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Bio-control of Important Pests on Vegetable Crops by Using Microorganisms and Microbial Toxins

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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 *Nomuraea rileyi*, or worms like *Steinernema*. Important microbial toxins are *Saccharopolyspora spinosa* and *Streptomyces avermitilis.* The management of the main vegetable insect pests of tomato, brinjal, okra, and cole crops is described here, as well as the significance of these organisms in that management.

Key words : Microorganism, Microbial, Biocontrol, Vegetable insects pests, Management.

Introduction

India is a major agricultural nation. With more than 60% of its inhabitants living in rural areas and working in agriculture. The agricultural sector in India makes a significant contribution to the GDP of the country. Nearly all crops, including food grains, horticulture crops, and commercial crops, are produced in India. (Vanitha *et al.*, 2013). Vegetables have significant contributions to both area and production of horticulture crops, with important crops including okra, brinjal,

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tomato, cabbage, onion, potato, and cucurbits are grown in the country throughout the crop periods. (NHB, 2018). In north east India major vegetables like brinjal, lady's finger, cabbage, chilli, pointed goard, auliflower etc are grown commercially but insect and mite pests attack limits the production (Ghosh *et al.*, 1999; Ghosh *et al.*, 2000; Ghosh and Senapati 2001a; Chaudhury *et al.*, 2001). 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 damage vegetables both in protected structures (net house, polyhouse) and open field with variable damage (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. However, the careless and indiscriminate use of chemical pesticides resulted in a number of issues, including product residues, adverse effects on people and animals, and environmental degradation. On the other hand, numerous findings from various researchers indicate that the majority of insect pests have developed resistance to important 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).

Significant research and development programme have taken up during past few years for bio-control of insect pests. Over the past 50 years, biological control remains as one of the components of IPM and showing a steady but promising growth in IPM (Orr, 2009). Looking into the importance of bio-control, literature study was carried out and review work was done on many pests of major vegetable crops like the extent of damage and their safe management using bio-control agents. The detailed literature is provided in following paragraphs.

Microbial 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*

Major pests of vegetable crops with their extent of damage in India

Sl. No.	Crop	Pest	Damage (%)
1	Brinjal	Shoot and fruit borer (*Leucinodes orbonalis*)	11-93
2	Tomato	Tomato fruit borers, (*Spodoptera litura),* (*Helicoverpa armigera)*	24-65
3	Cabbage	Diamond back moth, (*Plutella xylostella*)	17-99
4	Cabbage	Cabbage caterpillar (*Peiris brasicae*)	69
5	Cabbage	Cabbage leaf webber (*Crocidolomia binotalis*)	28-51
6	Chilli	Thrips (*Scirothrips dorsalis*)	12-90
7	Chilli	Mites (*Polyphagotarsonemus latus*)	34
8	Okra	Fruit borer (*Heliothis armigera*)	22
9	Okra	Leafhopper (*Amrasca biguttula biguttula*)	54-66
10	Okra	Whitefly (*Bemisia tabaci*)	54
11	Okra	Shoot and fruit borer (*Earias vittella*)	23-54
12	Cucurbits	Fruitfly (*Bactrocera cucurbitae*)	
13	Bitter gourd	Fruitfly (*Bactrocera cucurbitae*)	60-80
14	Cucumber	Fruitfly (*Bactrocera cucurbitae*)	20-39
15	Ivy gourds	Fruitfly (*Bactrocera cucurbitae*)	63
16	Musk melon	Fruitfly (*Bactrocera cucurbitae*)	76-100
17	Snake gourd	Fruitfly (*Bactrocera cucurbitae*)	63
18	Sponge gourd	Fruitfly (*Bactrocera cucurbitae*)	50

Source : Shivalingaswamy *et al.*, 2002

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

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*.

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*. Important pests causing damage to tomato crop are aphid (Aphis spp.), whitefly (*Bemesia spp.*), leaf miner *Lyriomyza spp.*), thrips (*Thrips spp*), Jassid (*Empoasca spp.*), Flea beetle (*Phyllotreta spp.*) (Laskar and Ghosh, 2005; Subba *et al.*, 2014; Subba *et al.*, 2015; Subba *et al.*, 2016; Subba *et al.*, 2017; Thakoor *et al.*, 2019). Microbial agents like HaNPV, *Bt* and *N. rileyi* have been tested for its control under field condition in India. (Table-1)

The application of three rounds of Ha NPV @ 250 LE / ha (1.5x10^{12} POB / ha) along with adjuvants during the evening hours at weekly intervals right from the flower initiation had resulted in significant reduction in the borer damage (Narayanan and Gopalakrishnan, 1987 a ; Mohan *et al.*, 1996). The efficacy of Ha NPV has been tested extensively in farmers' field in Karnataka (Gopalakrishnan and Asokan, 1998). Application of five rounds of Ha NPV @250 LE / ha at weekly intervals commencing the first spray on flower initiation is needed to cheek the pest very effectively on tomato. The same pest was found to be effectively controlled by *Bt* commercial formulation (Dipel) at 0.25-0.5 kg / ha, when sprayed at intervals of ten days (Krishnaiah *et al.*, 1981). Results of three winter crops experiments with *N. rileyi* for the control of *H. armigera* on tomato revealed that the application of five rounds of fungus @ 3.2x10^{8} spore /ml along with Triton x-100 (0.01%) at weekly interval right from flowering effectively controlled the fruit borer population on tomato (Gopalakrishnan and mohan, 2001 b).

Further, for effective control of the fruit borer, integration of the parasitoid, *Trichogramma pretiosum* either with Ha NPV or *Bt* is also suggested (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 Ha NPV or *Bt*. Gupta and Babu (1998) found that three releases of *T. Pretiosum* + three sprays of *Bt* @ 1kg / ha were found to be highly effective in reducing the damage caused by *H. Armigera* on tomato in Himachal Pradesh. In some trials, Ha NPV 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 Ha NPV (250 LE / ha) for the effective management of tomato fruit borer. Ganguli and Dubey (1998) recommended one application of Ha NPV @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 up to 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). Ghosh (2020) reported that Imidacloprid resulted the best suppression of whitefly population on tomato (81.48% suppression) followed by avermectin (73.33%) and mixed formulation of azadirachtin with Spilenthes (71.65%) extracts. Ghosh (2020) reported that mixed formulation Azadiractin + polygonum, microbial toxin spinosad, botanical pesticide Azadiractin, tobacco leaf extract, extracts of *Polygonum* floral parts gave moderate to higher results, recording about 76.09 %, 75.07%, 71.77%, 57.59% and 55.35% aphids suppression respectively.

Eggplant (Brinjal) :

The shoot and fruit borer, *Leucinodes orbanalis* (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. Ghosh and Senapati (2009) reported that in the foot hills of the Himalaya so called terai region of India, fruit and shoot borer was recorded very active in hot and rainy season, specifically during April- September and made about 50-80 % damage to fruits. Hadda/ spotted beetle (*Henosepilachna spp.*), aphid (*Aphis spp.*), jassid (*Amrasca spp.*), thrips (*Thrips spp.*), red mite (*Tetranychus spp.*) and white fly (*Bemisia spp.*) are important pests of eggplant that causes heavy damage (Ghosh, 1999). The aphid population causes heavy damage and limits the production (Ghosh, 2015; Ghosh, 2017). Ghosh (2019) reported that mite causes heavy damage to brinjal crop. Heavy incidence of the spotted beetle is reported in the temperature ranging 24-31°C and RH 58-75% at field condition (Ramzan et al., 1990; Ghosh and Senapati, 2001b.).

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. Microbial toxin like abamectin, extracted from soil acyinomycetes (*Streptomyces avermitilies*) is very effective against soft bodied insect and provides 66.59% control of aphid on Brinjal (Ghosh *et al.*, 2004). The insecticides evaluated in the field for *L. orbonalis* control on eggplant revealed that averrnectin (Vertimec 1.9 EC; 0.5 ml/L) was the most effective in suppressing dead heart caused by the pest, closely followed by *Beauveria bassiana* (Biorin 107 conidia/ ml; I ml/L) and *Bacillus thuringiensis* Berliner (Biolep 5 x 107 spores/ml; I g/L) (Ghosh and Senapati, 2009). Ghosh *et al.* (2006) reported from a field evaluation of pesticides revealed that DDVP was found relatively more effective against flea beetle on brinjal (33.43% control), followed by avermectin (30.34 % control) and neern (30-28 % control).

Okra :

Earias vitella Fab., *E.insulana* F. and *H. armigera* are the major Lepidopterous pests affecting Okra. They cause up to 50% loss in different parts of country. The important pest of ladysfinger are aphid (*Aphis spp.*), Iassid (*Amrasca spp.*), whitefly (*Bemisia spp.*), different species of flee beetle and red spider mite (*Tetranychus spp.*) (Ghosh *et al.*, 2009 a; Ghosh *et al.,* 2009 b; Das *et al.*, 2010; Ghosh, 2013; Ghosh, *et al.*, 2013). *Bt* and Ha NPV were 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 Ha NPV @250 LE/ ha, through checked larval population of *H. armigera* on okra, but failed to increase the yield. Whereas, Ha NPV @500 LE/ha reduced fruit damage and increased 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), Ha NPV and *T. pretiosum* gave effective control of the fruit borers, *E. Vitella* and *H. armigera* under field condition (Table-2). Botanical extract, *Polygonum hydropiper* floral part, pathogens, *Beauveria bassiana* and *Bacillus thuringiensis* caused significant lower killing of the predator (less than 30 %) whereas the synthetic insecticides, profenophos and methomyl caused significantly higher killing (more than 52 %) (Ghosh, 2013). Ghosh (2015) reported that imidacloprid provided the best suppression of jassid population (83.24 %) closely followed by microbial toxin *Saccharopolyspora spinosa* (74.76% suppression). Ghosh *et al.* (2009 a) reported that microbial toxin *Streptomyces avermitilis* was found best for suppression of mite population in okra (83.42% suppression).

Cabbage and Cauliflower :

Diamondback moth (DBM) *P. xylostella*, *Crocidolomia binotalis*, *Pieris brassicae* (L.), *H. armigera*, *S. litura*, and *Trichoplusia ni* 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. Several Bt formulations were tested in different parts of the country and found effective in reducing the larval population and increasing the yield substantially (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 due to the resistance development in the insect pest towards *Bt*. Application of five rounds of *P. farinosus* or *Metarhizium anisopliae* var. *anisopliae* (Metchinikoff) @1.7x10^8 spore / ml at weekly interval significantly brought down the larval population of DBM 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, *Nomuraea rileyi* (1.6x10^8 spore/ml) along with low dose of endosulfan (0.035%) gave effective control of *H.armigera*, *S. litura*, *Trichoplusia ni* 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* (Px NPV @ 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). The potential of the above viral and fungal pathogens has to be exploited for the management of DBM and other Lepidopterous insect pests in Cole crops.

Most of the conventional insecticides have killed key parasitoid but not the pest resulting in the increased populations of DBM in recent years. On the other hand, non-conventional insecticides like, NSKE and the microbial pathogens (Bt and fungus) help in managing the pest population without reducing the local natural enemies (Table-3).

Bt commercial formulation were 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.

Benefits of bio-control:

1. Insect or weed pest repression to manageable levels and reduces potential legal hazard of chemical use. Chemical pesticides can cause a wide range of human health problems such as nerve, skin, and eye irritation.
2. Chemical pesticides can spoil agricultural land by affecting beneficial insect species, soil microorganisms, and worms responsible for soil health. Chemicals also disturb plant root and

immune systems, and thus reduce concentrations of nitrogen and phosphorous in soil which are essential plant nutrients.

3. Reduces acute and long-term impact of chemical pesticides on human, animals, non-target organisms and the environment. Biocontrol agents are usually very specific and present less danger to environment and water.
4. There is no resistance buildup making treatment increasingly less effective.
5. Protection of biodiversity and restoring natural ecosystems.
6. Chemical residue-free products from farms and natural systems.
7. Potential to be permanent reductions of pest organisms.
8. There are usually no phytotoxic effects on young plants (on leaves, flowers and fruits).
9. The use of biological agents in agriculture has a high benefit to cost ratio.

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.

1. 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.
2. 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.
3. Fungal pathogen use is limited under hot and dry weather, their use along with suitable humectants to be studied. Selection or development of virulent strains of pathogens which perform well under adverse situation need more research.
4. Development of application technology mimicking natural situation needs to be given greater importance in research.
5. Today, biocontrol has found a permanent place at the centre 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.
6. The Whitefly, *Bemisia tabaci* 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.

7. 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.

Conclusion

The need for knowledgeable administration and planning is perhaps the biggest obstacle to efficient biocontrol. The user must comprehend the biology of both the target pests and their natural enemies for maximum benefit. The dangers of biocontrol to human and animal health are extremely low. There have been a few isolated reports of workers at manufacturing facilities experiencing mild allergic responses. Microbial biocontrol agents can sustain the pest management alternative to chemical pesticides. Though biological control will not control all the insects at a time, it should be an integrative component of integrated pest management. Many strategies of sustainable pest management in vegetable crops and others are studied and recommended, but most are not much effectivein field conditions. 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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Table 1. 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)
		Ha NPV	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)
		Ha NPV+ Cypermethrin	250 LE/ ha 0.00375 %	Highly effective	Pokharkar and Chaudhary (1997)
		Ha NPV + 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	Tomato	Ha NPV	250 LE/ ha	Highlyeffective	Rehman *et al.* (2001)
Spodoptera litura		*T. pretiosum*	50,000adults/ha		Brar *et al.* (2002) Singh *et al.* (2002)
Trichoplusia ni		Ha NPV + *T. pretiosum* +Endosulfan	250 LE/ ha +50,000 adult /ha +0.07%	Highly effective	Kaur (2001)
		Ha NPV Marigold	250 LE/ ha	Highly effective	Krishna Moorthy *et al.* (2002)
		Nomuraea rileyi	3.2 x10^8 spore /ml	Effective	Gopalakrishnan and Mohan (1996)
			3.2 x 10^8spore / ml	Effective	Gopalakrishnan and Mohan (2001b)

Table 2. Microbial agents for Insect pest of egg plant and Okra.

Insect Pest	Crop	Bioagent / Fomulation	Dose used	Result	Reference
Leucinodes orbonalis	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)
		Halt, Endosulfan	1 kg /ha + 0.035%	Moderately effective	Gopalakrishnan (1999)
Earias vitella	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 Ha NPV *T. pretiosum*	1 kg/ ha 250 LE/ ha 50,000 adults/ha	Highly effective	Praveen and Dhandapani (2001)
H. armigera	Okra	Ha NPV	500 LE/ ha	Highly effective	Gopalakrishnan (2001a)

Table 3. 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	Px NPV	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,	Cajrab	5 kg/ ha	Highly effective	Krishnaiah,*et al.* (1981)
C. binotalis	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	DipelCentari	1kg /ha 1kg/ha	Effective	Asokan *et al.* (1996)
	Mutant Btk	300g protein/ ha	Highly effective	Mohan *et al.* (1997)
Pieris brassicae	Dipel,1kg/ha Centari	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* Dipel, Nimbicidine 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)
 P. xylostella, H. undalis	Bioasp, Biolep *Bt*	2 kg/ha 1.5kg/ ha	Highly effective Highly effective	Sharma *et al.* (2000) Battu and Arora (2001)