BIOLOGICAL MANAGEMENT OF MAJOR VEGETABLE INSECT PESTS WITH MICROORGANISMS FOR FOOD SAFETY AND SECURITY

Abstract

The most devastating obstacles to global agriculture are insect pests. Under the effect of shifting climatic circumstances, the extent of damage rises continuously. Due to insect pest outbreaks in crops, which are the main source of international trade, the developing countries suffer more. Vegetables that are consumed domestically and exported to other nations are largely produced in India. But because they are the root of many epidemics, insect pests create a significant threat to production and productivity. In order to rapidly eliminate these insect pests, chemical pesticides are being applied. However, overuse of these chemical pesticides frequently resulted in environmental degradation, population growth, pesticide residual issues in the soil and water, and bug resistance to these chemicals. Target specificity, self-perpetuation, and environmental safety make biological control highly regarded. Various microscopic parasitic organisms that infect insects are mostly used in biological pest management. These include bacteria like Bacillus thuringiensis and B. papillae, viruses like Nuclear polyhedrosis virus and Granulosis virus, fungus like *Beauveria bassiana* and *Metarhizium anisopliae*, *Lecanicillium (=Verticillium) lecanii* and *Nomuraearileyi*, or worms like *Steinernema*. This chapter describes the importance of these organisms in the management of the insect pests of the tomato, brinjal, okra, and cole crops.

Keywords: Microorganism, Microbial, Biocontrol, Vegetable Insects Pests, Management.

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I. INTRODUCTION

India is a major agricultural nation. With over sixty percent of its population working in agriculture and residing in rural areas. Indian agriculture has a huge economic impact on the nation. Nearly all crops, including food grains, horticulture crops, and commercial crops, are produced in India. (Vanitha et al., 2013; APEDA 2020). Vegetables have significant contributions to both area and production of horticulture crops, with important crops including okra, brinjal, tomato, cabbage, onion, potato, and cucurbits are grown in the country throughout the crop periods. (NHB 2018). In our daily diet, vegetables are important source of proteins, minerals, vitamins, dietary fibre, micronutrients, antioxidants, and phytochemicals. In addition to providing nourishment for our diet, they also include a variety of phytochemicals, such as anti-carcinogenic and elements antioxidants like flavonoids, glucosinolates, and isothyocyanates that aid of many diseases treatment.

Vegetable crop productivity and production are increased, but still there are a number of obstacles to their growth, including diseases, pests, and other abiotic issues. Vegetable crops are among them, and insect pests attack them at different phases of growth, greatly reducing their yield and quality. (Sharma *et al*., 2017). They cause varying amounts of damage to plants in open fields as well as in protected structures (net houses and polyhouses)(Rai *et al*., 2014). Though there are many ways to prevent the injuries, chemical pesticides are used extensively, particularly in the years after the green revolution. But the reckless and indiscriminate application of chemical pesticides led to a number of problems, including product residues, detrimental impacts on people and animals, and environmental deterioration. However, a variety of research findings show that the majority of insect pests have evolved a resistance to significant insecticides.

Many areas of the country are experiencing a bug resurgence. Researchers and growers are now seriously concerned about the issue and are looking towards alternative or corrective pest control methods to achieve sustainable crop protection, production, and environmental safety.

Another possibility is biological control, which eventually won out over synthetic pesticides as the most efficient and environmentally benign way to handle insect pests in plants. Here, insect populations are kept below economic threshold levels (ETL), which also safeguard natural adversaries, by using living organisms and their products. (Altieri *et al*., 2005; Mahr *et al*., 2008).

Over the past few years, a sizable research and development effort has been launched for the bio-control of insect pests. Biological control has remained a part of IPM for the past 50 years and is progressing steadily but favourably (Orr 2009). A literature evaluation and assessment of several pests of important vegetable crops, including the level of damage and their safe treatment using bio-control agents, were done in order to examine the significance of bio-control. In the paragraphs that follow, we'll cover the relevant works in comprehensive way.

Major pests of vegetable crops with their damage (%) in India

Sl. No.	Crop	Pest	Damage (%)
1	Brinjal	Shoot and fruit borer (*Leucinodesorbonalis*)	11-93
2	Tomato	Tomato fruit borers, (*Spodoptera litura),* (*Helicoverpaarmigera)*	24-65
3	Cabbage	Diamond back moth, (*Plutellaxylostella*)	17-99
4	Cabbage	Cabbage caterpillar (*Peiris brasicae*)	69
5	Cabbage	Cabbage leaf webber(*Crocidolomiabinotalis*)	28-51
6	Chilli	Thrips (*Scirothrips dorsalis*)	12-90
7	Chilli	Mites (*Polyphagotarsonemus latus*)	34
8	Okra	Fruit borer (*H. armigera*)	22
9	Okra	Leafhopper (*Amrascabiguttulabiguttula*)	54-66
10	Okra	Whitefly (*Bemisiatabaci*)	54
11	Okra	Shoot and fruit borer (*Eariasvittella*)	23-54
12	Cucurbits	Fruitfly (*Bactroceracucurbitae*)	
13	Bitter gourd	Fruitfly (*Bactroceracucurbitae*)	60-80
14	Cucumber	Fruitfly (*Bactroceracucurbitae*)	20-39
15	Ivy gourds	Fruitfly (*Bactroceracucurbitae*)	63
16	Muskmelon	Fruitfly (*Bactroceracucurbitae*)	76-100
17	Snake gourd	Fruitfly (*Bactroceracucurbitae*)	63
18	Sponge gourd	Fruitfly (*Bactroceracucurbitae*)	50

Damage by major insect pests also depends on crop variety, season, geographical area, cultural practices and fertility status of soil.

Source: Shivalingaswamy*et al*., 2002

II. MICROBIAL BIOCONTROL AGENTS USED AGAINST DIFFERENT INSECT PEST OF VEGETABLE CROPS

Similar to plant pathogens, these microorganisms—fungi, bacteria,viruses,protozoa, actinomycetes, and nematodes—prevent insect pests. Insect-pathogenic fungi (*Metarhizium, Beauveria, Paecilomyces*), insect-pathogenic bacteria (*Bacillus thuringiensis-Bt*), entamopathogenic nematodes (*Heterorhabditis*and *Steinernema*), and viruses (nuclear polyhedrosis virus-NPV and granulosis viruses (GV)) can all be released after innudative application. (Flint and Dreistadt 1998). It has been demonstrated that they are effective against Lepidoptera, Homoptera, Coleoptera, Orthoptera, and mites. The majority of bacterial biological control agents are *Bt* formulations based on *Bacillus thuringiensis*.

1. **Tomato:** Among the several pests of tomato, *H. armigera* is causing severe damage limiting the production of tomato in India. The inset pest causes 20-50% damage in different parts of the country. In recent years, conventional and synthetic pyrethroid insecticides used by the growers have shown reduced effectiveness in the control of *H. armigera*. Microbial agents like HaNPV, *BT* and *N. rileyi* have been tested for its control under field condition in India. (Table-1)

The amount of borer damage was significantly reduced after three rounds of HaNPV@250 LE / ha (1.5x1012POB / ha) were applied coupled with adjuvants in the evening at weekly intervals beginning at the flower commencement (Narayanan and Gopalakrishnan, 1987a; Mohan et al., 1996). In Karnataka, farmers' fields have been used to investigate the effectiveness of HaNPV extensively (Gopalakrishnan and Asokan, 1998). To effectively combat the pest on tomatoes, five rounds of HaNPV @250 LE / ha must be used at weekly intervals, beginning with the first spray on blossom initiation. When sprayed at intervals of ten days, *Bt* commercial formulation (Dipel) at a rate of 0.25–0.5 kg/ha was found to be efficient in controlling the same pest (Krishnaiah et al., 1981). The application of five rounds of fungus @ 3.2x108 spore/ml along with Triton x-100(0.01%) at weekly intervals right from flowering effectively controlled the fruit borer population on tomato, according to the results of three winter crop experiments with *N. rileyi* for the control of *H. armigera* on tomato (Gopalakrishnan and mohan, 2001 b).

In addition, incorporation of the parasite Trichogrammapretiosum with either HaNPV or BT is advised for successful control of the fruit borer. (Table-1). The integration of these bioagents is mainly aimed attacking the different stages of the pest. However, consistent results were not obtained when the release of *T. pretiosum* was integrated with the application of HaNPV or *Bt*. In order to lessen the harm caused by *H. armigera* to tomato plants, Gupta and Babu (1998) demonstrated that three releases of *T. pretiosum* and three sprays of *Bt* at 1 kg/ha were quite beneficialin Himachal Pradesh. In some trials, HaNPV alone was found better while in some other experiments, release of *T. pretiosum* also was found on par with combination of treatments. Krishnamoorthy *et al.* (2002) suggested the release of *T. pretiosum* (2.5 lakhs /ha) + 2 sprays of HaNPV (250 LE / ha) for the effective management of tomato fruit borer. Ganguli and Dubey (1998) recommended one application of HaNPV @250 LE /ha at the time of pest occurrence followed by spraying of endosulfan 0.07% to protect the crop from *H. armigera*. *Spodoptera litura* (Fab.) also caused fruit damage upto 32% in Orissa.

The work on tomato for the control of *H.armigera* with the use of *Bt* is meagre. This may be due to the inconsistent result obtained due to development of resistance in the Pest towards *Bt*. However, integration of *Bt* with the parasitoid*T. pretiosum* has given good result against *H.armigera*in tomato in Himachal Pradesh (Gupta and Babu, 1998).

Table1: Microbial Agents for Insect Pest of Tomato.

Insect Pest	Crop	Bioagent /Formulation	Dose used	Result	Reference
H. armigera	Tomato	Dipel	0.5 kg/ ha	Highly effective	Krshnaiah*et al.* (1981)
		HaNPV	100 LE/ ha	Highly effective	Anon. (1983)
			100 LE/ ha	Effective	Mistry *et al*. (1984)
			250 LE/ ha	Highly effective	Narayanan and Gopalakrishnan (1987)
			300 LE/ ha	Highly effective	Mohan *et al*. (1999)
		HaNPV+ Cypermethrin	250 LE/ ha 0.00375 %	Highly effective	Pokharkar and Chaudhary (1997)
		HaNPV + Endosulfan	100 LE/ ha 0.035 %	Highly effective	Satpathy*et al.* (2000)
		Bt-T.pretiosum	1 kg/ ha, 50,000/ ha	Highlyeffective	Guptha and Babu (1998)
		HaNPV+ Endosulfan + NSKE	250LE/ ha, 0.035 %3%	Highlyeffective	Gopal and Senguttuvan (1997)
H.armigera Spodoptera litura Trichoplusiani	Tomato	HaNPV T.pretiosum	250 LE/ ha 50,000adults/ha	Highlyeffective	Rehman *et al*. (2001) Brar *et al*. (2002) Singh *et al. (*2002)
		HaNPV + T.pretiosum + Endosulfan	250 LE/ ha +50,000adult /ha + 0.07%	Highly effective	Kaur (2001)
		HaNPV Marigold	250 LE/ ha	Highly effective	Krishna Moorthy *et al.* (2002)
		Nomuraearileyi	3.2 x10^8 spore /ml	Effective	Gopalakrishnan and Mohan (1996)
			3.2 x 10^8spore / ml	Effective	Gopalakrishnan and Mohan (2001b)

2. **Eggplant (Brinjal):** The shoot and fruit borer, *Leucinodesorbanalis (Guence),* is the most destructive pest of brinjal, endemic in nature and causes direct losses to the extent of 26.3 to 62.5 percent in different parts of the country. There has been a progressive decrease in the effectiveness of insecticides controlling the pest. According to Puranik*et al.* (2001), Dipel was very effective and on par with other *Bt* formulation (Delfin, Halt and Biolep) tested. Dipel in combination with carbaryl or endosulfan (Baskaran and Kumar, 1980; Krishnaiah *et al*., 1981) or Methomyl (Qureshi *et al*., 1998) was found to be better in reducing the borer damage in brinjal fields. There was 30% reduction in larval population and 48.3% yield increase in the brinjal plots applied with Halt in combination with low dose of endosulfan (Gopalakrishnan, 1999). Bt alone has not given desired control of the pest and Bt with chemical pesticides has given only 30% control. Hence, it is suggested to integrate the release of *Trichogramma spp*. With Bt and safer chemicals to bring down the borer damage in eggplant.

3. **Okra:** *Eariasvitella Fab., E.insulana* F. and *H. armigera* are the major lepidopterous pests affecting Okra. They cause up to 50% loss across the country. *BT* and HaNPV was field tested for their control (Table-2). Three applications of *BT* (Dipel) @0.5 Kg / ha at weekly intervals reduced the damage by *E.vitella* (Krishnaiah, *et al*., 1981. Chandrashekaran *et al*.,2001). In Orissa, both *E.vitella* and *H.armigera* were controlled effectively with the application of *BT* (Biolep) @2 Kg/ ha (Satapathy and Panda 1997). Three weekly sprays of HaNPV @250 LE/ ha, through checked larval population of *H.armigera* on okra, but failed to increase the yield. Whereas, HaNPV @500 LE/ha reduced fruit loss and surge the yield (Gopalakrishnan, 2001). This may be due to the alkaline pH of the leaf (>9.0) which probably destroyed the polyhedral occlusion bodies consumed by the larva. Integration of *Bt* (Dipel), HaNPV and *T. pretiosum* gave effective control of the fruit borers, *E. vitella* and *H. armigera* under field condition (Table-2).

Table2. Microbial Agents for Insect Pest of Egg Plant and Okra.

Insect Pest	Crop	Bioagent / Fomulation	Dose used	Result	Reference
Leucinodesorbonalis	Eggplant	Dipel+ Carbaryl	0.5 %	Moderately effective	Baskaran and Kumar (1980) Krshnaiah*et al.* (1981)
		Dipel	0.5 kg/ ha	Not effective	Krshnaiah*et al.* (1981)
			2 %	Effective	Puranik*et al.* (2001)
		Dipel+Methomyl		Moderately effective	Quereshi*et al.* (1998)
		HaltEndosulfan	1 kg /ha + 0.035%	Moderately effective	Gopalakrishnan (1999)
Eariasvitella	Okra	Dipel	1 kg/ ha	Effective	Krishnaiah *et al.* (1981)
		Biolep	2 kg / ha	Effective	Satapathy and Panda, (1997)
E. vitella *H. armigera*	Okra	Dipel HaNPV *T.pretiosum*	1 kg/ ha 250 LE/ ha 50,000 adults/ha	Highly effective	Praveen and Dhandapani (2001)
H. armigera	Okra	HaNPV	500 LE/ ha	Highly effective	Gopalakrishnan (2001a)

4. **Cabbage and Cauliflower:** Diamondback moth (DBM) *P.xylostella*, *Crocidolomiabinotaliszell*., *Pieris brassicae* (L.), *H. armigera*, *S. litura*, and *Trichoplusiani* are the major Lepidopterous pests found causing damage to cabbage, cauliflower and crops in different parts of the country *P. xylostella*has developed resistance to most of the commonly used insecticides resulting in inadequate control. Numerous Bt formulations were tested across the nation and proved to be successful in lowering the larval population and significantly raising production. (Table-3). BT formulation like Delfin, Dipel, Halt and Biobit were also found effective in reducing the damage caused by *H. armigera* on cabbage and also other Lepidopterans pests attacking cabbage in Gujarat (PDBC, 1999). Bt formulation besides controlling DBM, also reduced the larval population of *C. binotalis* (64.4% reduction) on cabbage (Malathi *et al*., 1999) and *P. brassicae* on cauliflower (Atwal and Singh, 1969;Justin *et al*.,1990;Justin and Nirmala, 2000; Kandoria, *et al*.,2000). Combination of Dipel and Chlordimecron (0.25 kg /ha) were also found superior to Dipel alone at 0.5 Kg/ ha (Krishnaiah, *et al*., 1981). The effectiveness of *Bt* against DBM and other insect pest on cauliflower is the same as on cabbage (Table-3).

   About a dozen commercial formulation of *Bt* are now available in the market. There are lot of variation in their field efficacy against DBM on cabbage and cauliflower and the result are not consistent (Table-3).This may be due to non-uniformity in the dosage, number of sprays, the spore load in the formulations and also for the resistance development in the insect pest towards *Bt*. Application of five times of *P. farinosus* or *Metarhizium anisopliae* var. anisopliae (Metchinikoff)@1.7x10^8 spore / ml at 7 days interval significantly minimised the amount of DBM larvae on cabbage. The yield of cabbage was significantly higher (43.7-49.0 kg/plot) in fungus-treated plot as compared to a low yield of 30.9 Kg/plot recorded in control check Gopalakrishnan, 2000; Gopalakrishnan and Mohan, 2002a). The broad-spectrum fungal pathogen, *Nomuraearileyi* (1.6x10^8 spore/ml) along with low dose of endosulfan (0.035%) gave efficient management of *H.armigera*, *S. litura*, *Trichoplusiani* and DBM on cabbage (Gopalakrishnan and Mohan, 2002b).Kennedy *et al*. (2000) also indicated the scope of entomopathogenic fungi, *Beauveria bassiana* (Bals.) and *M. anisopliae* in the management of DBM. Application of NPV of *P. xylostella* (PxNPV @1.7x108 POB/ ml mixed with India ink gave maximum reduction of DBM on cabbage (Padmavathamma and Veeresh, 1995). A granulosis virus has also been isolated from *P. xylostella* by PDBC, Bangalore and TNAU, Coimbatore, S/NPV @250 LE/ ha along with endosulfan (0.07%) gave maximum control of *S. litura* on cabbage (Pawar *et al*., 1991) and cauliflower (Chowdhari and Ramakrishnan, 1980). Insect populations of DBM have recently expanded as a result of the majority of conventional insecticides killing important parasitoids but not the pest. However, non-traditional pesticides like NSKE and microbial pathogens (BT and fungus) assist control the pest population without harming its natural enemies. (Table-3).

   BT commercial formulation was extensively used to control DBM on cabbage and cauliflower. Since the formulations are imported, the cost is very high. Some of the formulations do not give desired result, Entomopathogenic fungi, which have high potential to tackle pest have to be developed as mycoinsecticides with suitable formulation, which will be environmentally safe and cost effective.

Table3. Microbial Agents for Insect Pest of Cabbage and Cauliflower.

Insect Pest	Bioagent / Fomulation	Dose used	Result	Reference
S.litura	SlNPV+Endosulfan	250 LE/ ha 0.07%	Highly effective	Pawar *et al*. (1991)
P.xylostella	PxNPV	1.7 x10^8 POB/ml	Effective	Padmavathamma and Veeresh (1995)
P.xylostella, H. armigera	Bt formulations	1 kg/ha	Effective	PDBC (1999)
P.xylostella	Biotrol	2.5 kg/ ha	Effective	Rajmohan and Jayaraj(1978)
P.xylostella , C.binotalis	Cajrab	5 kg/ ha	Highly effective	Krishnaiah,*et al.* (1981)
	Dipel+Chlordimecron	0.5 kg/ha + 0.25kg/ha	Highly effective	Krishnaiah, *et al.* (1981)
	Dipel	1kg/ ha	Highly effective	Malathi *et al. (*1999)
P.xylostella	Dipel Centari	1kg /ha 1kg/ha	Effective	Asokan*et al.* (1996)
	Mutant Btk	300g protein/ ha	Highly effective	Mohan *et al.* (1997)
Pieris brassicae	Dipel, Centari	1kg/ha, 1kg/ha	Highlyeffective	Shylesha and Azad Thakur (2000)
P. xylostella	Delfin	0.2%	Highlyeffective	Hadapad*et al. (*2001)
	Halt	1kg/ha	Effective	Gopalakrishnan (2001b)
	P.farinosus	1.7 x10^8 spore/ml	Effective	Gopalakrishnan (2000)

Insect Pest	**Bioagent / Fomulation**	**Dose used**	**Result**	**Reference**
P. xylostella	M.anisopliae	1.7 x10^8 spore/ ml	Effective	Gopalakrishnan and Mohan (2002b)
P. xylostella	C.plutellae C.carnea DipelNimbicidine phosalone	250000adults/ha 2500 eggs/ha 500ml/ ha625ml/ha 2.81/ha	Highly effective	Reddy and Guerrero (2000)
P. brassicae *P. xylostella*	Thuricide	4 %	Highly Effective	Atwal and Singh (1969)
P.xylostella	Bt formulation	750g a.i./ha	Effective	Justin *et al*. (1990) (79) Justin and Nirmala (2000)
	B.bassiana M.anisopliae		Effective	Kennedy *et al*. (2000)
	Dipel 8L	1.5l/ ha	Highly effective	Kandoria,*et al*. (2000)
	Bioasp, Biolep	2 kg/ha	Highly effective	Sharma, *et al*. (2000)
P.xylostellaH.undalis	Bt	1.5kg/ ha	Highly effective	Battu and Arora (2001)

III. BENEFITS OF BIOCONTROL

- Repression of insect or weed pests to manageable levels and a decrease in the potential legal risk associated with pesticide use. Chemical pesticides can harm people's health in a variety of ways, including by irritating their eyes, skin, and nerves.
- Chemical pesticides can damage agricultural land by harming worms that maintain healthy soil, beneficial insect species, and soil microbes. Chemicals can also affect a plant's immunological and root systems, which lowers soil levels of nitrogen and phosphorus, two vital plant nutrients.
- Reduces the immediate and long-term effects of chemical pesticides on people, animals, non-target organisms, and the environment. Typically, biocontrol agents are very targeted and pose less of a threat to the environment and water.
- No resistance develops, reducing the effectiveness of the treatment.
- Biodiversity preservation and ecosystem restoration.
- There are usually no phytotoxic effects on leaves, flowers and fruits).
- A high benefit to cost ratio exists when using biological agents in agriculture.

IV. CRITICAL GAPS

Most of the research in microbial control is concentrated more on vegetables and less on fruits. In vegetables the research was mostly directed on lepidopterous insect pests. The sucking pests in vegetables and fruits are very important because they cause extensive damage and yield loss. The following critical gaps are identified for future line of research.

- Quality control is an important aspect for the ultimate success of microbial pesticide. Hence adequate quality control measures should be developed involving qualified and experienced personnel in the field, to ensure quality of the microbial pesticides to the farmers.
- UV protection for all the bioagents should be identified as spraying large areas during evening hours, to prevent photo inactivation of the pathogen, is a difficult for the farmers.
- Fungal pathogen use is limited under hot and dry weather, their use along with suitable humectant to be studied. Selection or development of virulent strains of pathogens which perform well under adverse situation need more research.
- Development of application technology mimicking natural situation needs to be given greater importance in research.
- Today, biocontrol has found a permanent place at the center of the concept of IPM, their use along with botanicals and safer chemicals in IPM should be thoroughly studied and considered were ever possible, for effective, safer and economic management of different insect pests on vegetables and fruits.
- The Whitefly, *Bemisiatabaci* is a serious problem on tomato, which is the vector for tomato leaf curl virus. There is no chemical insecticide to control this pest. Fungal pathogens like *V. lecanii*, *P.farinosus*, etc. Offer excellent opportunity and hence more research is needed to develop an excellent mycoinsecticide to manage this pest under field condition.
- There is no suitable technology available to tackle the menace of shoot and fruit borer problem in eggplant. Event *Bt* has not given adequate control either alone or in combination with methods of control. There is an urgent need to identify potential

entomopathogens and other biological agents for effective management of this pest in an integrated manner.

V. CONCLUSION

The need for knowledgeable administration and planning is perhaps the biggest obstacle to efficient biocontrol. For greatest benefit, the user must be knowledgeable about the biological phenomena of the target pests as well as their natural adversaries. The dangers of biocontrol on human and animal are extremely low. There have been a few isolated reports of workers at manufacturing facilities experiencing mild allergic responses.

As a pest management alternative to conventional pesticides, microbial biocontrol agents can be effective. Biological control should be a part of integrated pest management even though it won't completely eradicate all insects at once. Vegetable crops and other crops are subject to a variety of sustainable pest management techniques, although the majority of these techniques are ineffective in actual field settings.

Activity of public-private partnership technology in production, distribution and quality control measures of IPM such as resistant varieties, plant based formulation, bio-pesticides and bio-control agentsare imperative, otherwise we may have to continue of talkingabout alternative methods of pest management for many years in future.

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