# EXTENSION BULLETIN

ICAR
NATIONAL INSTITUTE OF
BIOTIC STRESS
MANAGEMENT
Rendering Solution to Biotic Stress

## Eco-friendly Pest Management Technologies

2018

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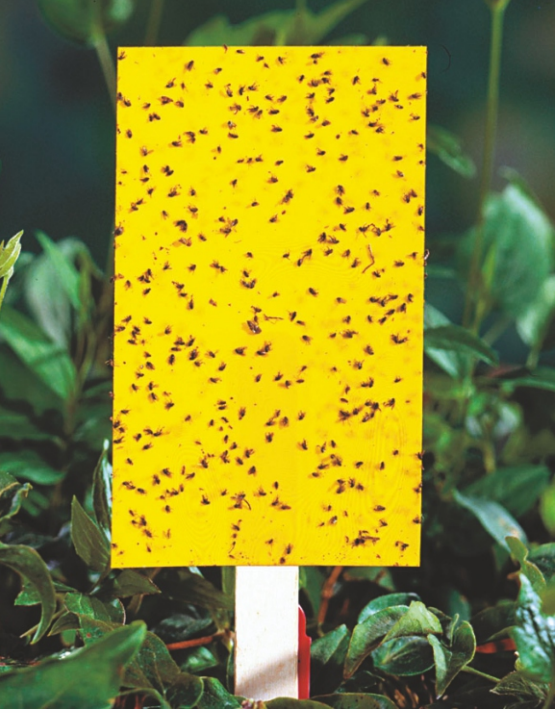

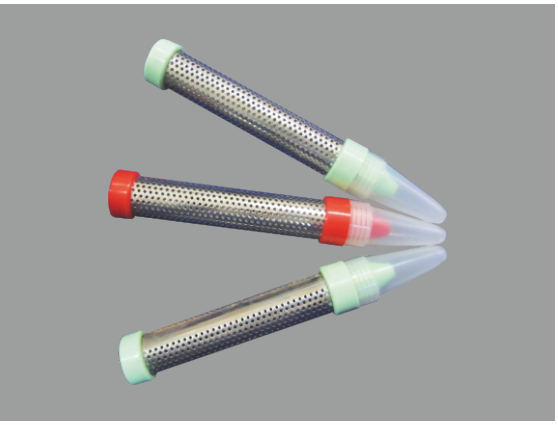

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TOP COVER PHOTO : *Trichogramma* EGG PARASITOID
LEFT COVER PHOTO : SEX PHEROMONE TRAP
CURRENT PAGE PHOTO : YELLOW STICKY TRAP &
INSECT PROBE TRAP

NIBSM Publication : NIBSM/EB/2018-01

# Eco-friendly Pest Management Technologies

## Contents



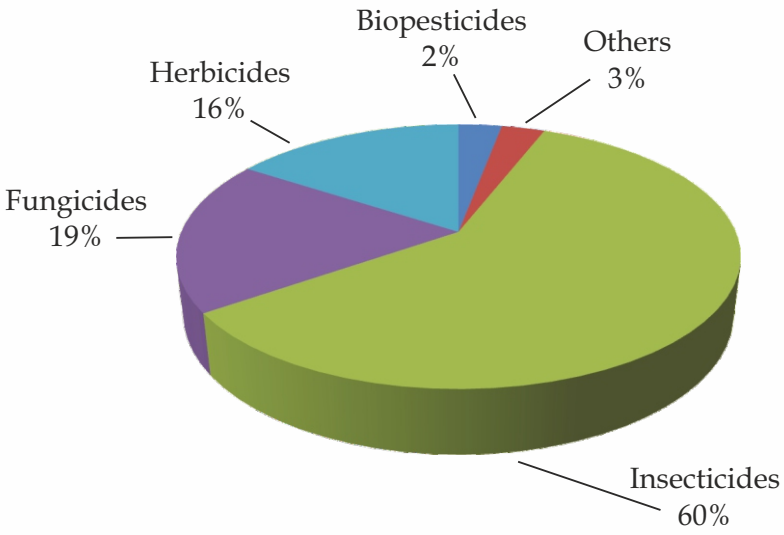
## Acknowledgements

The Extension Bulletin on 'Eco-friendly Pest Management Technologies' was prepared by the ICAR-NIBSM, Raipur with financial assistance of the MANAGE, Hyderabad. We acknowledge the help rendered from Dr. Jagdish Kumar, Director (Acting) and Dr. Kareem, Centre Head (EAAS), MANAGE, Hyderabad.

## Key Points

- Pest and Pathogen are major biotic stresses to cause economic damage and yield loss to field and horticultural crops
- Eco-friendly pest management technologies are best alternative to chemical control which are environmentally complementary/ focused with special attention to food security and sustainability
- Various traps like sex pheromone, yellow and blue sticky traps, fruit fly and fish meal traps; bio-control agents like green lacewing, brown lacewing, *Dipha aphidivora*, Australian ladybird beetle, black beetle, *Trichogramma* spp., Ichneumonfly, Braconid, *Brachymeria* and *Goniozus* wasps; insect pathogens such as *Bacillus thuringiensis*, nucleopolyhedron virus, Entomopathogenic fungi, Entomopathogenic nematode; antagonistic fungi like *Trichoderma* spp., *Pseudomonas etc.* are considered as eco-friendly pest management technologies in India
- Gadget technology for storage pest management is the recent advances of eco-friendly pest management
- The use of eco-friendly pest management methods is estimated as 5% of total pesticide usage in India (Fig. 1).

**Fig 1. Share of different classes of pesticides used in India**



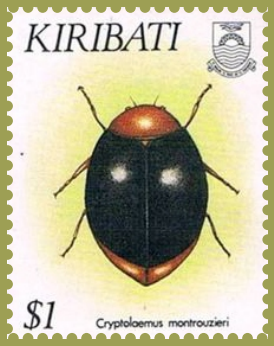

***Goniozus* adult on *Corcyra cephalonica***

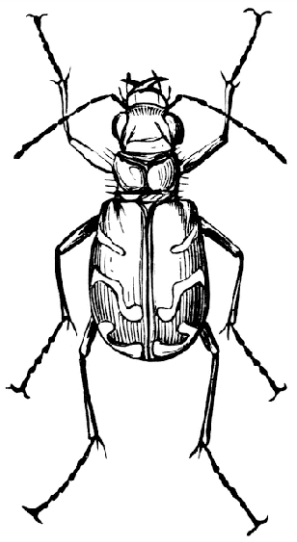
*"A grain saved is a grain produced - A seed saved is thousands produced"*

*"Eco-friendly pest management is an environmentally complementary/focused to prevent the occurrence of pest on crops"*

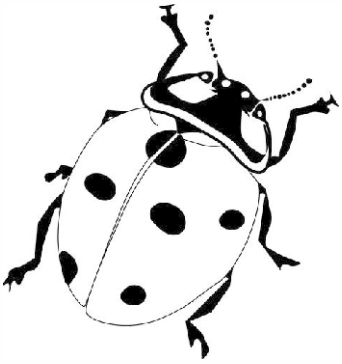
*"Biological control is the using of living organism to manage pest"*

*"Stamp for Australian ladybird beetle to respect its genuine service in managing mealybugs"*

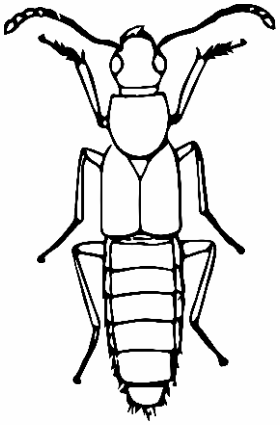




Tiger beetle



Ladybird beetle



Rove beetle

## Introduction

The rapid increase of human population during the last century has necessitated intensification of agriculture, which resulted in aggravation of pest problems and increasing pest-associated losses. During the last five decades, intensive agriculture utilizing green revolution technologies has caused tremendous damage to the natural resources that sustain it. Crop losses are usually defined as the reduction in either quantity or quality of yield and these may be caused by abiotic and biotic factors, leading to the reduction in crop productivity and lower actual yield than the attainable yield of crops. In India, the crop losses by insect pests was estimated as 23.3% during 1990s; 17.5% in 2010 and 15.7% in 2015. The crop-wise losses by insect pests is computed as 30% in cotton, 25% in rice, 20% in oilseeds, 15% in pulses, 5% in wheat, 18% in maize, 8% in sorghum and millets, 20% in sugarcane and 30 to 40% in vegetables. The post-harvest losses is computed to be around 9.3% of which losses during storage alone are estimated at 6.6%, out of which insect alone causes around 2.5% loss. In recent years, with changes in the cropping systems and climate, and introduction of highly input intensive high yielding varieties/hybrids, a shift in pest status has been observed.

Most of the plant protection recommendations in crops so far indicated the calendar based application of chemical insecticides. Around 272 pesticide molecules are registered and readily available in the market of India. Out of total insecticides used for pest management in India, 50% are diverted to cotton pest management. The use of insecticides and pesticides have increased manifolds during the past 3-4 decades with the introduction of intensive cropping. The annual insecticide application has increased from 7,000 t in 1997 to more than 16,000 t in the year 2000. The average consumption of pesticides in India is about 570 g/ha, as compared to developed countries like Japan, Thailand and Germany where the consumption rate is 11 kg, 17 kg and 3 kg/ha, respectively. Though the average quantum of pesticides usage in India is low, the damage caused due to their indiscriminate usage and poor quality maintenance is alarming.

Due to over dependence and indiscriminate use of insecticides, many ill-effects including residue in plant parts, resistance to insecticides, secondary pest out-break, pollution to natural resources, health complications for human and wildlife *etc.*, warrant to switch over to Integrated Pest Management (IPM). IPM aims at suppressing the pest species by combining more than one method of pest control in a harmonious way with least emphasis on the use of insecticides. In simple terms IPM is the right combination of cultural, biological and chemical measures which provides the most effective, environmentally sound and socially acceptable methods of managing pests, diseases and weeds. The major components of IPM are prevention, observation and intervention. The IPM seems to be the only answer to encounter some of the major pests of crops, which have become unmanageable in recent years. The success of IPM largely depends upon using eco-friendly pest management tools and conservation of naturally occurring biocontrol agents. Eco-friendly pest management is an environmentally complementary/ focused method with specific attention to its role in food security and sustainability. Some of such methods include traps, bio-control agents, food baits, gadgets, bio-pesticides *etc.*, which do not require any special protocols to be followed by the farmers in pest management under field condition (Fig. 2).

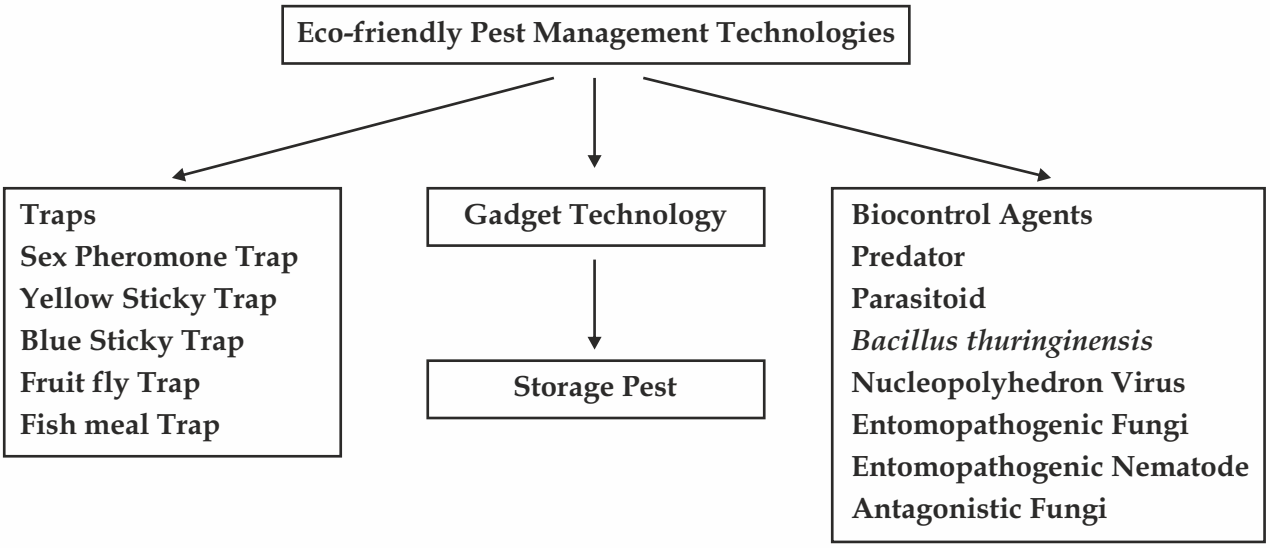



**Fig 2. Components of eco-friendly pest management**

## Insect Predators

A predator is relatively large compared to its host (prey) which it seizes and either devoures or sucks dry of its body fluids rather quickly. One predator consumes a number of hosts (single coccinellid adult feeds hundreds of aphids) in completing its development (Table 1).

**Table 1. List of important insect predators**

| Common Name | Scientific Name | Target pests |
|---|---|---|
| Ladybird beetle | *Cheilomenes sexmaculata, Chilocorus nigrita, Coccinella transversalis, Coccinella septempunctata, Curinus coeruleus, Cryptolaemus montrouzieri, Scymnus coccivora* | Aphids, mealybugs, scales, psyllids, whiteflies, eggs and early instar of Lepidoptera, Coleoptera, Thysanaptera, Diptera, mites |
| Mirid bug | *Cyrtorhinus lividipennis* | Eggs of rice leaf and planthoppers |
| Anthorocid bug | *Xylocoris flavipes* | Stored product pests |
| | *Cardiastethus exiguous* | Eggs and early instar of coconut black headed caterpillar |
| | *Blaptostethus pallescens* | Early instar of *Helicoverpa armigera* |
| Ant lion | *Chrysoperla carnea* | Eggs and early instar of *Helicoverpa armigera* |
| Brown lacewing | *Micromus igoratus* | Sugarcane woolly aphid |
| Syrphid fly | *Episyrphus, Betasyrphus, Ischiodon* | Aphids |

***Rodolia cardinalis***

***Cheilomenes sexmaculata***

***Chilocorus nigrita***

***Pharoscymnus horni***

***Coccinella transversalis***

***Coccinella septempunctata***

***Harmonia octomaculata***

***Curinus coeruleus***

*Brumoides suturalis*

*Illeis cincta*

*Cryptolaemus montrouzieri*

*Scymnus coccivora*

**Mirid bug**

**Anthocorid bug**

**Green lacewing**

**Brown lacewing**

**Syrphid fly**

**Ground beetle**

**Tiger beetle**

**Rove beetle**

**Reduviid bug**

**Pentatomid bug**

**Dragonfly**

*Yield loss in crops*

**Weeds: 33%**
**Insects: 26%**
**Diseases: 20%**
**Rodents: 6%**
**Others: 6-8%**

*Crop losses by insect pests*

**1990: 23.3%**
**2010: 17.5%**
**2015: 15.7%**

*Crop-wise losses by insect pests*

**Cotton: 30%**
**Rice: 25%**
**Oil seeds: 20%**
**Pulses: 15%**
**Wheat: 05%**
**Maize: 18%**
**Sorghum & Millet: 08%**
**Sugarcane: 20%**
**Fruits & Vegetables: 30-40%**

*Post harvest losses*

**Total post-harvest losses: 9.3%**
**Non-scientific storage: 6.6%**
**Storage insect: 2.5%**
**Rodent: 6.0%**

*Average consumption of pesticides*

**India: 570 g/ha**
**Japan: 11 kg/ha**
**Thailand : 17 kg/ha**
**Germany: 03 kg/ha**

## Insect Parasitoids

The parasitoid is almost parasitic in its immature stages and develops within or upon a single host which is slowly destroyed as the parasitic larva completes its development (Table 2).

**Table 2. List of important insect parasitoids**

| Common Name | Scientific Name | Target pests |
|---|---|---|
| Ichneumonid wasp | *Campoletis chlorideae, Eriborus argenteopilosus* | *Helicoverpa armigera* |
| | *Xanthopimpla* spp. | Stem borers of cereal crops |
| | *Eriborus trochanteratus* | Coconut black headed caterpillar |
| Egg larval parasitoid | *Chelonus blackburni* | Cotton spotted bollworms |
| Larval parasitoid | *Bracon brevicornis* | *Opisina arenosella* |
| | *Distatrix papilionis* | *Papilio demoleus, Diaeretiella rapae* |
| | *Stenobracon* sp. | Tephritidae |
| Egg parasitoid | *Trichogramma* spp. | Eggs of lepidopteran pests |
| Eulophid parasitoid | *Telenomus remus* | Eggs of *Spodoptera litura* |
| | *Pediobius foveolatus* | *Epilachna* larvae |
| | *Trichospilus pupivora, Tetrastichus israeli* | Pupa of *Opisina arenosella* |
| Encyrtid parasitoid | *Copidosoma* sp | *Plusia* sp. |
| | *Acerophagus papayae* | Papaya mealybug |
| Rice gall midge parasitoid | *Platygaster oryzae, Platygaster foersteri* | *Orseolia oryzae* |
| Bethylid parasitoid | *Goniozus nephantidis* | Coconut black headed caterpillar |
| | *Prorops nasuta* | Coffee berry borer |

**Parasitoid of coconut BHC**

**Parasitoid of lepidopteran larvae**

Larval parasitoid of lemon butterfly

Egg parasitoid

Pupal parasitoid of coconut BHC

Parasitoid of papaya mealybug

Parasitoid of rice gallmidge

## Biological Control of Sugarcane Woolly Aphid

Symptoms of damage

Winged forms of woolly aphids

Severely infested field of sugarcane

Sooty mould

### Biocontrol agents

*Dipha aphidivora* - Lepidopteran predator

NPV infected larva

*Beauveria* infected larva


*Metarhizium* infection

*Lecanicillium* infected aphid

Entomopathogenic Nematode

**Brown lacewing grub**

**Brown lacewing adult**

***S. grandis* feeding on aphid**

**Adults of *Synonycha grandis* released in sugarcane field**

**Life cycle of *Synonycha grandis***

**Egg**

**Grub**

**Pupa**

**Adult**

## Mass Production of Important Insect Predators

### Green lacewing/aphid lion

In India, 65 species of chrysopids belonging to 21 genera have been recorded from various crop ecosystems. Some species are distributed widely and are important natural enemies of aphids and other soft bodied insects. Amongst them, *Chrysoperla zastrowi sillemi* is the most common. It has been used in cotton ecosystem for protection from aphids and other soft bodied insects. The mass rearing technique of this predator involves two steps, larval rearing and adult rearing.

**Larval rearing**

250 grubs/basin

↓

25 cc of *Corcyra* eggs/500 grubs
@ 5cc/day at alternate days

↓

Grubs pupate in10 days

**Adult rearing**

250 adults/G. I. tray (30 x 12 cm)

↓

Semisynthetic diet
(honey, protein hydrolysate, yeast)

↓

Stalked eggs laid on brown sheet wrapper

### Australian ladybird beetle/mealybug destroyer

This beetle was introduced in to India during 1989 for the management of mealybug, destroying crops and its mass production involve two steps of rearing of mealybugs on red pumpkin and rearing of grubs.

Tender pumpkin with small stalk, ridges, furrows

↓

Sterilize outer surface with 0.1% bavistine, seal wounds with wax, air dried

↓

Release crawlers of mealybug on pumpkin, maintain in dark

↓

Confine mealybug infested pumpkin in cage (3 0x 3 0x 30 cm)

↓

Expose infested fruits to adult beetle for oviposition and remove the fruit after 48 h

↓

Grubs of beetle feed on mealybug, pupate on pumpkin

The optimum field dose for the management of various crop pests is appended in the table 3.

**Table 3. Field dose of key predators for pest management**

| Common Name | Scientific Name | Crop | Target pests | Field dose |
|---|---|---|---|---|
| Green lacewing | *Chrysoperla zastrowi sillemi* | Cotton, groundnut, sunflower, vegetables, flowers | Aphids, whitefly, eggs and neonate larvae of *Spodoptera, Helicoverpa*, pink bollworm | 20,000 eggs or first instar/acre for 3-5 times at 10 days interval |
| Australian lady bird beetle | *Cryptolaemus montrouzieri* | Grapevine, citrus, guava | Pink mealybug, citrus mealybug | 10-15 beetles/tree or vine |
| Lepidopteran predator | *Dipha aphidivora* | Sugarcane | Woolly aphid | 1000 cocoons/ac |
| Brown lacewing | *Micromus igorotus* | Sugarcane | Woolly aphid | 1000 cocoons/ac |
| Black beetle | *Chilocorus nigrita* | Coconut | Scale insect | 15 to 20 grubs or adults/infested shoot |

## Mass Production of Important Insect Parasitoids

### Mass production of egg parasitoid, *Trichogramma* spp.

1. Mass rearing of *Corcyra cephalonica*
2. Mass production of parasitoid

**_Corcyra_ medium ingredients**

1) 2.5 kg bajra grains
2) 100 g of groundnut powder
3) 5 g of powdered yeast
4) 0.05% streptomycin sulphate (5 mL/tray)
5) 5 g of wettable sulphur
6) 0.5 cc of *Corcyra* eggs

***Corcyra* medium**

**Secure with *Khada* cloth**

**Stacking of trays**

***Corcyra* larvae**

***Corcyra* adult**

**Collection of *Corcyra* adult**

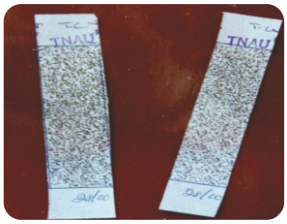
**Release of *Corcyra* adult in cage**

***Corcyra* adult in cage**

***Corcyra* egg**

**Egg card**

**Introduction of parasitoid**



**Tricho card**

### Quality parameters for *Trichogramma*

90 % parasitization
1 cc : 18,000 to 20,000 parasitoids

## Mass culturing of egg-larval parasitoid, *Chelonus blackburni*

Sprinkle *Corcyra* eggs on white card with gum

↓

Allow the parasitoids @ 1:100 in a plastic container

↓

Expose for 24 h

↓

Transfer the cards to another plastic container with 250 g of broken bajra grains

↓

Parasitoid develops inside the larvae and spin white cocoon

↓

Adult emerge in 15-20 days

***Chelonus blackburni***

## Mass culturing of larval parasitoid, *Bracon brevicornis*

Cover broader end of chimney with muslin cloth using rubber band

↓

Take one larva of *Corcyra* and cover with another muslin cloth

↓

Release two mated female *Bracon* adults through narrow end of chimney and closed with another muslin cloth

↓

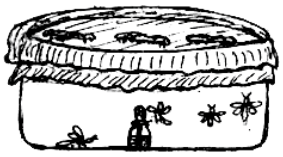
Each female lays 8-12 eggs on the ventral side

↓

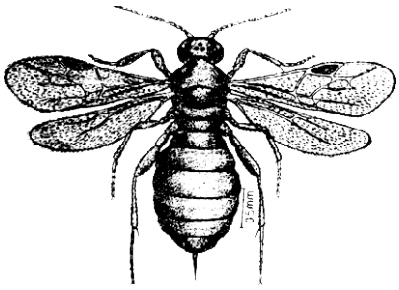
Transfer parasitized caterpillar in to container having folded papers

↓

Egg period 28-30 h; larval period 3-4 days; pupal period 2-3 days; Total life cycle 7-9 days



**Sandwich Method**



***Bracon brevicornis***

**Mass culturing of pupal parasitoid**

Take 5 pupae in a tube of 15 x 2.5 cm

↓

Release 30 mated female parasitoids

↓

They multiply inside the pupa

↓

Larval period: 6 days; Pupal period: 8-10 days

*Trichospilus pupivora*

*Tetrastichus israeli*

The field dose of candidate parasitoids for pest management is tabulated in table 4.

**Table 4. Field dose of key predators for pest management**

| Common Name | Scientific Name | Crop | Target pests | Field dose |
|---|---|---|---|---|
| Egg parasitoid | *Trichogramma japonicum* | Rice | Yellow stem-borer | 2 releases of *T. japonicum* @ 2.5 cc/ac/release at weekly interval on 30 and 37 DAT |
| Egg parasitoid | *Trichogramma chilonis* | Rice | Leaf folder | 3 releases of *T. chilonis* @ 2.5 cc/ac/release at weekly interval on 37, 44 and 51 DAT |
| Egg parasitoid | *Trichogramma chilonis* | Cotton | Bollworms | 3-4 releases of *T. chilonis* @ 2.5 cc/ac/release at weekly interval starting from 50 % flowering period |
| Braconid wasp | *Bracon hebetor* | Cotton | Bollworms | 8000 adults/ac |
| Braconid wasp | *Bracon brevicornis* | Coconut | Black headed caterpillar | 10 adults/tree |
| Egg larval parasitoid | *Chelonus blackburnii* | Cotton | Bollworms | 8000 parasitoids/ac |
| Larval parasitoid | *Goniozus nephantidis* | Coconut | Black headed caterpillar | 10 adults/tree |
| Pupal parasitoid | *Trichopilus pupivora, Tetrastichus israeli* | Coconut | Pupa of black headed caterpillar | 20 adults/tree |
| Encyrtid parasitoid | *Acerophagus papayae* | Papaya | Mealybug | 100 parasitoids/garden |

## Mass Production of Insect Pathogens

### *Bacillus thuringiensis*

*B. thuringiensis* is a gram positive spore forming bacteria, isolated from soil. Each bacterial cell forms a spore at one end and a crystal at the other end (Fig. 3). At the time of sporulation, they produce few insecticidal toxins *viz.*, α-exotoxin (heat labile), β-exotoxin (heat stable) and δ-endotoxin (crystalline toxin or crystal). Upon ingestion by the insects, this crystalline inclusion is solubilized in the midgut, releasing proteins called δ-endotoxins. These proteins are activated by midgut proteases and the activated toxins diffuses through the peritrophic membrane of midgut causing a disruption in membrane integrity and ultimately leading to insect death. Many *Bt* based formulations are available in the market (Table 5).

### Mass culturing of *Bt*

Mother culture from slant

↓

Inoculate 2-3 loopful of culture in 100 mL of broth

↓

Incubate in shaker for 48 h

↓

Inoculate in to 900 mL broth

↓

Incubate for 48 h

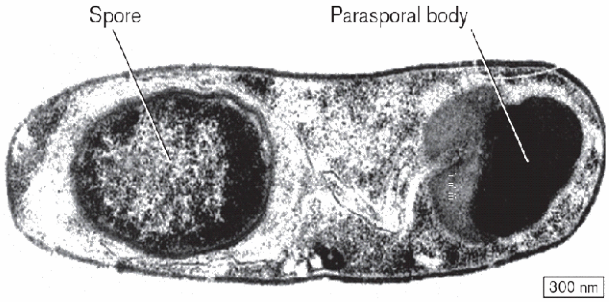



**Fig 3. *Bt* cell**

**Table 5. *Bt* based formulations commercially available in India**

| *Bt* strain | Trade Name | Target pests |
|---|---|---|
| *Bt* var. aizawai | Florback, Centari | Diamondback moth |
| *Bt* var. galleriae | Certan | Wax moth larvae |
| *Bt* var. israelensis | Bactimos, Bactis, Turimos, Vectobac | Larvae of mosquitoes and black flies |
| *Bt* var. kurstaki | Bt, Biobit, Dipel, Delfin, Javelin | Lepidopteran larvae |
| *Bt* var. sandiego | Diterra, M-one plus | Beetles and weevils |
| *Bt* var. thringiensis | Muscabac, Thuricid | Flies, lepidopterous larvae |

## Nucleopolyhedron Virus

The viruses belonging the class Baculoviridae are being used for pest management. Among them, nucleopolyhedron virus is a candidate virus. NPV is species specific virus and separate strains are needed to be used for *Spodoptera litura* and *Helicoverpa armigera*. Soon after entry into the insect gut, due to the action of the alkaline gut juice followed by the action of proteolytic enzymes, the polyhedral coat is loosened and dissolved resulting in the liberation of the virions. The liberated virions pass through the mid gut cells enter the haemocoel and start infesting the nuclei or cytoplasm of cells of different tissues like fat body, tracheal matrix, haemocytes, sarcolemma of muscles, neurilemma, nerve cells of ganglion and brain, hypodermis and gonads. The mass culturing of host insects and production of virus are given in figures 4, 5 and 6. The formulations of NPVs are readily available in biocontrol laboratories (Table 6; Fig. 7).

**Fig 4. Mass culturing of *Spodoptera* and *Helicoverpa***

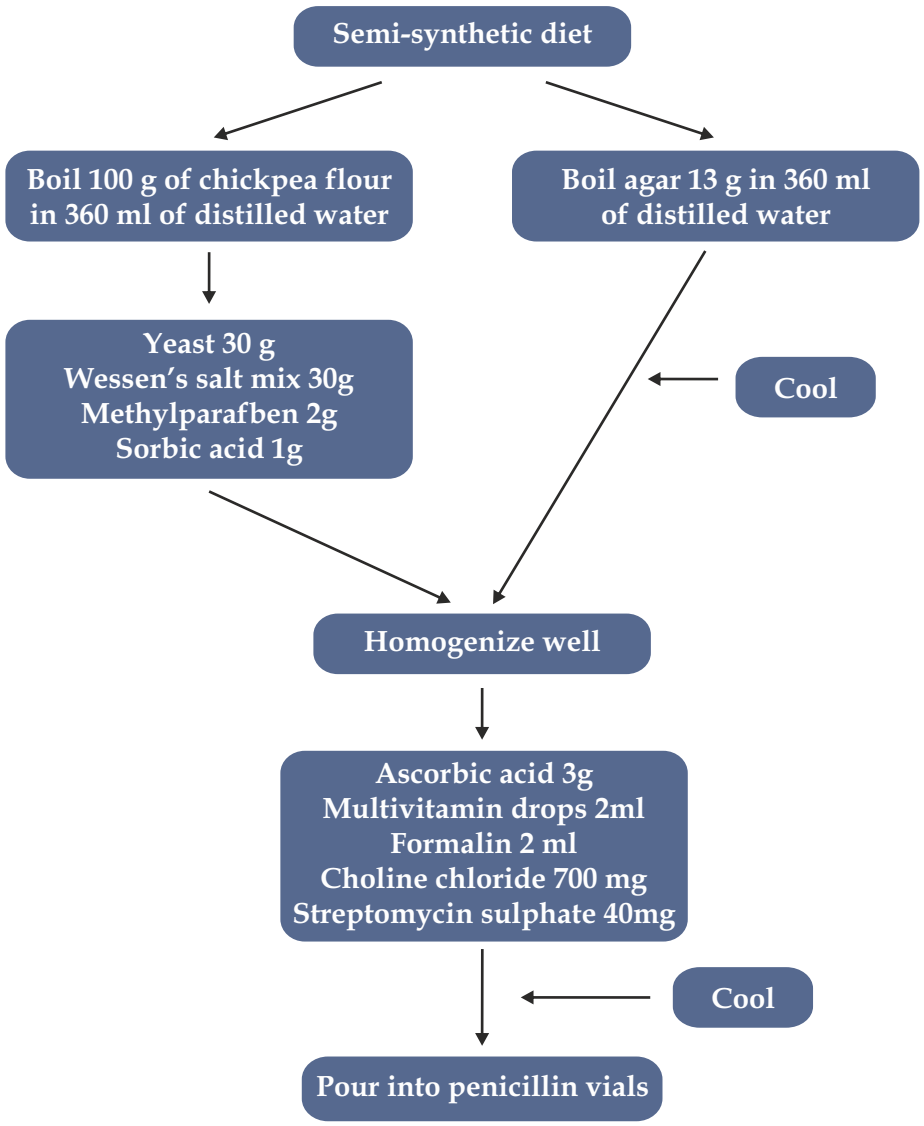


Fig 5. Mass production of *Helicoverpa* NPV

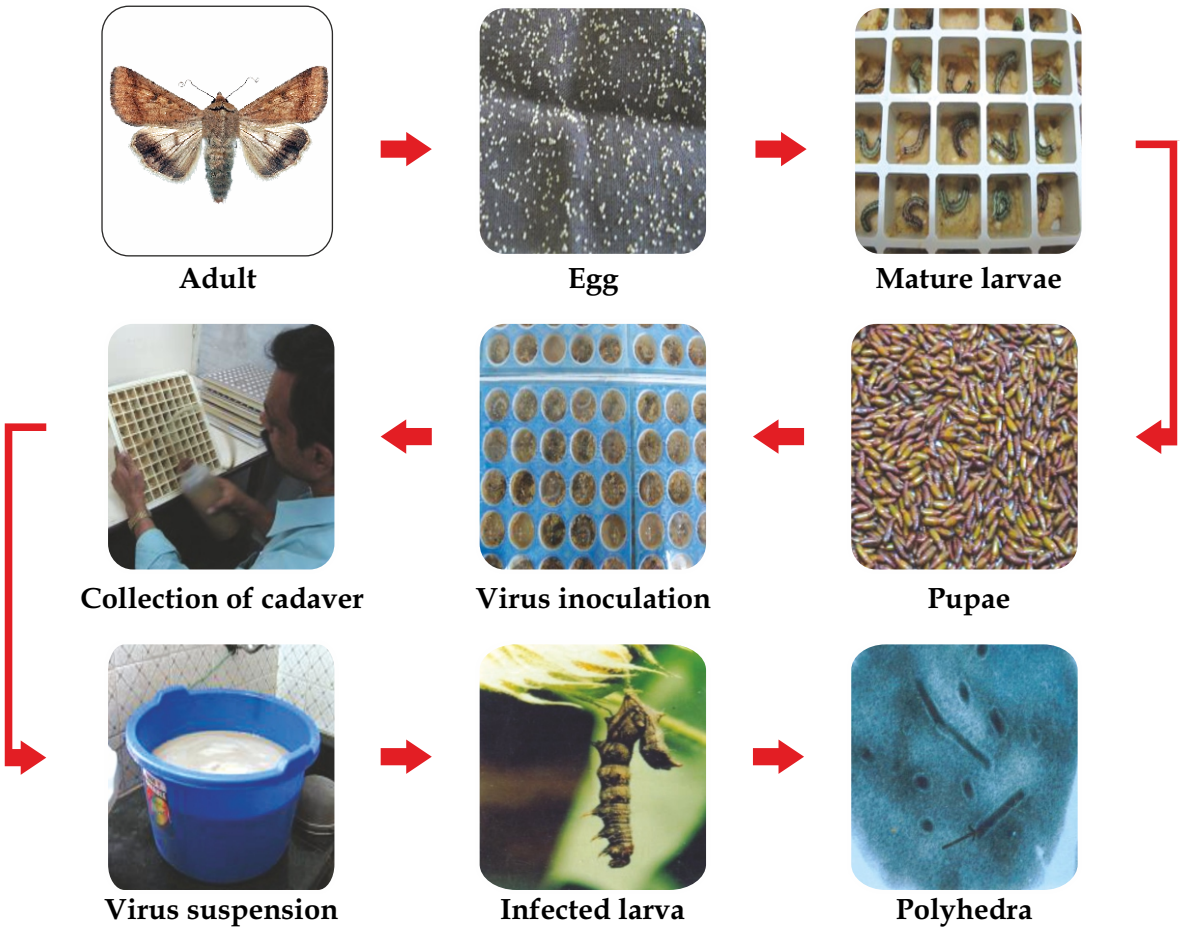



Fig 6. Mass production of *Spodoptera* NPV

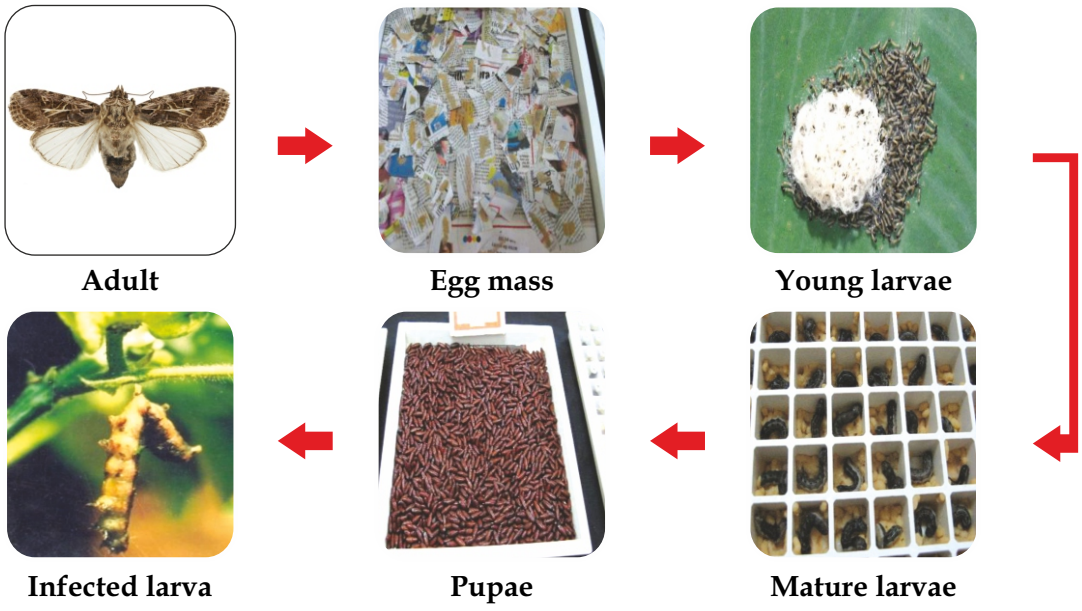


**Table 6. List of NPV formulations available in India**

| Company | Product Name | Formulation | Dosage |
|---|---|---|---|
| Biotech International Ltd., New Delhi | Biovirus H | Liquid formulation | 0.6 to 1 mL/L |
| Som Phytopharma (India) Ltd., Hyderabad | SOMSTAR-Ha | Liquid formulation | 1 mL/L |
| Pest Control (India) Pvt. Ltd., Mumbai | Heli-cide | Liquid formulation | 100 mL/acre |
| Pest Control (India) Pvt. Ltd., Mumbai | Spodo-cide | Liquid formulation | 100 mL/acre |
| Biotech International Ltd., New Delhi | BIOVIRUS-H | Liquid formulation | 250 to 500 mL/ha |
| Biotech International Ltd., Noida | BIOVIRUS-S | Liquid formulation | 1 mL/L |
| Ajay Biotech, Pune | Spodopterin, Heliokill | Liquid formulation | 1 mL/L |

**Fig 7. NPV formulations**

## Recommendation

*Spodoptera* NPV: 1 x $10^9$ POBs/mL; 200 litres of water; 1 kg of jaggery; 0.1% teepol (to be sprayed during evening hours)

*Helicoverpa* NPV: 1 x $10^9$ POBs/mL; 200 litres of water; 1 kg cotton seed powder; 0.1% teepol (to be sprayed during evening hours)

## Field application

1. Spray NPV 2-3 times, as soon as the young instars of pest are seen in field or approximately during flowering period
2. Spray virus using high volume sprayer (200 litres of $H_2O$) during non rainy evening hours
3. Add 1 kg of crude sugar or molasses/ac as phagostimulant
4. Add 200 mL of teepol or soap solution as sticking agent
5. Add 250 g of cotton seed powder for *Helicoverpa*
6. NPV also compatible with chlorpyriphos can be applied when two many pests are seen in same field or overlapping of generation of the target pests

## Entomopathogenic fungi

Among the insect pathogens, fungi constituted the largest group with more than 750 species causing mycoses in insects. The classes Phycomycetes and Deuteromycetes (fungi imperfecti) include most of the fungal pathogens and among them, the genera *Entomophthora, Metarhizium, Beauveria, Nomuraea* and *Verticillium* are noteworthy. Fungus diseases are commonly seen in insect orders such as Homoptera, Lepidoptera, Coleoptera, Hymenoptera and Diptera. Fungus based biopesticides are popularly called as Mycoinsecticides. The formulations of various such beneficial fungi are available in the Indian market (Table 7, 8).

## Mass production

The fungus can be mass produced in conventional laboratory media as well as on crushed maize grains, *etc*. The cheapest media known till date are coconut water wasted from copra making industry or carrot broth (Fig. 8,9).

**Fig 8. Coconut water method**

Coconut water 40 mL + 375 mL water

↓

Incubate at 15 psi for 20 min

↓

Inoculate 1 mL of stock suspension

↓

Harvest spores after 25-30 days of incubation

**Fig 9. Carrot broth method**

40 g carrot pieces + 15 mL water

↓

Autoclave at 15 psi for 20 min

↓

Inoculate a loopful of fungus

↓

Harvest spores after 15 days of incubation

**Table 7. Formulations of Mycoinsecticides in India**

| Fungus | Brand Name | Target Pests | Crop | Manufacturer |
|---|---|---|---|---|
| *Beauveria bassiana* | Myco-Jaal | Diamond back moth | Cabbage | PCI India Ltd. |
| | Biosoft | *Helicoverpa* sucking pests | Several crops | Agriland Biotech |
| | Biowonder | Rice pests | Rice | Indore Biotech |
| *Metarhizium anisopliae* | Bio Magic | BPH | Rice | T. Stanes, India |
| | Multiplex | Root grubs | Several crops | Multiplex |
| *Lecanicillium lecanii* | Mycotal | Whitefly, thrips | Several crops | Inora, India |
| | Inovert | Aphids, scales, mealybugs | Several crops | Inora, India |
| | Biocatch | Whitefly | Cotton | T. Stanes, India |
| | Verticare | Mealybugs, scales | Citrus | Viswamitra Bio Agro |
| *Isaria fumosorosea* | Prioroty | Mites | Several crops | T. Stanes, India |

**Table 8. Field dose of entomopathogenic fungi for pest management**

| Fungus | Crop and Pest | Recommended dose |
|---|---|---|
| *Beauveria bassiana* | Rice hispa | 10 million spores/mL |
| | Coffee berry borer | $1 \times 10^7$ spores/mL containing 0.1% sunflower oil and 0.1% wetting agent |
| | Tea looper caterpillar | 2.5 g/L |
| | Sunflower *Helicoverpa armigera* | Oil suspension @ 200 mg/L |
| | Green gram white grubs | Soil application @ $5 \times 10^{13}$ conidia/ha |
| *B. brongniarti* | Sugarcane white grub | Soil application @ 1 kg/acre |
| *Metarhizium anisopliae* | Coconut rhinoceros beetle | Spraying in breeding sites @ $5 \times 10^{11}$ spores/$m^3$ |
| | Sugarcane white grub | $1 \times 10^{13}$/ha |
| | Potato white grubs | Soil application @ $5 \times 10^{13}$ conidia/ha |
| | Soyabean white grub | Soil application @ $5 \times 10^{13}$ conidia/ha |
| *Lecanicillium lecanii* | Coffee green scale | $16 \times 10^6$ spores/mL along with Tween 80 twice at 2 weeks interval |
| | Citrus green scale | $2 \times 10^6$ spores/mL along with 0.005% quinalphos and 0.05% Teepol |
| | Mustard aphids | $10^6$ spores/mL |
| *Nomuraea rileyi* | Castor *Spodoptera litura* | $10 \times 10^{10}$ spores/ml along with 0.02% Tween 80 |
| | Soybean *Spodoptera litura*, *Helicoverpa armigera*, *Thysonoplusia orichalcea* | $2 \times 10^8$ spores/mL twice at 10 days interval |

## Entomopathogenic Nematode

Nematodes which kill or affect fecundity of insects are known as entomopathogenic nematodes and have potential of being used as biocontrol agents. The most commonly insect parasitic nematode species belong to the families are Allantonematidae, Mermithidae, Steinernematidae and Heterorhabditidae. The infective juveniles locate the host in the soil and enter through a natural opening, mouth, anus or spiracle. They then penetrate through the midgut wall or tracheae in to the haemocoel. The insect is inoculated with symbiotic bacteria like *Xenorhbadus*. The bacteria rapidly multiply and kill the host within 48 h by septicemia. The immature nematodes ingest bacterial cells and host tissues and then develop to adults. Male and female are separate and mate to produce progeny. When the condition are suitable, IJ's exit the cadaver to seek a new host. The life cycle takes 10-14 days to complete.

## Antagonistic Fungi

The recommendations of antagonistic fungi in the management of plant diseases is tabulated (Table 9).

**Table 9. List of antagonistic fungi for the management of plant diseases of crops**

| Crop / Disease | Pathogen | Reported BCAs |
|---|---|---|
| Rice Blast | *Pyricularia oryzae* | *Pseudomonas fluorescens, Trichoderma* spp. |
| Rice sheath blight | *Rhizoctonia solani* | *P. fluorescens, P. putida, T. harzianum, T. viride, T. virens, Aspergillus niger* AN27 |
| Rice bacterial leaf blight | *Xanthomonas oryzae* pv. *oryzae* | *Bacillus* spp. |
| Wheat root rot | *Sclerotium rolfsii, Fusarium oxysporum* | *T. harzianum* |
| Maize charcoal rot, banded leaf & sheath blight | *Macrophomina phaseolina, R. solani* | *Trichoderma* spp. |
| Pigeonpea wilt | *Fusarium udum* | *T. viride, T. hamatum, T. harzianum, T. koningii, Bacillus subtilis* |
| Chickpea wilt | *F. oxysporum* f. sp. *ciceri* | *T. viride, T. harzianum, T. virens, B. subtilis, A. niger* AN27 |
| Chickpea root rot | *R. solani, M. phaseolina* | *T. viride, T. harzianum* |
| Chickpea collar rot | *Sclerotium rolfsii* | *T. viride, T. harzianum, P. fluorescens* |
| Soybean dry root rot | *M. phaseolina* | *T. viride, T. harzianum* |
| Mungbean root rot | *M. phaseolina* | *T. harzianum, T. viride* |
| Groundnut crown rot | *Aspergillus niger* | *T. viride, T. harzianum, B. subtilis* |
| Groundnut stem & pod rot | *S. rolfsii* | *T. harzianum* |

| Crop / Disease | Pathogen | Reported BCAs |
|---|---|---|
| Groundnut late leaf spot | *Phaeoisariopsis personata* | *Penicillum islandicum, P. fluorescens T. harzianum, B. subtilis* |
| Groundnut root and stem rot | *R. solani* | *T. virens, T. longibrachiatum* |
| Groundnut rust | *Puccinia arachidis* | *Verticillium lecanii, T. harzianum* |
| Mustard damping-off | *Pythium aphanidermatum* | *T. harzianum, T. viride* |
| Sesamum wilt | *F. oxysporum* f.sp. *sesami* | *A. niger* AN27 |
| Root rot | *M. phasolina* | *Trichoderma* sp., *Gliocladium* sp., *B. subtilis* |
| Sunflower blight | *Alternaria helianthii* | *T. virens* |
| Root/collar rot | *S. rolfsii, R. solani, Scerotinia sclerotiorum* | *T. harzianum, T. hamatum* |
| Bottlegourd wilt/ root rot | *F. oxysporum, R. solani* | *A. niger* AN27 |
| Cauliflower damping off | *P. aphanidermatum* | *A. niger* AN27 |
| Chilli root rot | *S. rolfsii* | *T. harzianum* |
| Chilli fruit root and die back | *Colletotrichum capsici* | *T. viride, T. harzianum, T. konningii, T. hamatum, T. longibrachiatum, T. pileatus* |
| Cucumber seedling diseases | *Phytophthora* or *Pythium* sp., *F. oxysporum* f.sp. *cucumerinum* | *T. harzianum, A. niger AN27* |
| Brinjal wilt, damping off | *F. solani, P. aphanidermatum* | *T. viride, T. konningii* |
| Collar rot | *S. sclerotiorum* | *T. viride, T. virens* |
| French bean root rot | *R. solani* | *T. viride, T. hamatum* |
| Pea seed & collar rot, white rot | *Pythium* sp., *R. solani S. sclerotiorum* | *T. harzianum, T. hamatum T. viride* |
| Potato black-scurf | *R. solani* | *T. viride, T. viride, B. subtilis* |
| Tomato damping-off and wilt | *F. oxysporum* f. sp. *lycopersici* | *T. harzianum, P. fluorescens* |

## Biocontrol Laboratories

Various bio-control agents, being in recommendation for pest management can be procured from the bio-control laboratories listed in the table 10 and 11.

**Table 10. Bio-control Laboratories in India**

| Sl. No. | Type of Lab | Number of Labs |
|---|---|---|
| 1. | CIPMCs | 35 |
| 2. | SBCL (Grant in aid) | 38 |
| 3. | ICAR | 49 |
| 4. | SBCL | 98 |
| 5. | Private | 141 |
| | Total | 361 |

**Table 11. State Bio-control Laboratories (SBCLs) in States/UTs**

| Sl. No. | States | Location |
|---|---|---|
| 1. | Andhra Pradesh | Nidadavola West Godavari |
| 2. | Andaman & Nicobar Islands | Haddo, A&N Admn., Port Blair |
| 3. | Arunachal Pradesh | Naharlagun, Papumpore, Itanagar |
| 4. | Assam | 1. Dalgaon, Distt. Darrang<br>2. R.K. Mission Road, Ulubari, Guwahati–7. |
| 5. | Bihar | Mithapur, Patna |
| 6. | Chhattisgarh | Raipur |
| 7. | Goa | Farmers' Training Centre, Ela Farm, Old Goa |
| 8. | Gujarat | 1. Gandhinagar<br>2. Navasari Agril. University, Navasari-396450 |
| 9. | Haryana | 1. Sirsa<br>2. Chandigarh |
| 10. | Himachal Pradesh | 1. Holta, Palanpur, Distt. Kangra<br>2. Distt. Mandi, H.P. |
| 11. | Jammu & Kashmir | Lal Mandi Campus, Srinagar |
| 12. | Jharkhand | Ranchi |
| 13. | Karnataka | Kotnur "D", Gulbarga-585102 |
| 14. | Kerala | 1. Mannuthy, Thrissur-680655<br>2. Thiruvananthapuram |
| 15. | Lakshadweep | Andrott Islands |
| 16. | Maharashtra | 1. Aurangabad Distt.<br>2. Nandurbar Distt. |
| 17. | Madhya Pradesh | Barkheri Kalan, Bhadbhada, Bhopal |
| 18. | Meghalaya | P.O. Nonglyer, Upper Shillong-793009, East Khasi Hill |
| 19. | Mizoram | Neihbawih, Siphir |
| 20. | Manipur | Mantripukhri, Imphal |
| 21. | Nagaland | Metziphema, Kohima |
| 22. | Orissa | Baramunda, Post Delta Colony, Bhubaneshwar-751003 |
| 23. | Pondicherry | KVK Kurumbapett-9 |
| 24. | Punjab | Mansa |
| 25. | Rajasthan | Durgapura, Tonk Road, Jaipur |
| 26. | Sikkim | Tadong, Gangtok |
| 27. | Tamil Nadu | Vinayapuram, Melur Taluk, Madurai |
| 28. | Tripura | Dutta Tilla, Badharghat, P.O. Arundhuti Nagar, Tripura West-799003 |

| Sl. No. | States | Location |
|---|---|---|
| 29. | Uttar Pradesh | Moradabad |
| 30. | Uttarakhand | 1. Haldwani<br>2. Dhakrani, Dehradun |
| 31. | West Bengal | 230A, Neta ji Subhash Chandra Road, Kolkata-700040 |
| | Total number of **SBCLs** | **38** |

## Eco-friendly Traps in Pest Management

### Sex Pheromone Trap

It is an intra-specific semiochemicals called 'Sex Pheromone' which is being produced by virgin female adult to attract male adult of the same species for mating. Traps mounted with respective lures are to be installed one at each corner and at centre of the field and also 10 to 15 feet away from the bund of the field. Traps are to be installed 10 to 15 days after transplanting in case of paddy and sowing/dibbling of seeds for other crops. The male adults caught in the traps should be collected daily and killed. Lure is to be changed once in a fortnight for 5 to 6 times based on the number of broods of the pests and duration of the crops. The lures available for various insects are given in the table 12.

**Cost:** Rs. 15/lure; Rs. 25 to 30/trap

**Recommendation:** 5 traps/ac for monitoring; 12 traps/ac for mass-trapping

**Table 12. List of pheromones available in India for pest management**

| Crop | Insect pests | Name of lure |
|---|---|---|
| Rice | Yellow stem-borer | Scirpo lure |
| Vegetable & flower crops, oilseeds, pulses, chickpea, soybean, cotton, sunflower | Tobacco cut worm | Spodo lure |
| | Gram pod borer | Heli lure |
| Brinjal | Shoot and fruit borer | Sex pheromone lure |
| Okra | Shoot and fruit borer | Sex pheromone lure |
| Sweet potato | Weevil | Aggregation pheromone lure |
| Tomato | Leaf miner and fruit borer | Sex pheromone lure |

## Light Trap

Light trap technology is developed based on the behaviour of attraction of insects to light sources. Light source of trap attracts both sexes of flying insects. The light traps are effective only during night hours and the insects caught should be collected and killed daily early morning of next day or they can be killed by keeping cotton swab with any insecticides. It is useful to monitor the activities of insect pests and to time the plant protection measures. Battery operated LED light sources can be used in rainfed/dryland condition where power source is not practically possible. Various light sources provide visual cue to the insects and attract towards light by stimulating the compound and simple eyes of the insects.

**Time of operation:** Between 7 pm to 11 pm; to be installed at the inception of crops

**Recommendation:** One light trap with 220 W mercury lamp/5 acres. Number of traps may vary according to the light sources.

**Cost:** Mercury light trap: Rs. 7000 to 10000/unit; Battery operated light trap: Rs. 500 to 1000/unit

## Yellow Sticky Trap

**Pest attracted:** Whiteflies, aphids, leaf miners

**Crops:** Cotton, mustard, vegetable and flowers

**No. of traps:** 6-8 numbers/ac

---

Sex pheromone lures and other traps can be procured from M/s Pest Control of India Limited, Bengaluru and Pune.

Solar light trap

Blue sticky trap

Fruit fly trap

## Panchagavya

Panchagavya, an organic product has the potential to play the role of promoting growth and providing immunity in plant system. Panchagavya consists of nine products viz. cow dung, cow urine, milk, curd, jaggery, ghee, banana, Tender coconut and water. When suitably mixed and used, these have miraculous effects.

- Cow dung - 7 kg
- Cow ghee - 1 kg

Mix the above two ingredients thoroughly both in morning and evening hours and keep it for 3 days

- Cow Urine - 10 liters
- Water - 10 liters

After 3 days mix cow urine and water and keep it for 15 days with regular mixing both in morning and evening hours. After 15 days mix the following and panchagavya will be ready after 30 days.

- Cow milk - 3 liters
- Cow curd - 2 liters
- Tender coconut water - 3 liters
- Jaggery - 3 kg
- Well ripened poovan banana – 12 nos.

**Preparation**

All the above items can be added to a wide mouthed mud pot, concrete tank or plastic can as per the above order. The container should be kept open under shade. The content is to be stirred twice a day both in morning and evening. The Panchagavya stock solution will be ready after 30 days. (Care should be taken not to mix buffalo products. The products of local breeds of cow is said to have potency than exotic breeds). It should be kept in the shade and covered with a wire mesh or plastic mosquito net to prevent houseflies from laying eggs and the formation of maggots in the solution. If sugarcane juice is not available add 500 g of jaggery dissolved in 3 liter of water.

**Physico chemical and biological properties of Panchagavya**

Physico-chemical properties of Panchagavya revealed that they possess almost all the major nutrients, micro nutrients and growth harmones (IAA & GA) required for crop growth. Predominance of fermentative microorganisms like yeast and lactobacillus might be due to the combined effect of low pH, milk products and addition of jaggery/sugarcane juice as substrate for their growth.

**Table 13. Chemical composition**

| | |
|---|---|
| pH | 5.45 |
| EC dSm2 | 10.22 |
| Total N (ppm) | 229 |
| Total P (ppm) | 209 |
| Total K (ppm) | 232 |
| Sodium | 90 |
| Calcium | 25 |
| IAA (ppm) | 8.5 |
| GA (ppm) | 3.5 |

**Table 14. Microbial Load**

| | |
|---|---|
| Fungi | 38800/mL |
| Bacteria | 1880000/mL |
| Lactobacillus | 2260000/mL |
| Total anaerobes | 10000/mL |
| Acid formers | 360/mL |
| Methanogen | 250/mL |

## Ingredients of Panchagavya


Cow dung


Cow urine

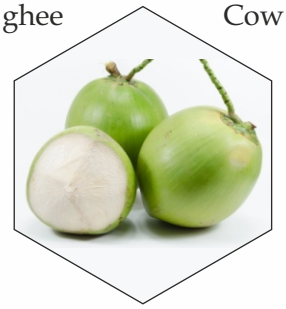

Cow ghee

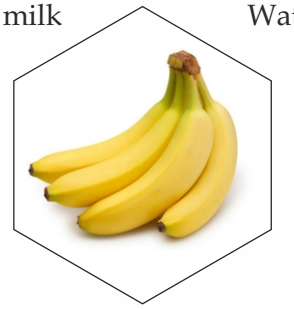

Cow milk


Water


Cow curd


Jaggery


Tender coconut


Well ripened banana

## Recommended Dosage

**Spray system :** 3% solution was found to be most effective compared to the higher and lower concentrations investigated. Three litres of Panchagavya to every 100 litres of water is ideal for all crops. The power sprayers of 10 litres capacity may need 300 ml/tank.

**Flow system :** The solution of Panchagavya can be mixed with irrigation water at 50 litres per hectare either through drip irrigation or flow irrigation

**Seed/seedling treatment :** 3% solution of Panchagavya can be used to soak the seeds or dip the seedlings before planting. Soaking for 20 minutes is sufficient. Rhizomes of Turmeric, Ginger and sets of Sugarcane can be soaked for 30 minutes before planting.

**Seed storage :** 3% of Panchagavya solution can be used to dip the seeds before drying and storing them.

**Table 15. Time of application of Panchagavya for different crops is given as follows**

| Crops | Time Schedule |
|---|---|
| Rice | 10,15,30 and 50th DAT |
| Sunflower | 30,45 and 60 DAS |
| Black gram | Rainfed: 1st flowering and 15 DAF<br>Irrigated: 15, 25 and 40 DAS |
| Green gram | 15, 25, 30, 40 and 50 DAS |
| Castor | 30 and 45 DAS |
| Groundnut | 25 and 30th DAS |
| Bhendi | 30, 45, 60 and 75 DAS |

| Crops | Time Schedule |
|---|---|
| Moringa | Before flowering & pod formation |
| Tomato | Nursery and 40 DAT:<br>seed treatment with 1 % for 12 hrs |
| Onion | 0, 45 and 60 DAT |
| Rose | At the time of pruning and budding |
| Jasmine | Bud initiation and setting |
| Vanilla | Dipping setts before planting |

DAT : Days after transplanting, DAF : Days after flowering, DAS : Days after sowing

## Gadgets in storage pests management

A total of 14 species are well adopted for living in stored grains and responsible for most of the damage. The post-harvest losses are estimated to be around 9.3%, of which losses during storage alone are estimated at 6.6% and insect alone causes

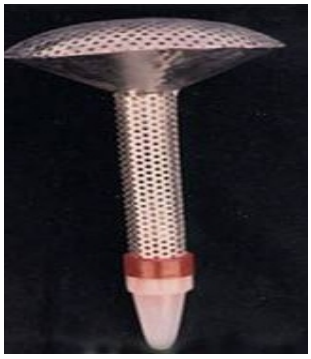
around 2.5% loss. The timely detection of insects in the stored produces is essential to plan timely control measures. Many devices have been developed for stored grain insect management, some of which are popularly used across the country in households/farms/go-downs. All these devices can be used for both monitoring and mass trapping of stored grain insects.

### Insect Probe Trap

It consists of a main tube, insect trapping tube and a detachable cone at the bottom. Equispaced perforations of 2 mm diameter are made in the main tube. The insect trap has to be kept in the grain like rice, wheat *etc*, vertically with the white plastic cone downside. The top red cap must be with the level of the grain. Once the insect enters the hole it falls down into the detachable white cone at the bottom. The white detachable cone can be unscrewed once in a week and the insects can be destroyed. It is effective against rice weevil, redflour beetle and lesser grain borer. The 2-3 traps/25 kg bin (28 cm dia and 39 cm length) can remove > 80% of the insects within 10-20 days.

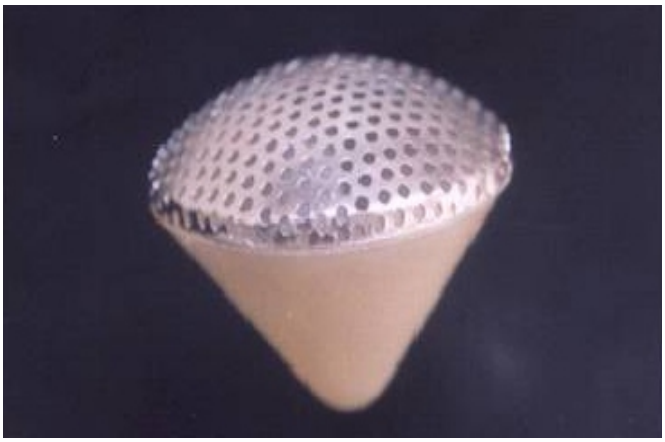
### Two-in-one Model Trap

Combination of probe and pitfall increase the trapping efficiency of insects. It is effective on pulse beetles and captured alive in this trap.



### Pit Fall Trap

Pitfall traps are used for capturing insects active on grain surface and in other layers of grain. It has perforated lid and cone shaped bottom which



tapers into a funnel shaped trapping tube. It is simple and economical (cost per trap is Rs. 25/- only) and easy to handle.

### Indicator Device

It consists of a cone shaped perforated cup (3mm perforation) with a lid at the top. The cup is fixed at the bottom with a container and circular dish, which are to be smeared with sticky material like vaseline.

Farmers, before storing their pulses, should take 200 g of pulses to be stored and put them in the cup. When the field carried over beetles start emerging, due to their wandering behaviour, they enter the perforations and get slipped off and fall into the trapping portions. The device with 2 mm perforations can be used for cereals. This will help in eliminating the initial population, which acts as the major source for further build up.

### Automatic Insect Removal Bin

The structure has four major parts namely outer container, inner perforated container, collection vessel and the lid. The grains are held in the specially designed inner perforated container. Insects, while wandering, enter the perforation to reach the aerated part and get slipped off and fall into the collection vessel through a pitfall mechanism provided in the collection vessel. The container will be useful for storing rice, wheat, broken pulses, coriander *etc* It is effective against rice weevil, lesser grain borer, red flour beetle and saw toothed beetle. More than 90% insects can be removed in 10 days. The containers are available in 2 kg, 5 kg, 25 kg, 100 kg and 500 kg capacities.

### UV-light trap for grain storage godowns

The UV light trap (4 W germicidal lamp) emitting 250 nm is fitted at the centre of a funnel of 310 mm diameter at the top and 35 mm diameter at the bottom. The bottom end of the funnel is attached with a transparent plastic container for collecting the trapped insects. Three hooks and a tripod stand have been provided at the periphery of the funnel to hang the unit. The UV light trap can be placed in storage godowns at 1.5 m above ground level, preferably in corners. The trap can be operated during the night hours. The light trap attracts stored

product insects of paddy like lesser grain borer, redflour beetle and saw-toothed beetle in large numbers. Normally 2 numbers of UV light trap per 60 x 20 m (L x B) godown with 5 m height is suggested.

### Device to remove Insect Eggs from Stored Pulse Seeds

The gadget can successfully crush the eggs of pulse beetle The gadget has outer container and an inner perforated container with a rotating rod having fixed with plastic brushes on all sides. The seeds with eggs are to be stored in the perforated container and the rod has to be rotated one full circumference clockwise and anti-clockwise for 10 minutes, 3 times a day (morning, noon and afternoon). Due to the splashing action of the brush in rotating rod, the eggs get crushed and thus the damage is prevented. The treatment does not affect the germination of seeds.

### Trap for monitoring stored product insects in warehouse

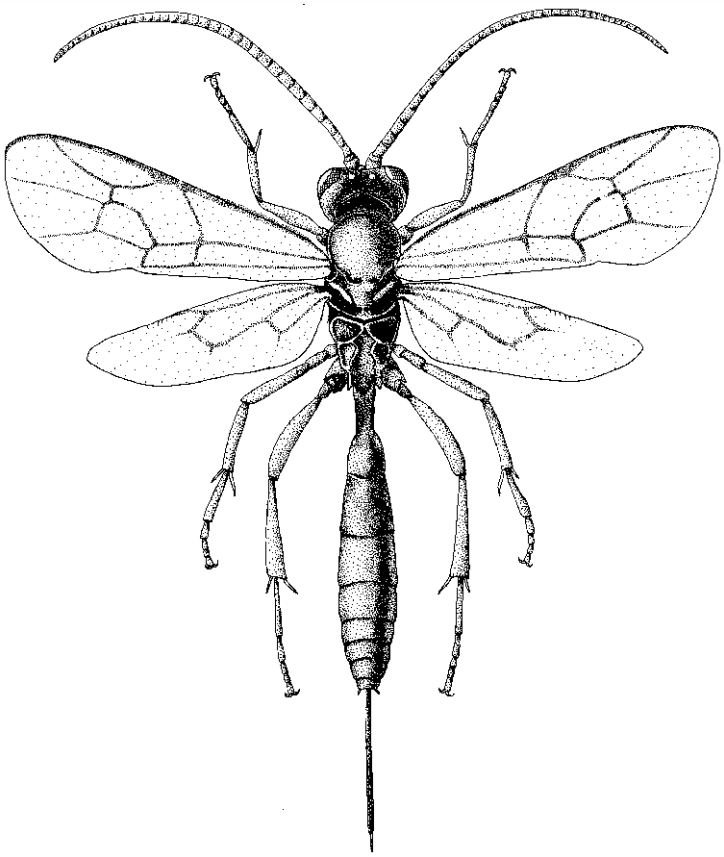
It is a device for detecting stored grain insects in bag-stacks which comprises a main hollow tube having a diameter in the range of 1.8 to 2.0 cm with equi-spaced perforation in the range of 1.8 to 2 mm on its upper portion with a bend at one end which ends in a transparent collection unit to collect the insects falling down from the bend, the other end of main tube being closed.

Gadgets for storage pest management can be obtained from M/s Melwin Engineering, No. 18/2, Gandhiji Street, Bharathiar Nagar, Podanur, Coimbatore 641 023.

## Conclusion

Eco-friendly pest management technologies are the best alternative to chemical control in respect of giving special focus on safe-guarding environment, natural resources and non-target organisms. Bio-control agents are typically derived from living organisms, microorganisms, and other natural sources they pose less risk to people and the environment and hence gain worldwide attention as a new tool to kill insects and plant disease. Development and promotion of bio-pesticides usage in India need to be well addressed through promoting their manufacture at village level as an ancillary profession to agriculture. Registration process of bio-pesticides in India may be simplified without compromising quality and authenticity of the product. Various traps being used now-a-days in India are of having paramount importance to manage pests of crops, however their timely availability to stakeholders has to be taken care by extension officers and policy makers. The gadget technology to manage storage pests is a novel method and getting popular in India, however its awareness among the extension officers and farmers is in infancy which need to be addressed suitably.

Photo : Ichneumonfly



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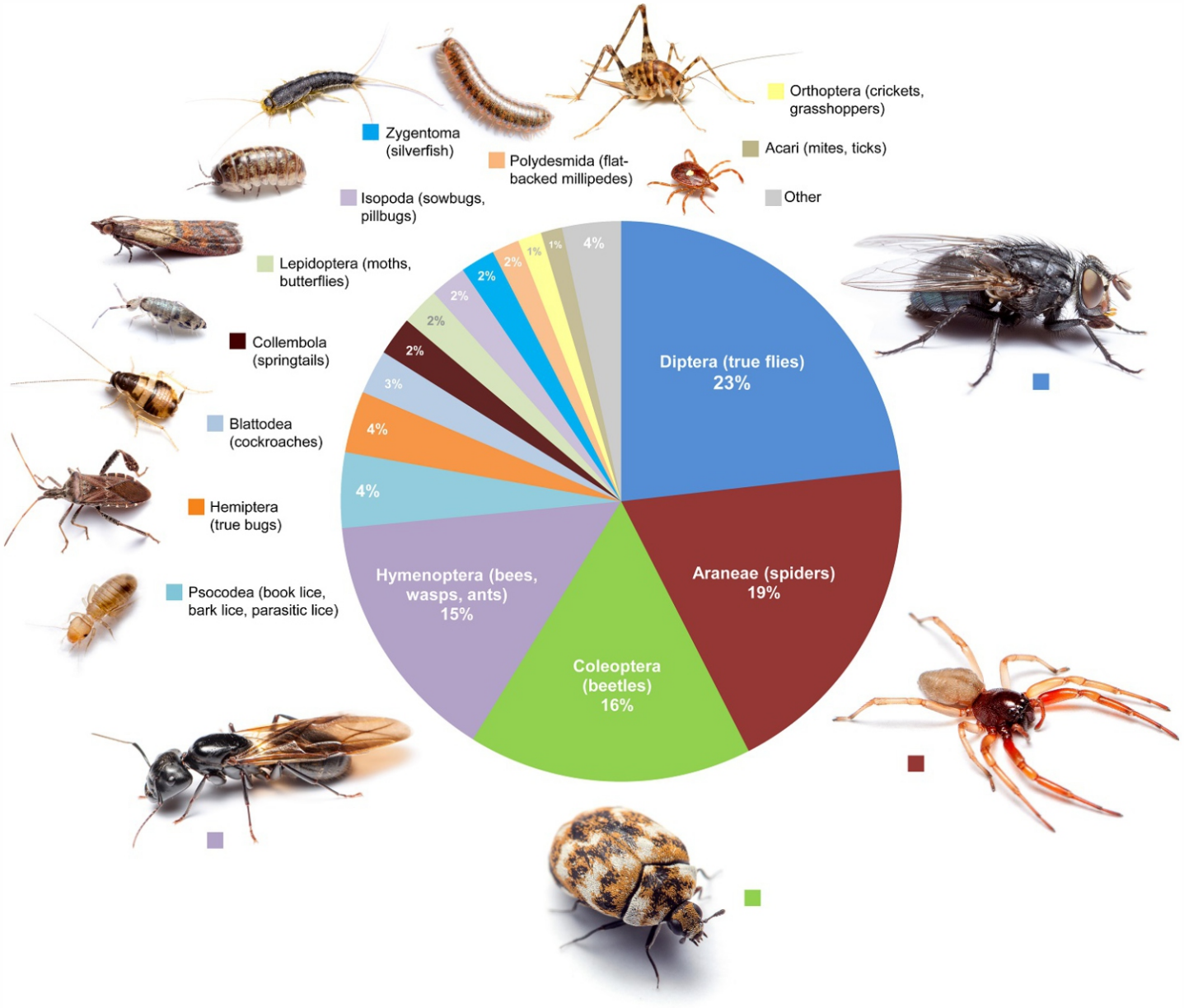
TNAU, Coimbatore, Tamil Nadu
ICAR-NBAIR, Bengaluru, Karnataka




*"Farmers and Scientists are two sentinels of New India and they have to work together to transform agriculture"*

*Shri Narendra Modi*
*Hon'ble Prime Minister of India*