for managing eggplant fruit and shoot borer in South Asia. The adoption of eggplant fruit and shoot borer IPM strategy led to a 70 percent reduction in pesticide use in Bangladesh [53-54].

Vegetable Disease Management

Biopesticides are used primarily as preventative measures, so they may not perform as quickly as some synthetic chemical pesticides. However, biopesticides are generally less toxic to the user and are non-target organisms, making them desirable and sustainable tools for disease management. While their use is not overly complicated, the application of some biopesticides may require a high level of understanding and knowledge of the diseases and pathogens that they are designed to control. As with any disease management program, proper timing and application are essential to ensuring efficacy.

Table 2: Some successful experimental use of bio-pesticides against various diseases

Bioagent	Pathogen	Host (Crop)	Reference
T. harzianum	*Phytophthora capsici, Fusarium oxysporum f. Sp lycopersici*	Tomato	Sriram *et al*., 2010 [55].
Tricihoderma spp.	*Botrytis cinera*	Tomato	Tucci *et al*., 2011 [56].
Pseudomonas aeruginosa	*Sclerotinia sclerotiorum*	Tomato	Deshwal, 2012 [57].
B. subtilis	*Ralstonia solanacearum*	Tomato	Chen *et al*., 2013 [58].
T. viride	*Colletotrichum capsici*	Chilli	Jagtap *et al*., 2013 [59].
Xanthomonas spp. Pseudomonas syringae pv. Tomato	Bacterial spot & bacterial speck	Tomatoes and pepper	Coa *et al*. 2018 [60].
Streptomyces lydicus WYEC 108	**Soilborne pathogens:** *Pythium spp., Rhizoctonia spp., Phytophthora spp., Fusarium spp., Verticillium spp., Phymatotrichum omnivorum,* and other root decay fungi **Foliar pathogens:** *Podosphaera spp., Botrytis spp., Schlerotinia spp., Monilinia spp., Alternaria spp., Peronospora spp.,* and other foliar fun	Greenhouse, nursery, and turf	
Bacillus pumilus QST 2808	Rust, powdery mildew, cercospora, and brown spot	Potatoes	
Bacillus subtilis GB03	*Rhizoctonia, Fusarium, Alternaria, Aspergillus,* and others that attack the root systems of plants	peas, and beans	
Trichoderma harzianum Rifai strain KRL-AG2	Fusarium, Pythium, and Rhizoctonia	Cucurbit vegetables, leafy vegetables, cole crops and hydroponic crops,	
Bacillus subtilis QST 708	anthracnose, and dollar spot	leafy vegetables, and bulbs	
Bacillus subtilis strain QST 713	Bacterial spot, powdery mildew, rust, gray mold, leaf blight, scab, and more	Vegetables	
Trichoderma virens (formerly *Gliocladium virens*)	Pythium, Rhizoctonia, and root rots	Potato, Cucumber, Lima beans,	
Bacillus pumilus QST 2808	Fungal pests such as molds, mildews, blights, and rusts	Lettuce, Broccol, Radish	
Trichoderma harzianum Rifai strain KRL-AG2	Fusarium, Pythium, and Rhizoctonia	bulb crops, cucurbits, fruiting vegetables, herbs, spices, leafy vegetables, cole crops, legumes, root crops, small grains, and tuber crops	

Simultaneous use of bio and chemical fertilizer

Even though bio-fertilizer is superior to chemical fertilizer in terms of sustainable agriculture, it's immediately its complete replacement in place of chemical fertilizer is not possible. A modality of balanced path that involves combined use of chemical and bio-fertilizer can be evolved. It was observed that the application of PSB, Bacillus megatherium var. phosphaticum, increased the PSB population in the rhizosphere and P availability in the soil. It also enhanced sugarcane growth, its yield and quality. When used in conjunction with P fertilizers, PSB reduced the required P dosage by 25%. In addition, 50% of costly superphosphate could be replaced by a cheap rock phosphate, when applied in combination with PSB [61]. The effects of a combined treatment of multifunctional biofertilizer plus 50% chemical fertilizer on lettuce yield. From his results it is observed that there was a 25% increase of lettuce yield for the treatment of ½ chemical fertilizer plus biofertilizer compared to that of the chemical fertilizer treatment, indicating that at least 50% of chemical fertilizer can be saved as multifunctional biofertilizer was used along with chemical fertilizer [62]. Again an employment of multifunctional biofertilizer on rhizosphere microbial activity and the growth of water celery in a field showed that the dry weight of water celery in the treatment with 50% organic compound fertilizer with multifunctional biofertilizer was increased by 34% compared to the treatment with 100% organic compound fertilizer [63].

Role of Government in Bio-Fertilizer Promotion

Government of India has been implementing the scheme for the promotion of biofertilizers since 7th Five Year Plan. Under this scheme, one national centre and six regional centres have been established. The main functions of these centres include the promotion of bio-fertilizer through training, demonstration and supply of 10 efficient cultures for production of bio-fertilizers. The promotion of bio-fertilizer also needs extensive extension work to convince the farmers about the need of bio-fertilizer use for increase in productivity. Seminars on bio-fertilizers and micronutrients are regularly being organized by Government of India which are attended by executives of fertilizer industries, agriculture research and extension specialists, academicians, administrators, policy makers and farmers. Marketing of bio-fertilizer is a very difficult task as they are not primary inputs like seed and fertilizer. Again, the farmers' acceptance to bio-fertilizer use has been far from satisfactory. This is the main reason why effective demand has not been created so far. Even if in few cases there is the demand of bio fertilizer but it's limited to few varieties like Rhizobium, Azotobacter, and Phosphorus Solubilizing Micro-organism. As observed from still there is significant amount of unused capacity of bio fertilizer production. To create awareness amongst the farmers and to popularize the product emphasis has been given to the (1) Demonstration (2) Field Day, group discussions and (3) farmers' visits to Agriculture Universities and bio-fertilizer units, literature, publicity, seminar and training. Besides farmers awareness there are also some other technical constraints of the promotion of bio fertilizer in India. Like: Marketing constraints, because of its short self-life, lack of proper storage, consumer illiteracy, low awareness amongst consumers, inadequate guidelines to consumers, inadequate production/promotion effort. Secondly is that Environmental constraints due to seasonal conditions, soil fertility, usage of high dose of chemical fertilizers, pesticides etc. The Government of India and the various State Governments have been promoting the nascent biofertilizers market both at the level of the user-farmer and the producer-investor through (i) farm level extension and promotion programmes, (ii) financial assistance to investors in setting up units, (iii) subsidies on sales and (iv) direct production in public sector and cooperative organizations and in universities and research institutions. A National Biofertilizer Development Centre was established at Ghaziabad as a subordinate office of the Department of Agriculture and Cooperation with six regional centres. The purpose of the scheme covered organization of training courses for extension workers and field demonstrations and providing quality control services. Production and distribution of different biofertilizers were also undertaken but subsequently discontinued as the centres redefined their role towards R&D and HRD related activities [64].

General Advantages of Biopesticides

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

1. Reduce over dependence on chemical fertilizers and pesticides that has created problems in agriculture [65].
2. Farming with bio-fertilizer involves natural pesticides, resulting in -no reduction to nutrient value of vegetable.
3. Nutritional quality significantly higher in the grown bio-fertilizer produced product [66].
4. Bio-fertilizer works as vegetative and yield growth promoters.
5. It is beneficial always in terms of soil fertility, ecological health etc.
6. Biopesticides are usually inherently less harmful/toxic and cause less environmental load or pollutions.
7. Designed to only one specific pest or, in some cases, a few target pests as opposed to chemical that have a broad spectrum activity.
8. Cost of developing biopesticides is significantly lower than those of synthetic chemical pesticides.
9. Their nature of control is preventive not curative and their effects on flower is less.

Disadvantages of Biopesticides

1. Specificity 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 becomes a threat to crops.
3. Biopesticides are not suited for a standalone treatment rather they have to be with a compatible method for high efficacy.
4. Living organisms evolve and increase their resistance to biological, chemical, physical and any other form of control [67].

Conclusion

There is no doubt that bio-fertilizers are the potential tools for sustainable Vegetable production not only in India but also globally. Despite the many challenges facing the adoption of biopesticides, they still remain suitable alternatives to conventional pesticides. Training on production and quality control to manufacturers, organizational training to extension workers and farmers to popularize biopesticides would be essential for better adoption of biopesticides.

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