



P. Parvatha Reddy

# Organic Farming

for Sustainable  
Horticulture



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# **ORGANIC FARMING FOR SUSTAINABLE HORTICULTURE : PRINCIPLES AND PRACTICES**

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## PREFACE

Through “Green Revolution” in late 1960’s, India achieved self sufficiency in food production. The “Green Revolution” is associated not only with higher production through enhanced productivity, but also with several negative ecological and social consequences. Intensive farming system warranted the use of high doses of chemical fertilizers, herbicides and plant protection chemicals which have damaged the soil health (soil flora and fauna), productivity and also sustainability. Therefore, lack of sustainability in production in recent years is becoming a major cause of concern.

A major portion of applied fertilizer is lost from soil – plant system by leaching, runoff, denitrification and volatilization and pollutes the soil, water bodies and the atmosphere. Application of chemical fertilizers cause pollution to the soil by nitrates and phosphates which upon leaching can accumulate to the levels of chemical impurities of more than 100 to 200 mg/litre. These levels can cause cancer in human beings and kill them as well as animals. Many fertilizers, particularly phosphate fertilizers, contain heavy metals (Fe, As, Cd, Co, Cr, Hg, Ni, Pb etc.) and their excess concentration in the environment is harmful to human and animal health. The emission of nitrous oxide, methane, etc. are responsible for destruction of stratospheric ozone.

Pesticides cause soil pollution and adversely affect useful microflora and fauna which interact with pathogens at the soil-root interface. They are harmful to endomycorrhizae, rhizobia, actinorhyza and other micro-organisms normally contributing to the nutritional economy of the plants and possibly bring about disturbance in the microbial equilibrium. Pesticides pollute water and deteriorate water quality. Most of them have been detected in ground water.

The indiscriminate use of fertilizers, weedicides and pesticides (insecticides, acaricides, fungicides and nematocides) created a new challenge for sustainability of modern horticulture and environment. Organic farming is thus considered as a movement directed towards the philosophy of “ Back to Nature”. It aims at low input farming thus

reducing dependence on inorganic fertilizers, herbicides and plant protection chemicals.

Horticulture in India is fast emerging as a major commercial venture, because of higher remuneration per unit area and the realization that consumption of fruits and vegetables is essential for health and nutrition. In the last one decade, export potential of horticultural crops has significantly increased attracting even multinationals into floriculture, processing and value added products. Since the horticultural produce especially fruits and vegetables are consumed afresh, consumers expect residue-free produce both for internal and export markets. In modern society where consumers are becoming increasingly health conscious and environmentally aware, a major market for organic foods has developed and the organic sector, in particular, has sprung back into life to become one of the most dynamic sectors of the international food market.

The information on organic farming especially crop-wise information is very much scattered and there is no book which deals with principles and practices of organic farming entirely on horticultural crops. Hence, the present book is an attempt which comprehensively deals with both principles and practices. The book is divided into two parts. The first part deals with the principles of organic farming covering aspects such as enrichment of soil with organic matter, cropping systems, bio-fertilizers, weed management and pest management. The second part of the book deals with package of practices for organic farming in fruits, vegetables, ornamentals, medicinal and aromatic, plantation, spice and tuber crops. Three aspects, namely – nutrient management, weed management and pest management are dealt with separately for each crop. An entire chapter is devoted for sources of critical inputs used for organic farming which would be very much useful to the organic farmers to obtain the same.

This book is a practical guide to practicing organic farmers of horticultural crops. Further, it is a useful reference to policy makers, research workers and students. The material can also be used for teaching undergraduate and post-graduate courses. Suggestions to improve the contents of the book are most welcome (E-mail: [reddy\\_parvatha@yahoo.com](mailto:reddy_parvatha@yahoo.com)).

Bangalore  
April 13, 2007

**P. Parvatha Reddy**



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*PART – I*

**PRINCIPLES OF  
ORGANIC FARMING**



## Chapter 1

# INTRODUCTION

The record production of 208.87 million tonnes of food grains in 1999-2000, which was the highest achieved ever, is hailed as a breakthrough on the farm front by international agricultural experts. Most of the growth in food production during the green revolution period is attributed to the use of improved crop varieties and higher levels of inputs of fertilizers and pesticides. The modern agricultural techniques such as use of synthetic fertilizers and pesticides are continuing to destroy stable traditional ecosystems and the use of high yielding varieties of crops has resulted in the elimination of thousands of traditional varieties with the concurrent loss of genetic resources. The introduction of high yielding varieties changed the agricultural environment leading to numerous pest problems of economic importance. In the process of intensive farming, the environment has been treated in an unfriendly manner. The intensive production systems have led to depletion of major and minor nutrients from the soil apart from damaging the soil health, productivity and also sustainability. Intensive farming systems warrant the use of high doses of chemical fertilizers. Non-availability of organic forms of plant nutrients have also forced the increased use of chemical fertilizers. The per capita consumption of NPK increased from 0.6 kg/ha in 1950 to 50 kg/ha in 1997-98. This consumption is mostly confined to irrigated farming situations which constitute only about 30 % of the gross cropped area. The country expects that the fertilizer consumption to reach a target of 20 million tonnes by the turn of this century. The intensive use of major plant nutrients may lead to depletion of micro-nutrients like Zn and S. This depletion, in turn, may limit the productivity of major crops. A major portion of applied fertilizer is lost from soil – plant system by leaching, runoff,

denitrification and volatilization and pollutes the soil, water bodies and the atmosphere. Application of chemical fertilizers cause pollution to the soil by nitrates and phosphates which upon leaching can accumulate to the levels of chemical impurities of more than 100 to 200 mg/litre. These levels can cause cancer in human beings and kill them as well as animals. Many fertilizers, particularly phosphate fertilizers, contain heavy metals (Fe, As, Cd, Co, Cr, Hg, Ni, Pb etc.) and their excess concentration in the environment is harmful to human and animal health. The emission of nitrous oxide, methane, etc. are responsible for destruction of stratospheric ozone. The continuous use of chemical fertilizers and pesticides have damaged the soil flora and fauna. Earthworm activity in the soil has been reduced greatly. The green revolution is exploitative and has telling ill effects on natural resources namely soil, water, climate and the genetic base of plants and animals. A divergent view refers to it as Greed Revolution while referring to Green Revolution. Therefore, lack of sustainability in production in recent years is becoming a major cause of concern.

The future farming, therefore, requires judicious use of chemical fertilizers since the adverse effects of continued use of high doses of fertilizers can lead to (i) deficiency of Zn and S, (ii) adverse effects on soil biotic life particularly if the soil is acidic, and (iii) creating problems of high energy use, mono-cropping, imbalance of nutrients, decrease in soil productivity and pollution.

Soil organic matter is one of the most important components of the soil. Various organic manures like FYM, compost, green manure, etc. that are added to the soil from time to time further add to the store of organic matter. The decomposition of added organic manures would finally get converted into humus. Indian soils are generally low in the organic matter content.

The continued farming was practiced on the same land by intercropping, crop rotation, fallowing, composting and manuring practices for more than 2000 years without drop in yields. Further, the crops were relatively free from pests. Soil health and pest control were achieved using practices like shifting cultivation, conservation, the use of animal manures and farm wastes and the introduction of legumes in crop rotations.

Organic farming is thus considered as a movement directed towards the philosophy of "Back to Nature". It aims at low input farming thus reducing dependence on inorganic fertilizers, plant protection chemicals and weedicides.



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## 1.1. The Ills of Green Revolution

- Reduction in natural fertility of the soil.
- Destruction of soil structure, aeration and water holding capacity.
- Susceptibility to soil erosion by water and wind.
- Diminishing returns on inputs.
- Indiscriminate killing of useful natural enemies that check excess crop damage by pests.
- Breeding more virulent and resistant pests.
- Reducing genetic diversity of plant species.
- Pollution with toxic chemicals from the agro-chemicals and their production units.
- Endangering the health of farmers using chemicals and the workers who produce them.
- Poisoning the food with highly toxic pesticide residues.
- Cash crops displacing nutritious food crops.
- Chemicals changing the natural taste of food.
- High inputs increasing the agricultural expenses.
- Increasing the farmers work burden and tension.
- Depleting the fossil fuel resources.
- Increasing the irrigation needs of the land.
- Big irrigation projects often resulting in soil salinity and poor drainage.
- Depleting the ground water reserves.
- Lowering the drought tolerance of crops.
- Appearance of difficult weeds.
- Heightening the socio-economic disparities and land holding concentration.
- High input subsidies leading to inflationary spirals.
- Increasing the political and bureaucratic corruption.
- Destroying the local culture (commercialization and consumerization displacing self reliance).
- Throwing financial institutions into disarray (as impoverished farmers demand write-off of loans).

- Agricultural and economic problems sparking off social and political turmoil resulting in violence.

## **1.2 What is Organic Farming ?**

Organic Agriculture is a productive system which largely excludes or avoids the use of synthetically compounded fertilizers, pesticides, growth regulators, preservatives and livestock feed additives. The Organic Agriculture practices rely to the maximum extent on crop residues, animal manures, crop rotations, green and green leaf manures, off-farm organic wastes and biofertilizers to supply plant nutrients and adopt biological control methods to control pests, diseases and weeds. The concept of recognizing soil as a living entity that promotes the activities of beneficial organisms is central to this theme.

Organic farming envisages a comprehensive management approach to improve the health of underlying productivity of the soil. In a healthy soil, the biotic and abiotic components covering organic matter including soil life, mineral particles, soil air and water exist in a stage of dynamic equilibrium and regulate the ecosystem processes in mutual harmony by complementing and supplementing each other. When the soil is in good health, the population of soil flora and fauna multiplies rapidly, which in turn, will sustain the bio-chemical process of dissolution and synthesis at a high rate.

Organic farming techniques will help to increase the organic matter content of the soil, thus reducing the bulk density and decreasing compaction. There can be effective conservation systems since they provide soil cover during most of the year (little run-off and erosion) and with the greater use of rotations and green manure crops, crop residues and legumes, there is an increased emphasis on manure as a source of soil fertility.

Tropical soils are generally low in organic matter content. The low organic matter is primarily due to climate particularly due to high temperature and secondarily due to cultural practices. Organic matter increases with rainfall. In tropical and sub-tropical regions, although much organic matter is produced, it decays very rapidly. Whatever organic matter is added to the soil will be decomposed very fast (over 90% in a year) and hence, it is an Herculean task to raise the organic matter content of the soil.

Organic farming is a matter of giving back nature what was taken away back from it. It is a system of farming based on integral relationship between soil, plant, water and microflora. The use of

chemical fertilizers, pesticides and herbicides are completely avoided in this system.

The principal elements to be considered are:

- i. Maintaining a living soil.
- ii. Making available the essential nutrients.
- iii. Organic mulching for soil conservation.
- iv. Attaining sustainable high yield.

Organic farming, therefore, envisages a comprehensive management to improve the health of the soil. When the soil is in good health, the soil fauna and flora grow rapidly, become activated and facilitate the biochemical processes at a faster rate which shall enhance the regenerative capacity of the soil and make it resilient to absorb the effects of climatic vicissitudes.

Organic farming, therefore, is a farming system devoid of chemical inputs, in which the biological potential of the soil and underground water resources are conserved and protected from the natural and human induced degradation or depletion by adopting suitable cropping models and methods of organic replenishment, besides natural and biological means which are used for pest and disease management. The principal concept is that organic farming is the farming based on natural principles which alone are sustainable.

**Table 1.1. Area under organic farming in Europe (1999-00)**

Country	Area (Ha)	% Agricultural land
Sweden	268,000	11.2
Austria	345,000	10.0
Denmark	160,000	6.0
Germany	422,000	3.0
Italy	900,000	5.3
UK	425,000	2.5
France	220,000	1.0
EU average	---	2.2

### 1.3. Demand for Organic Foods

In modern society where consumers are becoming increasingly health conscious and environmentally aware, a major market for organic foods has developed and the organic sector, in particular, has

sprung back into life to become one of the most dynamic sectors of the international food market. In tune with consumer preference, more and more areas are brought under organic farming. The number of organic producers and processors are also increasing (Tables 1.1 and 1.2).

**Table 1.2. Organic processors and producers registered with Association Certification Ltd. in UK**

<b>Year</b>	<b>Organic producers</b>	<b>Organic processors</b>
1995-96	476	188
1996-97	559	264
1997-98	639	397
1998-99	897	555
1999-00	1,504	1,030
January 2001	2,038	1,660

In 1999-00, the projected figure for organic food sales in the UK was expected to be approximately 546 million dollars. Total household food and drink sales for 1999 was 54,152 billion dollars. So, organic food accounts for approximately 1% of all food sales. Total organic sales are expected to reach 1070 million dollars by 2001-02. Consumer demand for organic food has risen for the past 2 years at 40%. In 1996-97, the total retail value of organic food sales in the UK was 200 million dollars and in 1998-99 it was 390 million dollars. The percentage of organic produce sold in the European Union now accounts for 3% of food sold, up from 1% in 1992. Currently, 70% of organic products sold in the UK have to be met by imports.

Consumer attitudes to organic foods in the UK, according to a survey indicates that one third of the public buy organic food, primarily perceiving it as either healthy/better for you (53%), tasting better (43%), genetically modified free (30%), environment friendly/ animal welfare (25%).

A study by UNCTAD indicates that the sales of organic products in most industrialized countries represent 1 or 2% of the entire food sector. The United States is a leader in this area with sales of 8 billion dollars in organic foods annually, or 1.5% of the food trade. Germany follows with 2.2 to 2.4 billion dollars, a portion that varies between 1.25 and 1.5% of that country's food market. But the nations with greatest relative expansion in the consumption of organic products are Denmark with 2.5 to 3.0% of the domestic food market, Switzerland,

at 2.0 to 2.5% and Austria at 2.0%. Certified organic production of foods exist in more than 140 countries, including 90 from the developing world, of which 210 are found on the UN list of least developed countries. Despite the rather limited absolute figures, the organic foods market has expanded in recent years at rates varying from 10-30%.

Worldwide sales of organic produce are US\$ 11 billion which is expected to reach US\$ 100 billion in the next 10 years. Europe is world's largest organic produce market. Organic produce account for about 6% of all food stuffs in European Union alone. More than 130 countries produce certified organic foods, of these 100 are from Asia and Africa.

Among horticultural crops, fruits, which have greater scope for export are valued much as organic food. Most of the present day organic growers largely avoid inorganic fertilizers and substitute them with organic sources alone. In the real sense, scientific organic farming encompasses use of nutrient rich but cost effective organic manures, biofertilizers including endomycorrhizae and biopesticides to control insect pests, nematodes and diseases in an integrated manner.

Synthetic colours are used for colouring food preparations as well as industrial applications. Now, synthetic colours are not preferred because of the harmful effects to the human system and these synthetic colours are replaced by natural colourants extracted from plants. Turmeric, marigold and chilli are preferred for colour extraction particularly for yellow and red pigments. It is obvious that organic production of turmeric, marigold and chilli has to be taken up to meet this growing demand.

Similarly, synthetic flavours like vanillin are used for flavouring food preparations and confectionaries. Now, the consumers hesitate to consume synthetically flavoured food items because they are hazardous to health. Hence, they are preferring for natural flavours obtained from plants. Nowadays, the natural vanillin extracted from the orchid vanilla replace the synthetic vanillin. There is vast potential for production of organic vanilla to replace synthetic vanilla, because of the growing demand.

## **1.4. Objectives and Dimensions**

### ***1.4.1. Natural Capital***

- Improves the structure and fertility of soil.
- Work within closed cycle systems using local resources.

- Give livestock, conditions that confirm to their needs.
- Maintain and encourage wild life and their habitats.
- Minimize the use of non-renewable resources and avoid pollution.

#### ***1.4.2. Human Capital***

- Produce food of high nutritional quality and sufficient quantity.
- Enable producers to earn a living and to develop their potentiality.
- Create systems that are aesthetically pleasing.
- Use decentralized systems for local processing, distribution and marketing.

#### ***1.4.3. Dimensions***

- Ecologically sound.
- Economically viable.
- Socially just and equitable.
- Culturally sensitive.
- Promotes appropriate technology.
- Based on holistic science.
- Total human development.

### **1.5. Management of Organic Farming**

- Organization of crop and livestock production and the management of farm resources in such a way that it harmonizes rather than conflicts with natural systems.
- Achievement of a closed cycle between soil, plants, animals and people and avoidance of environmental pollution.
- Maintenance of soil fertility for optimum production, relying primarily on renewable resources.
- Reduction of pest and disease incidence through a carefully developed crop rotation, use of resistant varieties and encouragement of beneficial natural enemies.
- Use of animal husbandry practices for the welfare and behavioural needs of farm livestock.

- Use of appropriate farm machinery and cultivation techniques which reduces non-renewable resource consumption.
- Enhancement of the environment in such a way that wild life flourishes.

### 1.6. Advantages of Organic Farming

- Organic manures produce optimal conditions in the soil for high yields and good quality crops.
- They supply all the nutrients required by the plant (NPK, secondary and micronutrients).
- They improve plant growth and physiological activities of plants.
- They improve the soil physical properties such as granulation and good tilth, giving better aeration, easy root penetration and improved water holding capacity. The fibrous portion of the organic matter with its high carbon content promotes soil aggregation to improve the permeability and aeration of clayey soils while its ability to absorb moisture helps in the granulation of sandy soils and improves their water holding capacity. The carbon in the organic matter is the source of energy for microbes which help in aggregation.
- They improve soil chemical properties such as supply and retention of soil nutrients and promote favourable chemical reactions.
- They reduce the need of purchased inputs.
- Most of the organic manures are wastes or byproducts which on accumulation may lead to pollution. By way of utilizing them for organic farming, pollution is minimized.
- Organic manures are considered as complete plant food. Organic matter restores the pH of the soil which may become acid due to continuous application of chemical fertilizers.
- Organically grown crops are believed to provide more healthy and nutritiously superior food for man and animals than those grown with commercial fertilizers.
- Organically grown plants are more resistant to pests and diseases and hence only a few other protective treatments are required.

- There is an increasing consumer demand for agricultural produce which are free of toxic chemical residues.
- Organic farming helps to avoid chain reaction in the environment from chemical sprays and dusts.
- Organic farming helps to prevent environmental degradation and can be used to regenerate degraded areas.
- Since the basic aim is diversification of crops, much more secure income can be obtained than to rely on only one crop enterprise.

### **1.7. Components of Organic Farming**

The components of organic farming are as follows:

- Enrichment of soil with organic matter.
- Cropping systems.
- Biofertilizers.
- Weed management.
- Pest management.



## **Chapter 2**

# **ENRICHMENT OF SOIL WITH ORGANIC MATTER**

Most of the basic needs of the plant nutrients can be locally met through organic source, which in turn, makes production sustainable and creates more employment opportunity locally, eliminates the ill effects of fertilizers and reduces the cost of production. But, the large potential of organic resources remain untapped in the country. Composting of all organic waste, FYM and feedlot manure is important. The waste generated in agro-industries in India amounts to 105 million tonnes. This includes sugarcane bagasse, press mud, rice mill wastes, wastes from fruit processing industry, coir pith, oil cakes and waste of coffee industry. More than 200 million tonnes of animal waste (equivalent to 3 million tonnes of NPK) and 400 million tonnes of crop residues (equivalent to 6 million tonnes of NPK) are available annually in the country. Our starved drylands can be made productive only if we know how to convert “filth into wealth”.

### **Advantages of Organic Manures**

- Provides all the nutrients that are required by plants but in limited quantities.
- Helps in maintaining C:N ratio in the soil and also increases the fertility and productivity of the soil.
- Improves the physical, chemical and biological properties of the soil.
- Improves both the structure and texture of the soil.
- Increases the water holding capacity of the soil.

- Due to increase in the biological activity, the nutrients that are in the lower depths are made available to the plants.
- Acts as mulch, thereby minimizing the evaporation losses of moisture from the soil.

## 2.1. Green Manuring

The ultimate solution to organic manuring lies perhaps in the sustained promotion concept of *in situ* generation of organic matter in the cropped land itself by suitably modifying and modulating the cropping practices.

Green manuring is a low cost but effective technology in minimizing the investment cost of fertilizers and in safeguarding the productive capacity of the soil. It is a well known fact that N, for which soils have the greatest hunger, is a costly plant nutrient. This can be cheaply obtained by the inclusion of leguminous crops in rotations and their ploughing under. Legumes are usually utilized as green manure crops as they fix atmospheric N in the root nodules through symbiotic association with a bacterium, *Rhizobium* and leave part of it for utilization of the companion or succeeding crop.

Growing of leguminous green manure crops such as sunnhemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*), greengram (*Phaseolus* sp.), cowpea (*Vigna unguiculata*), khesari (*Lathyrus sativus*), berseem (*Trifolium alexandrium*) and *in situ* mulching adds 8 to 28 tonnes/ha of organic manure. Green manuring of dhaincha with *Azolla* inoculation at 3 tonnes/ha resulted in the grain yield similar to 90 kg N.

On the other hand, some common perinneal shrubs and trees like glyricidia (*Glyricidia maculata*, *G. septium*), subabul (*Leucaena leucophila*, *L. glauca*), honge (*Pongamia glabra*), neem (*Azadirachta indica*), *Cassia auriculata*, *C. tora*, *C. occidentalis*, *C. pistula*, *Derris indica*, *Ipomea cornea*, *Tephrosia purpurea*, *T. candida*, *Thespesia populenea*, *Calotropis gigantea*, *Delonix regia*, *D. elata*, *Jatropha gossypifolia*, *Dodanea viscosa*, *Hibiscus viscosa* and *Vitex negundo* which yield valuable green matter for composting can be grown all along the bunds and harvested at the right stage and composted along with farm waste and FYM. At least 20 to 30 million tonnes of green manure can be generated in this way.

Glyricidia rooted cuttings may be planted at every 2 m interval on the existing bunds. About 120 to 130 plants will produce sufficient biomass after 2 years. About 15 kg of biomass is produced from each plant. This production will be 3 times in a year. The biomass contains

70% water and 2.5% nitrogen. The plant should be cut at the base so that the subsequent sproutings will be proper. The green leaf manure is the best alternate source of organic matter.

### **2.1.1. On Farm Generation of Organic Matter**

The limitations on transport of bulky organic materials produced elsewhere to the field where they have to be utilized, there is an urgent need to identify strategies for the generation of organic matter on the farm itself in a non-competitive manner without interfering with the crop production in order to make sustainable horticulture – a practical reality.

#### *2.1.1.1. In-situ Generation of Organic Matter During Post Rainy Season and its Incorporation*

The long term analysis of rainfall in selected semi-arid tropical rainfed regions indicate that about 20-25% of the total rainfall is received during the post-monsoon period. This rainfall, which otherwise goes unutilized, can be employed for raising a fast growing, high biomass producing, drought tolerant, herbaceous legume like horsegram, which can be incorporated in the soil either at flowering or after harvesting the grain. The legume crop can be sown during the last week of October to first week of November after the harvest of *Kharif* crops. The legume crop receives, on an average, about 80 to 130 mm rainfall during the growth period. After about 75 days of growth, horsegram can be ploughed in or it can be allowed to mature till harvest. By ploughing in, about 1.5 tonnes of dry biomass could be added to the soil contributing about 35 kg N/ha. The harvested crop adds about 1.3 tonnes/ha of dry biomass and yields about 1.1 tonnes/ha of grain. The date of sowing and the quantum of post-monsoon rainfall are the two important factors that influence the amount of dry matter produced by the legume.

#### *2.1.1.2. Raising of N – fixing Trees as Separate Blocks or in Rows and Using their Foliage for Green Leaf Manuring*

Another strategy for on farm generation of organic matter could be to raise fast growing leguminous trees that provide abundant foliage either on a separate piece of land within the farm or in the form of rows in an alley cropping system. This system of generation of

organic matter in a part of the farm can be used to meet the nutrient requirement of crops grown in other part of the farm. *Leucaena leucocephala* and *Glyricidia maculata* can be raised in blocks of 0.25 ha (nutrient block) and the leaf material thus generated can be added to other blocks of 0.75 ha (food block). The legumes can be established by seeds. After one year, the foliage material can be harvested by cutting up to a height of 30 cm from ground level. Two year old trees of *Leucaena leucocephala* could provide 8.8 tonnes of fresh biomass which is equivalent to 75kg N/ha. Two cuttings could be obtained in a year. Thus the green leaf material produced from the nutrient block can be used to meet the N-demand of the food block successfully.

#### *2.1.1.3. Bund Farming with Trees and Grasses*

A third strategy to generate organic matter on farm is to plant fast growing N-fixing trees or bushes on single or both sides of bunds which are used for conserving soil and water. *Glyricidia maculata* cuttings can be planted on both sides of bunds at 1 m interval across the slope. *Stylosanthus hamata*, a pasture legume can be seeded on the flat bund surface. *Cenchrus* slips can be planted in between *Glyricidia* cuttings on the upstream side of the bunds. This strategy shall assure regular supply of organic matter from loppings of *Glyricidia*. Every running meter of live bunds can yield 2.88 kg fresh biomass of *Cenchrus* + *Stylosanthus* and 2.96 kg of *Glyricidia* leaves.

#### *2.1.1.4. Ley Farming*

This system involves rotation of legumes with non-legumes. Inclusion of legumes in the cropping system improves soil fertility. Inclusion of *Stylosanthus hamata* improves soil quality (build up of organic carbon, total and available N) and yield of rainfed crops.

### **2.1.2. Advantages of Green Manuring**

- Green manuring has a positive influence on the physical and chemical properties of the soil.
- It helps to maintain the organic matter status of aerable soils.
- It serves as a source of food and energy for the soil microbial population which multiplies rapidly in the presence of easily decomposable organic matter.
- The enhanced activities of soil organisms not only cause rapid decomposition of the green manure but also result in the release of plant nutrients in available forms for use by the crops.

- It improves aeration in the soils.
- Many green manure crops have additional use as sources of food, feed and fuel.
- It builds up soil structure and improves tilth.
- It promotes formation of crumbs in heavy soils leading to better aeration and drainage.
- Depending on the amount of humus formed, green manuring increases the water holding capacity of light soils.
- It forms a canopy cover over the soil and reduce the soil temperature and protect the soil from the erosive action of rain and water currents.
- It absorb nutrients from the lower layer of soils and leave them in the soil surface layer when ploughed in, for use by the succeeding crops.
- They prevent leaching of nutrients to lower layers.
- Leguminous green manure crops harbour N fixing bacteria, rhizobia in the root nodules and fix atmospheric N.
- They increase the solubility of lime phosphates, trace elements, etc. through the activity of the soil microorganisms and by producing organic acids during decomposition.
- A crop of green manure on an average fix 60-100 kg N/ha in a single season under favourable conditions.
- They help to ameliorate soil problems. Dhaincha, when applied to sodic soils continuously for 4-5 seasons, improves the permeability and helps to leach out the harmful sodic salts. The soil becomes fit for growing crops.
- Green leaf manure from *Argemone mexicana* and *Tamarindus indica* has a buffering effect when applied to sodic soils.
- They increase yield of crops to an extent of 15-20%.
- Vitamin and protein content of rice have been found to be increased by green manuring.
- Certain green manure crops like Pongamia and Neem leaves have pest control effects.

### 2.1.3. Classification of Green Manure Crops

**Legumes :** Green manure – Dhaincha, Sunnhemp, Kolinji.

Green leaf manure – Glyricidia, Cassia, Pongamia.

**Non legumes:** Green manure – Sunflower, Buck wheat.

Green leaf manure – Calotropis, Adathoda, Thespesia.

#### 2.1.4. Advantages of Leguminous Green Manure Crops

- Fix free N from atmosphere.
- Physical condition of the soil is improved by cultivation and incorporation.
- They are more succulent than the non-legumes and less soil moisture is utilized for their decomposition.
- They serve as cover crops by their vigorous growth and weeds are smothered.e.g. clover, dhaincha and cowpea.

**Table 2.1. Seed rate and yield of different green manuring crops**

Green manure crop	Seed rate (kg /ha)	Yield (tonnes/ha)	N fixation (kg/ha)
Cowpea	25-30	8-10	---
Sunnhemp	25 – 40	16.8	159
Dhaincha	20 – 25	26.3	185
<i>Sesbania rostrata</i>	30 – 40	3 – 5 (as border crop), 24.9 (as pure crop)	219
Glyricidia	375-400 plants/ha	2.5-5.0 kg/plant (2-3 cuttings / year) (2.5-3.5 t/ha)	---
Velvet bean	---	28 (30 x 20 cm spacing), 40 – 45 (thick sowing)	255
<i>Sesbania speciosa</i> (Sesbania)	35 – 50	5 – 8 (as border crop), 10 (60 days crop), 20 (90 days crop), 50 (120 days crop), 60 (150 days crop)	---
Wild Indigo	25 – 40	3.5 – 6 (as catch crop), 16.8 (as pure crop)	115
Madras Indigo	25 – 30	10 – 12	---
Phillipesara	20 – 35	19.6	126
<i>Calapogonium mucunoides</i>	8 – 10	5	---
<i>Ipomea carnea</i>	1800-2000 plants/ha	5 – 7 kg/plant/lopping 2-3 loppings/year	---

Pongamia	---	100-150 kg/tree/lopping (2 loppings/year) 1-2 tonnes/tree/year	---
Neem	---	150-200 kg/tree/lopping (2 loppings/year)	---
<i>Thespesia populnea</i>	---	100-150 kg/tree/lopping (2-3 loppings/year)	---
Lucern ( <i>Medicago sativa</i> )	5	10-12	---
Cluster bean ( <i>Cymopsis tetra – gonolobia</i> )	12-15	8-10	---
<i>Stylosanthus hamata</i>	4	8-10	---
Subabul ( <i>Leucena leucophila</i> )	1000-1500 plants	20-25 kg/plant	---
Green gram	15	4-5	---
Black gram	15	4-5	---

Some of the common leguminous green manure plant species are as follows:

Sesbania ( <i>Sesbania speciosa</i> )	Cowpea ( <i>Vigna unguiculata</i> )
Dhaincha ( <i>Sesbania aculeata</i> )	Clusterbean ( <i>Cyamopsis tetragonoloba</i> )
Sunnhemp ( <i>Crotalaria juncea</i> )	Green gram ( <i>Vigna radiata</i> )
Wild Indigo ( <i>Tephrosia purpurea</i> )	Black gram ( <i>Vigna mungo</i> )
Pillipesara ( <i>Phaseolus trilobus</i> )	Berseem ( <i>Trifolium alexandrium</i> )
Madras Indigo ( <i>Indigofera tinctoria</i> )	

**Table 2.2. Biomass production and nitrogen accumulation in green manure crops**

Green manure crop	Fresh biomass (t/ha)	N accumulation (kg/ha)
<i>Sesbania aculeata</i> (Dhaincha)	26.30	185.00
<i>S. rostrata</i>	24.90	219.00
<i>S. speciosa</i>	2.51	15.84
<i>S. grandiflora</i>	3.27	21.25
<i>Tephrosia purpurea</i>	16.80	115.00

<i>Crotolaria juncea</i> (Sunnhemp)	21.20	159.00
<i>Phaseolus trilobus</i> (Phillipesara)	19.60	201.00
<i>Vigna radiata</i> (Green gram)	8.00	42.00
<i>Vigna unguiculata</i> (Cowpea)	15.00	74.00
<i>Cymopsis tetragonoloba</i> (Guar)	20.00	68.00
<i>Melilotus alba</i> (Senji)	28.60	163.00
<i>Lathyrus sativus</i> (Khesari)	12.30	66.00
<i>Trifolium alexandrium</i> (Barseem)	15.50	67.00

**Table 2.3. Nutrient status of green manure crops**

Green manure crop	C:N Ratio	N (%)	P (%)	K (%)	Ca (%)
Sunnhemp	44:1	0.89	0.12	0.51	---
Dhaincha	21:1	0.68	0.13	0.40	---
Glyricidia	31:1	0.68	0.16	0.30	---
Sesbania	---	0.70	0.14	0.75	---
Kolanji	---	0.79	0.20	0.60	---
Honge	33:1	0.16	0.14	0.49	1.54
Calotropis	---	0.42	0.12	0.67	0.20
Lantana	---	0.88	0.15	0.90	0.61
Cowpea	---	0.71	0.15	0.58	---
Horse gram	---	0.91	0.18	0.65	---
Black gram/Green gram	---	0.82	0.18	0.52	---

**Table 2.4. Nutrient content of non-conventional green manures**

Green manure crop	Total N (%)	C:N Ratio	Total P (%)	Total K (%)
<b>Trees (Leaves/twigs)</b>				
<i>Azadirachta indica</i>	2.83	70:1	0.28	0.35
<i>Delonix elata</i>	3.51	27:1	0.31	0.13
<i>Delonix regia</i>	2.76	32:1	0.46	0.50
<i>Peltophorum ferrugenum</i>	2.63	34:1	0.37	0.50
<i>Cassia nigricans</i>	2.73	---	0.18	0.50



**Weeds**

<i>Adathoda vesica</i>	1.32	60:1	0.38	0.15
<i>Parthenium hysterophorus</i>	2.68	30:1	0.68	1.45
<i>Eicchornia crassipes</i>	3.01	29:1	0.90	0.15
<i>Trianthema portulacastrum</i>	2.64	32:1	0.43	1.30
<i>Ipomea carnea</i>	2.01	43:1	0.33	0.40
<i>Calotropis gigantea</i>	2.06	64:1	0.54	0.31
<i>Cassia pistula</i>	1.60	120:1	0.24	1.20

Besides the above crops, black gram, horse gram, green gram, field bean, cowpea can also be grown as green manures. Eight to Nine weeks after sowing, when they flower, they should be ploughed in. They rot in about a months time and become manure. After monsoon crops are harvested, sowing of green manure crops can be taken up.

In addition, many weed plants like water hyacinth (occupied 3 million ha land), eupatorium (25 t/ha/annum organic manure), ipomea, lantana, *Cassia* spp. which have spread menacingly threatening agriculture and environment, can supply large quantities of rich biomass. Eupatorium (*Chromolaena odorata*), a perinneal weed widely found in all areas, yields about 25 tonnes /ha/annum (comparable to glyricidia or pongamia) with 0.62% N, 0.2% P<sub>2</sub>O<sub>5</sub>, 0.46% K<sub>2</sub>O on dry matter basis. Application of 10 t/ha of eupatorium to paddy can reduce 50% fertilizer with less incidence of blast disease. Tea pruning yields considerable quantity of biomass (foliage and twigs about 10 t/ha) with low C:N ratio (11.1 to 16.9) which is ideal for composting.

Coir pith, coconut fronds, rice husk, sugarcane trash, etc. which were burnt hitherto can be digested using several techniques available now.

Nearly 750 million tonnes of cow dung, 250 million tonnes of buffalo manure and 100-115 million tonnes of crop residues are available. The nutrient value of these organics produced annually is in the order of 2.5, 2.0 and 3.0 million tonnes of N, P and K equivalent, respectively. Besides, hundreds of million tonnes of rural and urban compost could be collected.

The annual potential of plant nutrients through organic resources viz., excretion of livestock, human beings, crop residues, industrial wastes and microbial resources is to an extent of 17 million tonnes of NPK. Among them, the maximum contribution is from cattle and buffalo dung which shows a potential of 6.6 million tonnes of NPK.

The next important resource is night soil which if properly exploited can provide 4.72 million tonnes of NPK. Agricultural and industrial wastes include: rice straw, wheat and other cereal straw, sugarcane trash, rice husk, bagasse, press mud, molasses, tobacco waste, cotton mill waste, areca husk waste, coir wastes, jute mill wastes, forest litter, city refuses, sewage wastes, distillery sludge, tannery sludge, industrial sludge, dairy waste sludge, etc. The huge resources remain untapped.

### 2.1.5. Nutrient Status of Crop Residues and Oil Cakes

**Table 2.5. Nutrient status of crop residues**

Crop	N (%)	P (%)	K (%)
Rice	0.60	0.10	1.10
Wheat	0.50	0.10	1.00
Sorghum	0.50	0.10	1.20
Maize	0.60	0.10	1.30
Pearl millet	0.45	0.07	0.95
Barley	0.52	0.08	1.25
Sugarcane	0.50	0.10	1.20
Potato	0.52	0.09	0.85
Groundnut	1.70	0.10	1.20

**Table 2.6. Nutrient status of oil cakes**

Cake	N (%)	P (%)	K (%)
Groundnut	7.6	1.3	0.2
Castor	5.3	1.6	0.4
Neem	4.7	1.9	0.3
Gingelly	6.1	2.4	0.5
Pongamia	2.7	0.9	0.2
Cotton seed	3.9	1.8	1.6
Niger	4.8	1.8	1.3
<i>Bassia latifolia</i>	2.5	0.8	1.8
Rape seed	5.1	1.8	1.0
Linseed	5.5	1.4	1.2
Sunflower	4.8	1.4	1.2
Safflower	4.8-7.8	1.4-2.2	1.2-2.0

**Table 2.7. Quantity of leaf litter and estimated nutrients recycled**

Tree species	Dry wt. of leaf litter (kg/plant)	Nutrients recycled (g/plant)		
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Amla	9.94	79.26	10.98	35.95
Custard apple	1.58	20.19	1.60	3.96
Neem	4.89	69.71	5.90	15.69
Subabool	3.44	62.48	3.80	11.42
CD at 5%	0.542	7.060	0.608	1.83

Karanjin, the main constituent of *Pongamia glabra* seeds was found to be effective as nitrification retarder. Several simple and more potent furano compounds which are responsible for retarding nitrification were synthesized and one of the compounds, nitro benzoxime, was found as effective as N-serve, a commercially available nitrification inhibitor.

The nitrification retarding action of neem was due to more than one meliacin, the most active principle epinimbin was 50% as effective as N-serve. Nimbin, epinimbin and total limonoids stimulated the decomposition of FYM in soil. The antinemic action of neem has been attributed mainly to polar meliacins such as des-acetyl salanin, etc.

**Table 2.8. Leaf litter decomposition rate and their nutrient content**

Tree species	Leaf litter decomposed after 2 months (%)	Available nutrients (%)					
		N		P <sub>2</sub> O <sub>5</sub>		K <sub>2</sub> O	
		Undeco-composed	Decomposed	Undeco-composed	Decomposed	Undeco-composed	Decomposed
Amla	24.60	0.796	2.637	0.11	0.325	0.36	0.227
Custard apple	26.00	1.270	3.217	0.10	0.477	0.25	0.250
Neem	16.20	1.424	3.017	0.12	0.257	0.32	0.310
Subabool	44.60	1.798	2.732	0.11	0.277	0.33	0.325
CD at 5%	7.420	0.098	0.647	0.02	0.029	0.09	0.074

**Table 2.9. Influence of leaf litter on physico-chemical properties of soil.**

Tree species	Soil pH		Organic carbon (%)	N (kg/ha)	P <sub>2</sub> O <sub>5</sub> (kg/ha)	K <sub>2</sub> O (kg/ha)
	0-15 cm depth	15-30 cm depth				
Amla	6.29	6.60	0.51	169.97	8.25	101.05
Custard apple	6.64	6.39	0.50	162.04	11.77	105.57
Neem	6.70	7.05	0.39	145.14	10.94	76.07
Subabool	6.43	7.10	0.34	149.30	9.46	87.72
Control	6.81	7.35	0.32	130.32	8.08	74.47
CD at 5%	NS	NS	0.13	22.04	NS	21.32

Amla produced maximum leaf litter (9.94 kg/plant) followed by neem (4.89 kg/plant). Amla leaf litter recycled maximum N (79.26 g/plant), P (10.98 g/plant) and K (35.95 g/plant) to the soil. Maximum litter decomposition percentage was noticed in subabool (44.60%). Highest N content (3.21%) was recorded in decomposed custard apple litter and was at par with neem (3.01%). P content was maximum in decomposed custard apple (0.47%) followed by amla (0.32%). K content of decomposed litter was highest in subabool (0.32%) which was at par with neem (0.31%).

Organic carbon of the soil was maximum under amla (0.51%) which was at par with custard apple (0.50%). Maximum N content was observed in amla plot (169.97 kg/ha) whereas P<sub>2</sub>O<sub>5</sub> (105.57 kg/ha) and K<sub>2</sub>O (11.77 kg/ha) content were highest in custard apple plot.

It is concluded that physico-chemical properties of soil are improved due to addition of large quantity of leaf litter of different tree species responsible for conservation of soil moisture which triggers microbial activities eventually leading to the release of entrapped nutrients and accumulation of organic matter.

## 2.2. Composting

Composting is the art and science of combining available organic waste so that they decompose to form uniform and stable finished product. Microorganisms that do much of the work need high temperature, plenty of oxygen and moisture. These heat loving thermophilic organisms work best between 45-55°C.

The process of biological recycling by which waste is converted into organic manure is referred to as “composting”. In the process of composting, organic wastes are decomposed due to the activity of bacteria and fungi. Microorganisms oxidize organic compounds to CO<sub>2</sub>, nitrogen dioxide and nitrogen trioxide. Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Nutrients are released and pathogens destroyed as a result of which a dark brown, decomposed substance “humus” is formed. The microorganisms involved in the degradation of different materials are:

### 2.2.1. Microorganisms Degrading Cellulose and Hemi-Cellulose

**Bacteria:** Spices of *Cytophliga*, *Bacillus*, *Pseudomonas*, *Clostridium*, *Streptomyces*, etc.

**Fungi:** Spices of *Trichoderma*, *Fusarium*, *Rhizoctonia*, *Aspergillus*, etc.

### 2.2.2. Microorganisms Degrading Lignin

**Bacteria:** Spices of *Pseudomonas*, *Streptomyces*, *Actinomyces*, *Xanthomonas*, etc.

**Fungi:** Spices of *Fusarium*, *Polyporus*, *Hemicola*, *Mycena*, etc.

Organic waste is generated every day in our homes, market yards, agricultural fields (farm waste, crop residues, livestock droppings), backyards, offices, canteens, restaurants, gardens and industries. These wastes may be food, paper, packing materials, urban waste and industrial by-products. Generally these wastes contain decomposable substances like vegetable waste, kitchen waste and garden waste. These organic matter from the fields has to necessarily go back to enrich the soil. There is a lot of scope for increasing organic manure input for agricultural crops by proper management of waste. Composting of waste can produce good quality organic manure which also acts as a soil conditioner. The cost of organic manure is much lower as compared to chemical fertilizers.

**Table 2.10. Quantity of urban solid waste in different cities**

City	Compostable matter (%)	Density (kg/m <sup>2</sup> )
Kolkata	47	667
Delhi	35	322
Chennai	48	329
Hyderabad	37	369
Ahemadabad	49	535

Kanpur	41	691
Jaipur	26	537
Jabalpur	40	395
Chandigarh	35	397
Sangli	50	388

**Table 2.11. Statewise production of crop residues and their availability for incorporation as organic manure**

State	Total crop residues production (million tonnes)	Crop residues available for incorporation (million tonnes)
Andhra Pradesh	24.600	12.400
Assam	5.000	1.900
Bihar (including Jharkhand)	17.700	6.500
Gujarat	11.100	6.000
Haryana	15.450	6.310
Himachal Pradesh	21.000	0.710
Jammu & Khasmir	2.040	0.750
Karnataka	12.800	7.100
Kerala	1.240	0.470
Madhya Pradesh	29.400	13.000
Maharashtra	27.800	13.300
Orissa	12.280	5.500
Punjab	29.900	10.500
Rajasthan	19.800	9.800
Tamil Nadu	19.700	8.100
Uttar Pradesh (including Uttarakand)	60.000	26.000
West Bengal	18.440	6.870
Manipur	0.396	0.136
Meghalaya	0.226	0.087
Mizoram	0.119	0.048
Nagaland	0.305	0.133
Sikkim	0.776	0.283
Tripura	0.786	0.059
Delhi	0.205	0.109
Dadar & Nagar Haveli	0.035	0.011
Daman & Diu	0.003	0.001
Goa	0.236	0.080
Total	312.718	136.439

**Table 2.12. Potential of organic resources for NPK availability**

Organic source	Plant nutrients (million tonnes)			
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Total
Cattle	2.977	0.793	1.332	5.102
Buffalo	0.745	0.276	0.487	1.508
Goat and Sheep	0.214	0.063	0.020	0.297
Pig	0.044	0.027	0.029	0.100
Poultry	0.027	0.020	0.010	0.057
Other livestock	0.079	0.018	0.069	0.166
Human beings	3.228	0.776	0.715	4.719
Farm crop waste	5.600	2.300	10.700	18.600
Forest litter	0.075	0.030	0.075	0.180
Water hyacinth compost	0.060	0.033	0.075	0.168
Rural compost	1.130	0.678	1.130	2.938
Urban compost	0.024	0.015	0.030	0.069
Sewage sludge	0.012	0.009	0.003	0.024
Total	14.215	5.038	14.675	39.928

**Table 2.13. Fertilizer equivalents of some organic manures and bio-fertilizers**

Component	Input level	Fertilizer equivalent of input in terms of yield
FYM	Per tonne	3.6 kg N+P+K (2:1:1)
Green manure (Sesbania)	Per tonne	4.4 kg N
Green manure (Sesbania)	45 days crop	50-60 kg N for rice
Cowpea intercropped with castor	Legume buried after 6 weeks	30 kg N for castor
Subabul loppings	5 tonnes/ha	25 kg for sorghum
Sugarcane trash	5 tonnes/ha	12 kg N/tonne
Rice straw + water hyacinth	5 tonnes/ha	20 kg N/tonne
<i>Rhizobium</i>	Inoculant	19 – 22 kg N
<i>Azotobacter</i> and <i>Azospirillum</i>	Inoculant	20 kg N
Blue-green algae – <i>Azolla</i>	6 – 12 tonnes/ha	3- 4 kg N/tonne

The physical and chemical characteristics of Indian refuse show that 40-60% of this makes good compost, and that it has adequate nutrients (NPK), a moisture content of 40-50% and a C:N ratio of 25:1 to 40:1. In rural areas, 80% of the waste generated is biodegradable which is rich in nutrients and can easily be composted into organic manure. All naturally dead matter is gradually acted upon by microbes assisted by other environmental factors influenced by the forces of nature such as sun, wind and rain.

Composting can occur most easily if the average CN ratio of the material is about 25-40 parts of carbon for every part of nitrogen. Therefore, addition of green leaves to the dried farm waste would become necessary to get good compost. Microorganisms using materials containing 1% or less N need extra N for their growth and reproduction. Addition of animal excreta encourages quick build up of microorganisms. The dairy manure should be kept covered until it is composted. If it stays on the soil surface, about 25% of N is lost after one day and 45% after 4 days.

Good compost can be obtained by judicious mix of crop residues, green matter with animal excreta in 3:1 or 4:1 proportion maintaining 60% moisture and laid layer by layer on hard surface to a height of 1-1.5 m. After a month, it should be turned over and again the moisture should be maintained at 60%. Once again it is turned over after a month. In about 3 and a half months, a good compost with well digested humus is formed. Best results are obtained when fresh cow dung slurry is poured layer by layer on the biomass. This method is extensively adopted in Japan, China and Korea.

**Table 2.14. Estimated residue production from common crops.**

<b>Crop</b>	<b>Residue yield (t/ha)</b>
Maize	5.49
Wheat	2.04
Soybean	1.72
Grain sorghum	3.05
Sugarcane	85.07
Cotton	0.52

The process of composting enhances the nutrient value of the decomposed matter. The parameters that show significant improvement include: high conductivity, increases of organic carbon by 20-30%, available N/mineral N by 0.25-1.50% and available K by 0.10-



0.75%. It also enriches soil structure, texture and quality, increases the soil moisture retentive capacity considerably and improves the yield by supplying the nutrients. Since the composting technology is simple, farmers can easily adopt it. It is an eco-friendly and sustainable technology.

**Table 2.15. Estimates of the available plant potential from the residues of principal crops**

Crop	Residue yield (million tonnes)	Nutrient content (%)			Nutrient potential (lakh tonnes)
		N	P	K	
Rice	80.744	0.61	0.09	1.15	14.938
Wheat	44.987	0.48	0.07	0.98	6.883
Sorghum	11.563	0.52	0.10	1.21	2.162
Maize	6.219	0.58	0.09	1.25	1.194
Pearl millet	8.283	0.45	0.07	0.95	1.216
Barley	3.180	0.52	0.08	1.25	0.888
Sugarcane	15.645	0.45	0.08	1.20	2.707
Potato	5.062	0.52	0.09	0.85	0.739
Groundnut	9.580	1.65	0.12	1.23	2.773
Total	185.263	---	---	---	33.200

**Table 2.16. Crop residue potential**

Crop	Stubble added (t/ha)	Addition of nutrients (kg/ha)			
		Organic matter	N	P	K
Rice	4.200	1764	17.6	2.9	25.2
Sorghum	2.889	462	6.1	2.6	9.5
Maize	0.667	93	0.6	0.2	2.7
Ragi	3.111	899	43.5	3.8	20.5
Thenai	1.200	108	11.7	1.2	2.1
Samai	3.200	640	20.2	0.6	16.0
Kuthirai vali	0.800	104	7.8	2.2	6.6
Pani varagu	1.200	109	9.0	0.7	16.0
Sesame	0.778	56	5.5	0.2	1.3
Cowpea	0.444	36	3.1	0.3	3.1
Lucerne	0.333	36	0.47	0.6	1.1

**Table 2.17. Response of medicinal and aromatic plants to FYM/Vermicompost (VC)**

Crop	Rate of application (t/ha)	Increase in yield (%)
Ambrette ( <i>Abelmoschus moschatus</i> )	20 FYM	308.7
Bacopa	20 FYM	33.8
Periwinkle	15 FYM	NS
King of bitters	10 FYM	150.0
Indian ginseng	7.5 FYM	53.8
Velvet bean	5 VC	30.4
Davana	30 FYM	36.7
Jamrosa ( <i>Cymbopogan</i> sp.)	25 FYM	22.8
Menthol mint	20 FYM	22.1-37.7
Palmarosa	15 FYM	10.3
South American marigold	10 FYM	NS

### 2.2.3. Types of Composting

Composting can be done using different methods such as: Heap method, pit method and NADEP method.

**Heap Method:** All available organic material (bio-mass, crop residues, weeds and animal excreta) is stacked together in alternate layers. The surface is covered by a thin layer of soil or dry leaves.

- Collect the stalks of glyricidia, subabul, etc. and arrange them in a layer of 15-20 cm thickness for the base.
- Over this spread a layer of available carbon rich bio-mass such as straw or saw dust to a height of 20 cm.
- Add a layer of local legumes, dried or fresh leaves of beans, red gram, green gram, *Stylosanthus* sp., subabul, glyricidia, etc. to a height of 10 cm.
- Over this spread a layer of dung or soil free from stones, pebbles and glass.
- Continue this process of alternate layering until it attains a height of 1.5 m.
- Cover the top with a layer of top soil or mud to a thickness of 2 cm.

- Collect some bamboo/hollow sticks/waste pipes and lay them on the heap at a distance of 30 cm between each.
- Mix the heap once in 10 days with a pitch fork.
- The compost shall be ready in 4-6 weeks.

**Pit Method:** In this method the waste materials are placed in alternate layers in a pit of suitable dimensions. The filled in pit is then covered with soil. This method is suitable for drought areas as it reduces losses due to evaporation.

- Dig a pit measuring 1.5-2.0 m x 1.5 m x 1.0 m. The length can be increased depending upon the area and material available.
- Make use of available materials like coconut coir dust, straw, palm leaves and fibres, and arrange them to a level of 15-20 cm as a bottom layer.
- Add a layer of local, carbon rich bio-mass like straw or saw dust to a thickness of 20 cm.
- Over this spread a layer of legumes, crop residues or leaves of glyricidia or any other N-rich bio-mass to a height of 10 cm.
- Cover with soil/cow dung/slurry to a thickness of 2 cm.
- Repeat the process of filling the wastes in layers till the pit gets filled up.
- Care should be taken that the pit is dug under the shade of a tree or covered with either palmyrah, coconut leaves or polythene to protect it from rain.
- For proper aeration/ventilation, insert some bamboo sticks/waste pipes.
- The contents of the pit should be mixed/turned once in 15 days with a pitch fork.
- Maintain optimum moisture by sprinkling water now and then.
- The compost shall be ready in 3 months.

**NADEP Method:** This is a simple method using surface tanks with ventilation between every brick. A minimum of cow dung is required to produce a N-rich compost. Composting can be done in tanks built above the ground by utilizing local weeds, leaves, straw, dry stalks, animal excreta such as cow dung, dung of sheep, goat and horse.

- Prepare a tank measuring 3 m x 2 m x 1 m with bricks.

- Keep a gap after every brick for aeration. The gaps should be protected with wire mesh to prevent rodents and other harmful insects from entering inside.
- Plaster the tank sides and bottom with cement.
- Spray the bottom of the tank with cow dung slurry.
- Construct the tank close to where the manure can be utilized so that there will not be any transport problems.
- Utilize all the available weeds in the field, leaves and straw. Spread them in layers to a height of 15 cm. Use neem leaves, if available, for the bottom layer.
- Over this add a layer of cow dung of 15 cm thick.
- Cover with soil.
- Repeat the process till the tank is filled.
- Cover the top of the tank with soil to a thickness of 2 cm.
- If the material in the tank sinks, add a few more layers.
- The compost shall be ready in 3-4 months.

**Table 2.18. Nutrient status of compost obtained from different methods**

Content	Heap method	Pit method	NADEP method
Nitrogen (%)	0.75	0.85	1.5
Phosphorus (%)	0.50	0.50	1.4
Potassium (%)	0.25	0.57	0.8

**Composting of casuarina waste:** In coastal and other areas where casuarina is abundant, the green bio-mass can be utilized for composting, and the resultant semi-solid manure which is bio-active can be used as a growth stimulating substance (as a root and shoot initiator).

- Collect the casuarina phyllodes (needles) and stack in layers of 100 kg each to a length of 5 m.
- Add about 25 kg of poultry manure evenly over this layer.
- On the top, spread 250 g of mushroom spawn evenly over the second layer to form a complete stack.
- Repeat this process for nearly 10 stacks.
- The heap should be adequately watered to maintain moisture.

- Cover this with plastic sheets to protect from wind and drying.
- The excess water gets collected at the bottom of the heap.
- The compost shall be ready after 45 days.
- Compost thus formed is deficient in N which is good for tuber crops.

**Composting of Forest Waste:** Composting in the hilly forest areas can be done by utilizing forest litter comprising of leaves, twigs and decayed organic matter which is widely available. Recycling forest litter also prevents forest fires.

- Prepare a tank measuring 1.5 m x 1.2 m x 0.9 m using locally available stones.
- Leave gaps for ventilation.
- Plaster the bottom.
- Add a layer of dung/slurry at the bottom.
- Collect forest litter/leaves of sal/pine, ageratum, lantana, eupatorium, etc. and make a layer of 15 cm over the dung layer.
- Add cow dung slurry over the forest litter.
- Repeat the process until the tank is filled.
- Cover the top of the tank with soil.
- If the raw material in the tank sinks, add a few more layers and cover with soil.
- The compost shall be ready in 3-4 months.

**Composting of Water Hyacinth:** Water hyacinth is a commonly available weed and found almost everywhere in canals, streams and other water-logged areas. It can be utilized for composting and used as manure since it is rich in N and K.

- Cut the water hyacinth weed into 15 cm long bits and dry.
- Dig a pit either circular one (1.5 m diameter and 1.5 m depth) or rectangular one (3 m x 2 m x 1.5 m).
- Spread a layer of water hyacinth to a thickness of 30 cm.
- Over this add a layer of farm waste of 30 cm thickness.
- Add a layer of cow dung of 40 cm thickness over this.
- Repeat the process until the pit gets filled.
- Spread some partially decomposed water hyacinth over this to hasten decomposition.

- Arrange some bomboo sticks between the layers for aeration.
- The compost shall be ready in 4 months.

**Composting of Coir Pith:** Coconut coir pith is a renewable source which accumulates in large quantities near coir based industries. In India, 500,000 tonnes of coir pith is accumulated annually. Coir pith waste is a very valuable biomass. Coir pith contains lignin, cellulose, organic carbon, N, P, K, Ca, Mg, Fe, Zn and Cu. The fungus, *Pleurotus* sp. decompose the coir pith within 20 days. In coir pith, lignin is complexed with cellulose which remains underground for years together. The decomposed coir pith has a very promising value as nutrient (N-1.26%, P-1.0%, K-1.2%). It also contains all micronutrients required for plant growth. It is known to increase plant growth by 15-25% in grapes, cashew, coconut, mango, banana, citrus, flowers, tea, coffee, etc.

- Select a level site of 15 sq. m. (5 m x 3 m) under shade.
- Spread about 100 kg of coir pith evenly.
- Over this add about 300-400 g of *Pleurotus* spawn (mushroom) and spray water over it.
- Spread another layer of 100 kg of coir pith and 1 kg of urea and spray water.
- Repeat this procedure of 2 layers 10 times.
- Allow it to remain for 45 days after which the volume is reduced to 50% and a dark brown compost shall be obtained.

**Table 2.19. Changes in the composition of coir pith after composting**

Composition	Raw coir pith	Composted coir pith	% Increase / decrease
Lignin (%)	36.00	4.80	(-) 87
Cellulose (%)	26.50	10.10	(-) 62
Organic carbon (%)	24.00	24.90	(+) 4
Nitrogen (%)	0.30	1.06	(+) 253
Phosphorus (%)	0.01	0.06	(+) 500
Potassium (%)	0.78	1.20	(+) 54
Calcium (%)	0.40	0.50	(+) 25
Magnesium (%)	0.36	0.48	(+) 33
Iron (%)	0.07	0.09	(+) 29

Manganese (ppm)	1.25	20.10	(+) 1508
Zinc (ppm)	7.50	15.80	(+) 111
Copper (ppm)	3.10	6.20	(+) 100
Volume (m <sup>3</sup> )	1.00	0.58	(-) 42
C:N ratio	112:1	24:1	---

### Advantages of Coir Pith Manure

- Improves the soil physical and chemical properties.
- Increases soil water holding capacity by about 5-6 times and prevents evaporation and infiltration. The soil moisture is maintained at optimum level up to 30 days.
- Encourages luxurious root development which helps the plant in better absorption of nutrients.
- Increases the crop yield and nutritional value.
- Imparts resistance to plant diseases.

**Table 2.20. Recommended dose of coco peat for organic farming**

Crop	Dose
Banana	4 kg/plant
Citrus	20 kg/tree
Arecanut	9 kg/tree
Cashew	40 kg/tree
Pineapple	25 kg/ha
Cocoa	8 kg/plant
Black pepper	10 kg/vine
Ornamental plants	0.5 kg/plant
Mango	40 kg/tree

**Composting of Parthenium:** Parthenium, a problematic introduced weed prevailing in cultivable and fallow areas can be converted into useful organic manure by composting.

- Parthenium plants are to be cut into small pieces of 10 cm size by using chaff cutter.
- The chopped material is spread to a thickness of 10 cm.

- Over this, inoculum *viz.* compost cultures (*Trichoderma viride*, *Fusarium* spp.) is spread uniformly.
- Over this layer, 0.5% urea is spread (5 kg urea/tonne of chopped material).
- This has to be repeated till about 1 m height is obtained.
- Then plastering with mud is done to maintain 50-60% moisture.
- After 2 weeks, a thorough mixing is given.
- In 40-45 days, the parthenium compost is ready for field application.
- This compost contains N -2.49%, P – 0.73% and K – 1.37% with a C:N ratio of 21:1.

**Preparation of Enriched Sugarcane Trash Compost:** In India, 220 million tones of sugarcane are produced annually. At the rate of 10 – 20% of cane harvested, about 22 – 44 million tones of cane trash would be produced annually. By recycling the cane trash as manure, the productivity of crops can be enhanced besides achieving hygienic disposal of the trash avoiding environmental pollution and deterioration of soil health. This method is cost effective technology which would facilitate to leave productive soil to posterity.

- Dig a pit measuring 9 m x 5 m x 1 m in a corner of the field.
- Spread a layer of about 500 kg of cane trash.
- Over this spread about 500 kg of press mud or soil.
- Over these layers, sprinkle 25 kg of a fertilizer mixture prepared by mixing rock phosphate, gypsum and urea in the ratio of 2:2:1.
- These layers should be moistened with 500 litres of aqueous suspension of soil, cattle dung and decomposed manure mixed at the rate of about 5 kg each in 100 litres of water.
- Repeat the layers of cane trash, press mud or soil sprinkling with fertilizer mixture and moistening till 10 layers are laid.
- Over the final layer, spread a layer of press mud or soil to a thickness of 15 cm and cover the heap.
- Moisten the heap once in a week and allow for decomposition for 3 months.
- After 3 months, give a turning by mixing the layers and reheaping the materials.
- Continue moistening the heap once in 7-10 days for 2 months.



- After 5 months, completely decomposed manure is ready for field application.

**Table 2.21. Composition of enriched sugarcane trash compost**

Nutrients	Sugarcane trash	Press mud	Sugarcane trash compost
<b>Major nutrients (%)</b>			
Nitrogen (N)	0.50	1.90	1.60
Phosphorus (P)	0.13	1.50	1.10
Potassium (K)	0.40	0.50	0.50
Calcium (Ca)	0.55	3.20	1.00
Magnesium (MG)	0.30	2.00	0.60
Sulphur (S)	0.12	0.50	0.48
<b>Micro nutrients (ppm)</b>			
Iron (Fe)	360	2440	2710
Manganese (Mn)	110	400	450
Zinc (Zn)	90	260	370
Copper (Cu)	30	130	80
C:N Ratio	113:1	16:1	22:1

**Composting of Pressmud:** It can be done by mixing with distillery effluent which is also a rich nutrient source. First, the moisture content of the pressmud is reduced from 75% to 50% using aerotiller. Then, additives containing materials like composted coir pith 5%, sugarcane trash 2.5%, water hyacinth 2.5% and rock phosphate 2.5% are mixed with pressmud. Then, 1 tonne of pressmud is inoculated with 1.5 litre of composite culture containing thermophilic microbes (*Bacillus* sp. and *Pseudomonas* sp.). Above this, distillery effluent is added to bring 60% moisture level. Then, heap is reformed with aerotiller until a temprerature of 60-70° C is reached. After 4-5 days, adding of next dose of effluent is done when the moisture content goes below 50%. Again, the heap is reformed with aerotiller. Likewise composting of pressmud and adding of effluent are continued. The addition of effluent is about 4000 litres which is added in 1-2 months. For better enrichment of pressmud, super phosphate is added at 2.5% and mixed well. The heap is allowed for curing for about 15 days. Then, Fe SO<sub>4</sub>, at 10 kg/t of pressmud is added and allowed for curing for a period of 15 days. To the composted materials,

biofertilizers viz. *Azotobacter*, *Azospirillum* and phosphobacteria each at 2 kg/ha is added at the time of application, which enables N fixation and solubilization of native and added P.

2.3. Vermicomposting

The process of composting organic wastes through domesticated earthworms under controlled conditions is vermicomposting. Earthworms have tremendous ability to compost all biodegradable materials. Wastes subjected to earthworm consumption decompose 2 to 5 times faster than in conventional composting. During composting the wastes are deodourised, pathogenic micro-organisms are destroyed and 40 to 60% volume reduction in organic wastes takes place. It is estimated that the earthworms feed about 4 to 5 times their own weight of material daily. Thus one kg of worms decompose approximately 4 to 5 kgs of organic wastes in 24 hours.

Biodegradation of organic matter by earthworms is one of the recent developments in which earthworms and microbes work together and produce vermicompost or vermicastings which is a fecal matter with worm casts. Currently earthworm species *Eisemia foetida*, *Eudrilus eugeniae*, *Perionyx excavatus*, *Lumbricus rubellus* and *Pheretima longate* are being used for compost production. Paddy straw, sugarcane trash, maize, vegetable waste, etc. are suitable crop wastes which favour faster development of earthworms. Vermicompost provides vital macro elements like N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, Ca, Mg and micro-nutrients such as Fe, Mo, Zn, Cu, etc. apart from growth substances like NAA, cytokinins, gibberellins, etc. It also harbours beneficial microflora within it (Table 2.22).

Table 2.22. Nutrient status of vermicompost

Major nutrients (%)			Minor nutrients (ppm)			Micro-organisms (per g)		
N	P	K	Cu	Fe	Zn	Fungi	Bacteria	Actinomycetes
1.10	0.86	0.98	52.0	930.0	186.6	2.65x10 <sup>4</sup>	11.37x10 <sup>7</sup>	10.43x10 <sup>4</sup>

2.3.1. Vermicomposting of Farm Waste

- Dig a pit measuring 2 m x 1 m x 1 m.
- Prepare a vermibed by adding a layer of broken bricks and sand (5-10 cm thick) at the bottom of the pit.

- Add a layer of good loamy soil over this to a thickness of 15-20 cm.
- Moisten the bed and make sure that it is not flooded with water.
- Introduce about 100 earthworms in clusters (preferably local earthworms) and allow them to remain for 36 hours in order to penetrate the soil.
- Add a few lumps of dung and moisten them.
- Add a layer of 5 cm of farm or backyard waste, whichever is available, and spray with water.
- Allow the moisture to remain for 30 days, and make sure that it is always moist.
- Cover the pit with coconut/palmyrah leaves.
- After first 30 days, add a layer of bio-mass to a thickness of 5 cm every 2-3 days.
- Turn the waste every 15 days with a pitch fork.
- Continue watering for 30-45 days.
- The compost shall be ready after 45 days when no water should be added to the pit.
- Remove the compost and make it into a heap.
- The earthworms will settle down, and the compost can be sieved and stored.

### ***2.3.2. Vermicomposting of Dairy Waste***

Biogas slurry and dairy farm waste can be efficiently turned into compost with earthworms, as they consume almost any non-toxic organic waste, including food processing waste, paper and manure.

- Dig a trench measuring 1.5 m x 1.2 m x 0.3 m.
- Build some moistened straw, as a bed, to a height of 10 cm.
- Over this add 10 cm cow dung/biogas slurry and pour some water.
- Introduce about 100 earthworms/cu. ft. in the bed.
- Over this put 5 cm layer of farm waste and moisten with water.
- Add a 15 cm layer of slurry over this and water it to maintain moisture.
- Allow it to remain for 45 days.

- Mixing and turning using a pitch fork should be done every 15 days. It must be watered regularly.
- After 45 days, stop watering, sieve the manure and store.

**Table 2.23. Nutrient status of dairy waste Vermicompost.**

Nutrient	Value
pH	6.43
EC	1900
Nitrogen (g/t)	408.40
Phosphorus (g/t)	1047.48
Potassium (g/t)	2049.60
Chloride (%)	0.05
Sulphate (%)	Nil
Organic matter (%)	3.65
Total bacterial count	$1.4 \times 10^6$

### ***2.3.3. Vermicomposting of Kitchen Waste***

About 300-600 g/person/day of domestic waste is generated in urban areas. Considering 6-8 members per family, the waste generated is enormous which can be recycled using earthworms. Care should be taken that the waste is not mixed with plastic, polythene bags, glass and other non-biodegradable materials.

- Take a plastic tub (1 m x 1 m x 0.3 m) with holes at the bottom.
- Prepare a bed with husk/coir waste to a thickness of 5 cm and water it.
- Over this add a uniform layer of fine soil (free from clods and stones) over the coir to a height of 5 cm.
- Add a 5 cm layer of cow dung powder and moisten it.
- Now add about 15 cm of kitchen waste, water it and allow it to remain for 7-10 days.
- Introduce about 100 earthworms in clusters (preferably local earthworms).
- Collect the castings which come out of the tub and make a heap.

- Then add another layer of kitchen waste and continue this process. Keep collecting castings once in 15 days and add to the heap and allow to dry for 2-3 days. All the worms will settle down. Sieve the manure and store.

#### ***2.3.4. Vermicomposting of Community/Municipal Waste***

- Composting has to be done only by using wet waste free from stones and plastic material.
- Construct 2 pits (adjacent to each other) each of 1.80 m x 1.20 m x 0.90 m which are wide at the top and narrow at the bottom.
- In one pit mix the wet waste with leaf litter and dung and allow it to decompose for 2 to 3 weeks. Keep the mixture moist with regular watering.
- Cover the pit with an iron grill to protect people from falling into the pit.
- In the second pit, prepare a bed by locally available stones/pebbles.
- Add a layer of fine loamy soil from where the earthworms have been brought.
- Introduce about 100 earthworms into the pit.
- Remove the partially decomposed organic material from the first pit and add it to the second pit.
- Add a layer of 10-15 cm of waste once a week.
- Water it once in 2-3 days to maintain moisture.
- Repeat the process until the pit gets filled up.
- Allow the mixture to remain for 30 days.
- Then remove the compost and pile it into a heap.
- Cover the pit with an iron mesh/grill.

#### ***2.3.5. Vermicomposting of Sugarcane Bagasse***

- Chop sugarcane bagasse to a size of 10-15 cm.
- Dig a pit of 0.6 m x 0.9 m x 0.3 m under the shade of a tree.
- Fill the pit with the chopped sugarcane bagasse.
- Add a layer of cattle dung, urea and rock phosphate.
- Over this add a layer of top soil.

- Cover the pit. Allow the mixture to decompose for 10-15 days.
- After partial decomposition, add deep burrowing earthworms.
- Cover the pits with wet gunny bags or moisten by regular watering.
- Maintain sufficient moisture for 4 months.
- Compost shall be ready after this period.

**Table 2.24. Comparison of the available mineral elements in the cast of earthworms and in the upper layer of ploughed field**

Particulars	Earthworm cast	Depth of soil layer	
		0-15 cm	20-40 cm
Loss on ignition (%)	13.1	9.8	4.9
C:N Ratio	14.7	13.8	13.8
NO <sub>3</sub> Nitrogen (ppm)	21.9	4.7	1.7
Available P (ppm)	130.0	20.8	8.3
Available K (ppm)	335.0	32.0	27.0
Exchangeable Ca (ppm)	2.78	1.99	1.81
Total Ca (%)	1.19	0.88	0.81
Total Mg (%)	0.545	0.511	0.548
Exchangeable Mg (ppm)	49.2	162	69
pH	7.0	6.36	6.05

**Table 2.25. Physico-chemical and microbial properties of vermiwash**

Parameters	Quantity	Parameters	Quantity
Odour	Odourless	Mg	540 ppm
Colour	Honey brown	Fe	110 ppm
pH	8.7	Mn	273 ppm
EC	8.2 d sm <sup>-1</sup>	Zn	180 ppm
OC	0.048%	Cu	21 ppm
N	500 ppm	Bacteria	3.5 x 10 <sup>6</sup>
P	390 ppm	Fungi	1.5 x 10 <sup>5</sup>
K	460 ppm	Actinomycetes	1 x 10 <sup>7</sup>
Ca	640 ppm	N-fixing organisms	1 x 10 <sup>3</sup>

**Table 2.26. Nutrient content of some common composts of animal and plant origin**

Manure/compost	Nutrient content (%)		
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Cattle dung	0.35	0.12	0.17
Cattle urine	0.80	0.01	0.6
Sheep & goat dung	0.65	0.05	0.03
Night soil	1.35	0.80	0.50
Farm yard manure	0.80	0.41	0.74
Poultry manure	2.87	2.93	2.35
Rural compost	1.22	1.08	1.47
Urban compost	1.24	1.92	1.07
Mixed farm wastes	0.87	0.59	2.22
Mixed dry residues	0.90	0.45	1.95
Cotton stalks	1.61	0.48	3.38
Water hyacinth compost	2.00	1.00	2.30
Paddy straw	1.59	1.34	3.37
Dry grasses/weeds	1.90	0.55	1.09
Cotton waste/groundnut husk	1.62	1.04	1.26
Lantana stalks and leaves	1.55	0.52	1.07
Wheat straw	2.90	2.05	0.90
Maize stalks	1.99	1.30	1.01
Sugarcane trash	2.73	1.81	1.31
Vermicompost	1.60	2.20	0.67
Leather waste	7.00	0.10	0.30
Hair & wool waste	12.30	0.10	0.30
Blood meal	11.00	1.20	1.00
Raw bone meal	3.50	22.50	---
Steamed bone meal	1.50	27.50	---
Fish meal	7.50	6.00	1.8

**Table 2.27. Nutrient status of some industrial wastes**

Industrial waste	Nutrient content (%)		
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Coir pith	0.26	0.05	0.84
Pressmud	1.15	2.40	1.98
Spent coffee	0.80-3.36	0.08-0.70	0.036-0.41
Seaweed residue	1.50	0.50	4.20
Cotton mill waste	1.40	0.60	1.20
Saw dust	0.25	0.20	---
Sewage sludge	1.50	2.00	1.50
Bagasse	0.25	0.12	0.40
Biogas slurry	1.60	1.50	1.20
Mushroom spent waste	1.68	0.60	0.63
Fly ash	0.15-0.29	0.055-0.092	0.15-0.17
Paper industry	1.0-1.2	0.125-0.265	0.15-0.17

**Table 2.28. Nutrient potential and economic value of biological and industrial wastes**

Types of waste	Total qty. available (mt)	Total nutrients (lakh tonnes/year)				Economic value (Million Rs.)**
		N	P	K	Total	
Cattle manure	280	28.13	20.00	20.69	68.82	30,970
Crop residues	273	12.83	19.66	39.04	71.53	32,188
Forest litter	19	1.00	0.37	1.00	2.37	1,066
Rural compost	285	14.31	8.62	14.23	37.15	16,719
City refuse	14	0.98	0.84	1.12	2.94	1,323
Sewage sludge	1	0.05	0.03	0.03	0.11	49
Pressmud	3	0.33	0.79	0.55	1.68	756
Domestic waste water	6351*	3.18	1.40	1.91	6.48	2,915
Industrial waste	66*	0.03	0.01	0.01	0.05	22
Total	---	60.84	51.72	78.58	191.13	86,008

\* Million cu.m./annum

\*\* Compounded at Rs. 4,500/tonne NPK



## 2.4. Biodynamic Preparations

Basically there are 2 types of biodynamic preparations, i.e. Biodynamic compost preparations (BD-502 to BD-507) and Biodynamic field sprays (BD-500 and BD-501). The basic constituents, related planets and main elements with these BD sets (BD-502 to BD-507) are given below (Table 2.29).

**Table 2.29. Biodynamic preparations and relations with planets and constituents**

BD Set	Related planet	Base material	Nutrient composition
BD-500	Moon	Cow horn manure	Ca
BD-501	Sun	Cow horn silica	Si
BD-502	Venus	Fermented flower heads of Yarrow ( <i>Achillea millefolium</i> )	S, K & N
BD-503	Mars	Fermented Chamomile blossom ( <i>Matricaria chamomilla</i> )	Ca, S, K & N
BD-504	Mercury	Whole shoot of stinging nettle with flower ( <i>Urtica dioeca</i> ) fermented in the soil	Ca, S, K & Fe
BD-505	Moon	Fermented Oak bark ( <i>Quercus robur</i> )	Ca
BD-506	Jupiter	Fermented flower heads of Dandelion ( <i>Traxacum officinale</i> )	K & Si
BD-507	Saturn	Valerian flower extract ( <i>Valeriana officinalis</i> )	P

All the above preparations are made in descending period of the moon except the BD-507, which is prepared in the air/light (day). The BD sets are used in the Cow Pat Pit (CPP), BD-compost, Biodynamic liquid manure and Biodynamic liquid pesticides. These work to regulate the composting process and enable the different elements to be present in a living way.

### 2.4.1. Cow Pat Pit (CPP)

It is a biodynamic field preparation and is also called as ‘Soil Shampoo’. CPP is a strong soil conditioner. It enhances germination, promotes rooting in cutting and grafts, improves soil texture, provides resistance power to plants against pests and diseases, replenishes and rectifies the trace element deficiency. CPP is used to improve soil fertility before sowing and also as seed treatment and foliar

applications. The CPP may be prepared throughout the year. Depending upon the weather and temperature, the preparation will be ready for use in approximately 75 to 90 days. Soaking 0.5 to 1.0 kg of CPP in 40 to 50 litres of water overnight and sprinkling over acre of land before sowing may improve the germination and health of the soil. Its properties and applications are mentioned below:

### **Properties**

- Helps in spreading the effect and quality of BD (502-507) in large area by foliar and soil application.
- Enhances seed germination and rooting in cuttings.
- Replenishes and rectifies the essential elements deficiency in the plant and soil.
- Improves resistance capability of plants against pests and diseases (fungistatic).
- Provides nutrients and stimulates plant growth.
- Fasters way to get all the biodynamics to the soil.
- Cost effective, ecofriendly and farm friendly technology.
- Can be used as foliar and soil application with equal effectiveness.
- Regular use along with BD 500 facilitates better crumb and nut structure of soil.
- Makes soil more friable, lower penetration resistance and good water holding capacity.
- Improves organic matter content, soil respiration and ratio of mineralizable N to organic carbon.

### **Application**

- Prepare CPP manure slurry, sprinkle on seeds, mix, shade dry and sow.
- Dissolve 1 kg of CPP manure in water, make slurry with clay, dip the seedlings for 5 minutes and transplant.
- Dissolve CPP manure in pure water in a food grade plastic bucket or drum, stir in clock and anti-clockwise directions making vortex for 20 minutes. The solution can be sprinkled/spread in the low volume to make bigger droplets on the foliage.

- Soak CPP manure overnight, dissolve in pure water in a food grade plastic bucket or drum for 20 minutes by making vortex. Sprinkle the solution by brush/broom/sprayer under low volume spray to make bigger droplets on the foliage.
- In quality compost preparations, if BD (502-507) preparations are not available for the compost heap, CPP manure can be used for the purpose. Prepare CPP manure (2 kg) in 5 litres of pure water for 20 min. Pour the solution in different holes in the compost heap and rest over the heap.

### **2.4.2. Biodynamic Compost Heap**

Biodynamic compost is an effective soil conditioner and an immediate source of nutrient for crop. Biodynamic compost heap can be prepared by using green leaves and dry leaves. Green leaves (nitrogenous) and dry leaves (carbonaceous) are piled up in alternate layers of 15 to 25 cm thick of 5 m x 2 m x 1.5 m in size. For enriching the compost with different nutrients as per the need, rock phosphate (P), slack lime (Ca), wood ash (K) etc. can also be used. Composition of air, moisture and warmth is very important in the breakdown and decomposition of the material used. BD sets (502 to 507) are incorporated and the heap is plastered with mixtures of dung and clay. Enriched compost get ready in 75 to 100 days depending upon the temperature maintained.

### **2.4.3. Biodynamic Liquid Manures and Pesticides**

Liquid manures are prepared using different materials, i.e., liquid fish manure, liquid seaweed manure and liquid plant manure. The liquid manures are used for the different purposes based upon the quality and composition. On an average, preparation of liquid manure takes 8 to 12 weeks time. One litre of liquid manure dissolved in 4 litres of water is used on plant as foliar spray. Liquid manures prepared with neem, *Pongamia* and *Calotropis* leaves have insecticidal and fungicidal properties.

### **2.4.4. Biodynamic Field Sprays (BD 500-501)**

**BD-500:** These are the fundamental biodynamic field spray preparations. Cow horns filled with fresh cow dung from lactating cow are buried in fertile soil. Horns are buried in descending moon during autumn (October-November) for incubation during winter. It is taken out in March-April during descending period and used or stored in

earthen pots in dark and cool place. Its characteristics and applications are mentioned below:

- Regular application for 2 to 3 years improve soil characteristics.
- Earthworm activity, porosity, activity of humus forming bacteria, crumb structure, clover nodulation and root penetration are increased.
- The moisture absorbing capacity of the soil can be increased at least four fold over the years.
- Humus depth can be extended down about 30 cm.
- Soil pH rises up to a point which is conducive to the support of earthworms in the range of 5.8 to 6.5.
- The soil becomes able to allow the plants to express their natural characteristics.
- Promotes breathing of the earth.

BD-500 (25 g) is dissolved in 13.5 litres of water in plastic bucket by making vortex in clock and anti-clock wise for 1 hr in the evening and the solution is sprayed with the help of natural brush or with tree twig. Spraying of BD-500 is done at the time of field preparation in descending period of the moon. Very interesting increase in microbial activity of BD-500 during stirring response has been obtained from cosmos and earth (Table 2.28). It should be applied at least twice in a year once in spring and other in autumn.

**Table 2.29. Microbial count of BD-500 with different stirring time.**

Stirring time (min)	Microbial count (cfu/g)		
	Bacteria	Actinomycetes	Fungi
15	26 x 10 <sup>3</sup>	22 x 10 <sup>3</sup>	10 x 10 <sup>3</sup>
30	35 x 10 <sup>3</sup>	35 x 10 <sup>3</sup>	14 x 10 <sup>3</sup>
45	58 x 10 <sup>3</sup>	60 x 10 <sup>3</sup>	12 x 10 <sup>3</sup>
60	66 x 10 <sup>3</sup>	88 x 10 <sup>3</sup>	35 x 10 <sup>3</sup>

**BD-501:** It is prepared in ascending period of moon by filling cow horn with silica powder and buried in spring (March-April) after taking out BD-500. Within 6 months, the preparation is ready for use. The solution is prepared by dissolving 1 g in 13.5 litres of water. BD-501 is sprayed on the leaves in the form of mist before sunrise and the

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best constellation is Moon opposite to Saturn. Its characteristics and applications are mentioned bellow:

BD-501 is applied (1 g in 13.5 litres of water) in the early morning in ascending period of the moon once at the beginning of the plant's life (at the 4-leaf stage) and again at the flowering stage or fruit maturation stage for its maximum effect. BD-501 works on the photosynthetic process. It strengthens the quality of plant product and encourages the development of fruit and seeds. Due to enhancement of photosynthesis, starch, sugars and cellulose synthesis is improved. It also improves the storage life of the produce. It has been found specific for the control of fungi like powdery mildew, brown rot, rust, blight etc.

## Chapter 3

### CROPPING SYSTEMS

Cropping systems involving mixed farming, crop rotation, intercropping / mixed cropping, green manuring, cover cropping, trap cropping and barrier cropping can be effectively employed to enrich the soil with nutrients, weed management and pest management.

Mixed farming is integration of crop and livestock production on the farm, using crop residues in animal husbandary and manures for crop production.

Improved crop rotation (cereal – legume) and intercropping (cereal + fodder/legume) benefit the soil fertility in terms of N fixation by legumes. Improvement in stable aggregates, infiltration rate, water holding capacity have been reported with inclusion of fast growing legumes *viz.*, soybean, cowpea, green gram, groundnut and pigeon pea in sorghum based cropping system. Inclusion of legumes in a intercropping system also enables sustainability of land productivity since legumes are endowed with nitrogen fixing potential. Probably for this reason, Indian farmers could maintain land productivity at reasonable levels inspite of the land being under cultivation from time immemorial and also not being adequately fertilized. Certain legumes such as *Stylosanthes*, Lucerne, etc. with large N-fixing potential enrich soil, prevent soil erosion and add organic matter, hence useful as cover crops in plantations, fruit orchards and in also widely spaced long duration crops like cotton, chilli, etc. In case of short duration crops like pearl millet, yields are not adversely affected during first year under rainfed conditions. In addition to plant functions, crop rotation, intercropping and mixed cropping also helps in weed suppression, reduction in soil-borne insect pests and diseases, complementary nutrient supply, nutrient catching and soil covering.

In organic agriculture, incorporation of legumes in different cropping systems will sustain our agricultural production.

Crop rotation must be followed to avoid insect pest and disease problems. Crops belonging to the same botanical family should not be grown in the same piece of land (e.g. tomato – chilli, bottle gourd – pumpkin) to avoid pest and disease incidence. Similarly, growing of same vegetable crop year after year in the same piece of land should be avoided. It is better to follow crop rotation preferably with leguminous vegetables (e.g. tomato – field bean – pumpkin).

### 3.1. Nutrient Management

#### 3.1.1. Green manure Cropping

##### Fruit Crops

**Mango:** During the first 5 years, dhaincha can be raised as a green manure crop and ploughed *in situ* as an organic nutrient supplement. Groundnut can be grown as an intercrop and haulms can be incorporated into the soil as green leaf manure.

**Guava:** The growing of green manure crops like cowpea, cluster bean, sunnhemp and dhaincha during rainy season and ploughing *in situ* is recommended.

**Pomegranate:** Green manure crop like sunnhemp can be grown during rainy season and incorporated in the soil at the time of flowering.

**Custard Apple:** In bearing orchards, growing green manure crops and ploughing in during August is beneficial for improving vigour and production of the tree.

**Peach and Plum:** A suitable cover or green manure crop may be sown in rainy season after the fruits are picked and ploughed under during winter.

##### Plantation Crops

**Coffee:** In newly planted fields, green manure crops (*Crotalaria striata*, *C. anagyroides*, *Tephrosia vogelii*) and legumes (cowpea and horse gram) could be cultivated for 2 or 3 years during Kharif season (June-September) and incorporated into soil before flowering to build up the soil fertility. These crops not only contribute about 6 – 10 t/ha of dry matter but also suppress weed growth in the early years.

**Coconut:** Green manuring crops like *Indigofera*, *Tephrosia* and sunnhemp grow fast and provide organic manure. Planting of leguminous green manure plants, either seasonal or perennial can add a lot of green manure rich in N to soil in shortest possible time due to their ability to associate with atmospheric N fixing symbiotic *Rhizobium* spp. This N rich green matter will decompose easily and release the bound nutrients fast. Growth of legumes also increases the availability of phosphates. Because of their deep tap root system, they absorb nutrients that have leached down beyond the root zone of coconut palms and make them available to the palm when the biomass is incorporated into soil. The perennial leguminous green leaf manure tree glyricidia is very fast growing, hardy and resistant to regular harvesting of green leaves. This can be very well grown along the borders of coconut plantation and can generate adequate amounts of N rich green leaves. Basin management with legumes is an easily adoptable and less expensive agro-technique for supplying organic manure and N at the site itself.

**Arecanut:** Cultivation of green manure crops *in situ* can be taken up systematically in order to get increased yield. Growing of green manure crops on the onset of monsoon will help to suppress the weed growth, prevent soil erosion and add large quantities of organic matter to the soil.

### 3.1.2. Intercropping

#### Fruit Crops

**Mango:** To bring additional income to the grower until the trees begin to bear and to improve the health of trees, the intercrops are grown which are of the right type. The recommended intercrops in mango orchards for summer season are cowpea, black gram and green gram. For winter season, the intercrops suggested are peas and chickpea.

Intercropping of pre-bearing mango orchard with leguminous vegetables enrich the soil by N-fixation. Total available N (138.2 and 173.5 Kg N/ha) and gross total gain available N (19.5 and 45.9 kg N/ha) after 1 and 2 years was significantly maximum in Cluster bean – Chilli – Bottle gourd cropping. The gross total available P was significantly maximum in Colacasia – Amaranth – Cowpea (105.6 kg P<sub>2</sub>O<sub>5</sub>) after 1 year and Okra – French bean – Watermelon (158.0 kg P<sub>2</sub>O<sub>5</sub>) after 2 years. The gross gain in available P was significantly maximum in Okra – French bean – Watermelon (61.6 kg P<sub>2</sub>O<sub>5</sub>) after 1 year and Colacasia – Amaranth – Cowpea (115.4 kg P<sub>2</sub>O<sub>5</sub>) after 2



years. The total available K was significantly maximum in Potato – Cowpea – Amaranth (286 kg K<sub>2</sub>O/ha) after 1 year and Cowpea – Tomato – Okra (440 kg K<sub>2</sub>O/ha) after 2 years. Significant maximum gross total gain in available K is maximum in Cowpea – Tomato – Okra (144.6 kg K<sub>2</sub>O/ha) after 1 year and (161.9 kg K<sub>2</sub>O/ha) after 2 years. Intercropping vegetables in pre-bearing mango improved the available P and K content of orchard soil from low level in the beginning to medium and high levels after 2 years.

For bearing orchard, Tomato – Cowpea – Soybean – Coriander intercrop rotations; while for non - bearing orchard, Soybean – Peas - Cowpea – Palak – Chillies intercrop rotations have been suggested.

**Banana:** With closer spacing of 1.6 m x 1.6 m, only one intercrop of radish followed by short duration legume like green gram is possible during the initial 3-5 months after planting, the most remunerative combination being green gram-ginger for northern zone giving a net profit of Rs. 7312 and field beans-squashes for southern zone giving Rs. 3330 from intercrops. Intercropping of banana with green gram, black gram, soybean, groundnut or cowpea had no significant adverse effect, whereas intercrops gave additional returns, black gram being the best intercrop.

**Table 3.1. Intercropping schedules and profit earned in banana fields.**

Intercrops	Sowing time	Harvesting time	Crop duration (days)	Net income (Rs./ha)
<b>Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Kerala</b>				
Field bean	September	December	100	1131
French bean (Contender)	September	December	90	2300
Groundnut	June	October	100	1025
French bean (Contender)	October	January	90	2300
Green pea	September	December	90	1800
Field bean	June	September	100	1131

Intercropping with cowpea drastically reduced weed growth with corresponding higher yield in Robusta banana.

**Sapota:** Intercropping with cowpea, French beans and peas in inter rows may be taken up for the first 6 to 10 years.

**Guava:** Intercropping with pea, French bean and senji in rabi season and cowpea, cluster bean, black gram and green gram during kharif season have been recommended. Under dryland conditions, *Stylosanthus* cover crop gave additional fodder yield of 21.2 t/ha.

**Pomegranate:** Intercropping can be done with fodders like berseem and lucerne, pulse crops like cowpea and green gram and vegetables like beans and peas for first 5-6 years.

**Ber:** Intercrops like green gram, black gram, cluster bean and cowpea were proved to be best in western Rajasthan.

**Custard Apple:** In young orchards, legumes can be grown as intercrops for the first 5 years. Besides economic benefit, intercrops also check soil erosion and weed growth.

**Tamarind:** In young plantation, intercropping with leguminous crops during rainy season is advocated.

**Litchi:** Growing of intercrops like legumes during pre-bearing stage would bring more income to the grower besides improving the health of trees. In Bihar, leguminous crops like green gram, black gram and cowpea during summer season are recommended.

**Apple:** Intercropping of *Phaseolus* bean in apple orchard (cv. Red Delicious) was most economical.

**Peach:** Short duration intercrop crop like cowpea can be taken up in peach up to 4 years without any adverse effects on the productivity of peach trees and an income of Rs. 10,000/ha could be obtained.

### Spice Crops

**Cumin:** Pea and beans were found to be the most suitable intercrops for cumin as they are leguminous crops which fix atmospheric N in soil and improves soil fertility status besides giving better returns per unit area.

#### 3.1.3. Cover Cropping

### Fruit Crops

**Peach & Plum:** Peach under cover cropping with cowpea had better physiological condition of the soil, increased the organic matter content of the soil and improved water uptake by peach trees.

### Plantation Crops

**Coconut:** Leguminous cover crops grown in coconut plantations during rainy season protect the soil from direct impact of heavy rains

and serve as catch crops. Incorporation of legume biomass has also been found to enhance the soil microbial population, AMF population, soil enzyme activity and mineralization. Leguminous cover crops like *Mimosa invisa*, *Calapogonium* sp. and *Pueraria* sp. grown in basins can generate about 15-20 kg green biomass/basin and legumes such as *Crotolaria* app. grown in interspaces can generate 3-4 tonnes of green matter/ha.

## 3.2. Weed Management

### 3.2.1. Cover cropping

#### Fruit Crops

**Mango:** Cover cropping with sunnhemp in light soils and sesbania in heavy soils is followed in mango orchards to suppress the weed growth.

**Grapevine:** Cover cropping is practiced for reducing weed growth in vineyards. The cover crops grown in grape orchards are cowpea, French beans, cucurbits, sunnhemp and green gram.

**Ber:** Cover cropping with short duration vegetable crops or forage crops is done in between trees to keep down the weed population and to conserve soil moisture.

**Custard Apple:** In young orchards, leguminous cover crops can be grown for the first 5 years to suppress weed growth.

**Phalsa:** Cover cropping with short duration crops like beans and cowpea could be done not only to control weeds but also to conserve the soil moisture.

**Tamarind:** Cover crops can be grown in older plantations to avoid soil erosion, to conserve soil moisture and to suppress weeds.

**Apple:** Cover cropping can be done during rainy season with sod or leguminous crops for suppressing weeds.

#### Plantation Crops

**Coffee:** Cultivation of green manure crops/cover crops/grain legume crops help in smothering of weeds.

**Rubber:** Legume cover crops like *Calapogonium mucunoides*, *Pueraria phaseoloides* and *Centrosema pubescens* are grown in between rows of young rubber trees to suppress weeds.

**Coconut:** Growing cover crops such as *Calapogonium mucunoides* in coconut gardens suppressed the weeds very effectively within 3 months when grown as a green manure – cum - cover crop. Cover crops like *Calapogonium* (legume), *Mimosa invisa* and *Stylosanthus* aid in suppressing weed growth due to fast growing nature. Growing competitive crops like sunflower, soybean, green or black gram, cowpea and other legumes had a suppressing effect on weeds in coconut gardens.

**Arecanut:** The raising of cover crops such as *Calapogonium mucunoides*, *Mimosa invisa* and *Stylosanthus gracilis* was found to be advantageous to suppress the weed population. Cover crops like guinea grass can also be grown to suppress the weeds.

**Oil Palm:** Cover cropping with *Centrosema pubescens* and *Calapogonium caeruleum* in oil palm plantations helps in reducing the incidence of weeds.

### Spice Crops

**Black Pepper:** Cover crops (*Calapogonium mucunoides*, *Mimosa invisa*) are grown to provide effective soil cover and to suppress weeds.

### 3.2.2. Intercropping

#### Fruit Crops

**Apple:** Growing intercrops in rows between the trees and in the basins of apple trees suppressed weeds and supplemented the income. The suitable intercrops like tomato, cabbage, beans, strawberry, early potato, mustard, wheat, oat and to some extent barley can be taken during summer and rainy season.

**Peach & Plum:** Intercropping orchards with green gram, chickpea, pea and onion reduced the density of weeds both in basins and inter rows.

**Bael:** Any legume and forage crop can easily be taken during rainy season as intercrop to suppress weeds.

#### Medicinal crops

**Sarpagandha:** Growing of intercrops such as maize, cowpea or brinjal during kharif and radish, wheat or a cole crop during rabi gave largest overall profits. Intercropping with soybean, garlic or onion gave higher net returns than when grown alone. Even alkaloid content

was more when it was intercropped. Suppression of weeds by intercrops could be the reason for enhanced alkaloid yield in sarpagandha.

**Senna:** Intercropping of senna with gram, gingelly, chillies and cotton suppress weed population.

**Dioscorea:** Intercropping with cowpea or black gram is effective in controlling weeds and is superior to any herbicide in giving highest yields in the first and second year.

**Opium Poppy:** Intercropping with garlic in black soils is beneficial in controlling weeds.

## Aromatic Crops

**Palmarosa:** Intercropping with black gram is effective in reducing the weed population.

**Geranium:** Black gram, garlic, onion or peas can be taken as intercrops during the initial stages of the crop to keep down the weed population. One row of black gram or pea and 2 rows of garlic or onion are sown between 2 rows of geranium, subsequent to transplanting of geranium.

## Plantation Crops

**Coconut:** Intercropping and mixed cropping of coconut gardens with arecanut, ginger, turmeric, dioscorea, banana, tapioca, cocoa and cinnamon was found useful for keeping the plantation free from weeds to a great extent. All weeds except *Rottboellia exaltata* were suppressed by winged bean (*Psophocarpus tetragonolobus*) when it was fully established 4 months after sowing in coconut gardens.

**Arecanut:** Intercrops such as elephant foot yam, black pepper, arrowroot (*Manihot* spp.) and banana, and mixed cropping with cocoa, pepper and betelvine can be taken up to increase the income of growers without any detrimental effect to the yield of main crop and to suppress the weeds.

## Tuber Crops

**Elephant Foot Yam:** Intercropping with root crops like sweet potato, colocasia and tapioca suppress the weeds.

**Cassava & Yam:** Intercropping with legumes (cowpea and black gram) reduced the weed intensity in cassava. Intercropping saved 77% of weeding cost, besides obtaining additional income. Intercropping

with cowpea and ‘Egusi’ melon which suppressed weed growth gave highest economic returns under cassava.

### 3.2.3. Crop Rotation

#### Aromatic Crops

**Mint:** Crop rotation may also help to maintain a reasonable control on weed growth. Paddy as preceding crop in rotation with mint has been found to minimize weed competition by 30-40%. The following crop rotations are recommended to suppress weed population: i) Mint – Maize – Potato, ii) Mint – early Paddy – Potato, iii) Mint – Maize – Rapeseed/Mustard, iv) Mint – Paddy.

### 3.3. Pest Management

#### 3.3.1. Intercropping

#### Fruit Crops

##### Banana

**Nematodes:** Intercropping with *Tagetes*, *Crotalaria* or radish significantly reduced the *Radopholus similis* population. A significant reduction in *Pratylenchus coffeae* population (85%) was observed in the banana field where *Tagetes erecta* was grown as intercrop. The yield of the plants significantly increased (12 kg/plant) when intercropped with *Tagetes* spp. compared with the untreated control (9 kg/plant). Intercropping with sunnhemp in banana field was found effective in reducing *R. similis*, *P. coffeae* and *Helicotylenchus multicinctus* population by 38.4%, followed by marigold and cowpea which recorded a 29.0 and 22.3% reduction, respectively.

#### Vegetable Crops

##### Tomato

**Bacterial Wilt, *Ralstonia solanacearum*:** Intercropping of tomato with sorghum, maize, onion, garlic and marigold resulted in better crop stand.

**Root-knot Nematode, *Meloidogyne* spp.:** Intercropping with marigold or mustard with tomato reduced the damage of root-knot and reniform nematodes.

## Potato

**Brown Rot, *Ralstonia solanacearum*** : Intercropping of potato with maize and cowpea were the most effective in reducing the wilt incidence.

**Viruses** : Intercropping of mustard with potato prevents neither mustard aphid (*Lipaphis erysime*) colonization on potato crop nor transmission of the potato viruses.

## Ornamental Crops

### Rose

**Lesion Nematode, *Pratylenchus* sp.:** Intercropping with marigold helps in reducing the nematode population.

### Gladiolus

**Root-knot Nematodes, *Meloidogyne* spp.:** Intercropping with marigold helps in reducing the nematode population.

### Crossandra

**Nematodes, *Meloidogyne incognita*, *Pratylenchus delattrei*, *Longidorus africanus*** : Intercropping with marigold or pangola grass helps in reducing the nematode population in soil.

## Plantation Crops

### Coconut

**Root wilt (Phytoplasma):** Raising green manure crops in the basin and their incorporation into the soil and mixed farming in diseased gardens involving the raising of fodder crops in the interspaces helps to reduce the disease incidence. Mixed cropping with cocoa also increased the yield by 30% and slowed down the decline of palms. Cultivation of tapioca, elephant foot yam and yam in the interspaces of palms in disease affected gardens for a period of 3 years increased the nut yield.

**Burrowing Nematode, *Radopholus similis*:** Growing of intercrops like cocoa that enriches the soil with sizeable quantities of shed foliage which help in the build up of beneficial organisms which may inhibit nematode multiplication. *Crotalaria juncea* may be grown in the basins and interspaces and used as green manure which also suppresses nematode population.

### 3.3.2. Trap cropping

#### Vegetable Crops

##### *Tomato*

**Fruit Borer, *Helicoverpa armigera*:** Use of African marigold (*Tagetes erecta*) as a trap crop for the management of fruit borer on tomato involves planting one row of 45 day-old marigold seedlings after every 16 rows of 25 day-old tomato seedlings.

**Leaf Curl:** When tomato is grown along with French bean and brinjal, the incidence of TLCV is low as they act as trap crops for whiteflies.

##### *Cabbage & Cauliflower*

**Diamondback Moth, *Plutella xylostella*:** Growing 2 rows of Indian mustard as a trap crop after every 25 rows of cabbage traps diamondback moth, leaf webber and aphids.

##### *Chilli*

**Fruit Borer, *Helicoverpa armigera*:** *H. armigera* can be controlled by using marigold as a trap crop (planting 1 row of marigold after every 16 rows of chilli).

##### *Potato*

**Root-knot nematodes, *Meloidogyne* spp.:** Growing of trap crops like *Tagetes patula* and *T. erecta* (African marigold) in between 2 to 3 rows of potato reduces the root-knot nematode population.

##### *Cabbage & Cauliflower*

**Club Root:** Trap cropping with rayosak among susceptible brassicas in the first year and tori sarson and radish among resistant brassicas in the second year with 30 days optimum trapping period was found most effective in reducing the disease intensity and increasing the yield.

#### Ornamental Crops

##### *Gerbera*

**Leaf Miner, *Liriomyza trifolii*:** Intercropping with field bean (*Vicia faba*) which acts as a trap crop is effective.



## Spice Crops

### *Black Pepper*

**Nematodes, *Radopholus similis*, *Meloidogyne incognita*:** Growing of non-host cover crops like Siratro (*Macroptilium atropurpureus*) in the interspaces is recommended to reduce nematode population. Growing marigold as a trap crop and uprooting the trap crop at flowering stage and burning reduce the incidence of nematodes.

## Tuber Crops

### *Yam & Chinese Potato*

**Root-Knot Nematode, *Meloidogyne* spp.:** The root-knot nematode can be controlled by growing sweet potato cv. Shree Bhadra as a trap crop.

### **3.3.3. Barrier/Border Cropping**

## Vegetable Crops

### *Tomato*

**Leaf Curl:** Sowing of 5 rows of maize (border crop which prevents incoming viruliferous whiteflies from entering into the tomato crop) about 5 weeks before transplanting tomato resulted in low incidence of leaf curl disease (14.42%) followed by sunnhemp (18.27%) and jowar (23.94%) as compared to 48.09% in control. Hence growing maize as barrier crop around tomato crop is effective in preventing further spread of the leaf curl disease.

### *Brinjal*

**Shoot & Fruit Borer, *Leucinodes orbonalis*:** Growing a barrier crop such as maize help in reducing the borer damage.

### *Onion & Garlic*

**Thrips, *Thrips tabaci*:** Thrips are weak fliers and carried to long distances by wind. Blocking adult thrips can reduce the initial and subsequent pest load on onion. Barrier crops (2 rows of maize all round onion crop) can be employed for this purpose.

### 3.3.4. Crop Rotation

#### Vegetable Crops

##### *Tomato*

**Bacterial Wilt, *Ralstonia solanacearum*:** Following 3 years rotation with cereals/crucifers are effective for the management of wilt. Crop rotation with cowpea – maize - cabbage, okra – cowpea - maize, maize – cowpea - maize and finger millet - brinjal (Pusa Purple Cluster) - French bean are reported to be effective in reducing bacterial wilt.

**Root-knot Nematode, *Meloidogyne* spp.:** Crop rotation with non-host (maize, wheat, sorghum) or antagonistic crops (marigold, mustard, sesame) is effective in reducing the nematode population.

##### *Brinjal*

**Bacterial Wilt, *Ralstonia solanacearum*:** Crop rotation with cowpea – maize - cabbage, okra – cowpea - maize, maize – cowpea - maize and finger millet - brinjal (Pusa Purple Cluster) - French bean are reported effective in reducing bacterial wilt.

**Root-knot Nematodes, *Meloidogyne* spp.:** Rotation of brinjal with sweet potato (cv. Sree Bhadra) reduced the root-knot nematode population by 47% and increased the fruit yield by 22%. Crop rotation with sorghum, wheat and chilli reduced the root-knot nematode population. Intercropping with marigold, onion and garlic is also recommended.

##### *Chilli*

**Phomopsis Blight and Foot Rot, *Phomopsis vexans*:** Crop rotation with non-solanaceous crops helps in keeping the disease under check.

**Bacterial Wilt, *Ralstonia solanacearum*:** Crop rotation with French beans reduces bacterial wilt.

**Root-knot Nematodes, *Meloidogyne* spp.:** Crop rotation with cereals, sesame and mustard, so also intercropping with marigold, onion and garlic reduce nematode infestation.

##### *Potato*

**Common Scab:** Crop rotation with wheat, peas, oat, barley, lupin, soybean, sorghum and bajra keeps the disease in check.

**Brown Rot, *Ralstonia solanacearum*:** Crop rotation with maize, wheat, barley, oat, sorghum, lupin, sunnhemp, finger millet and vegetables like cabbage, onion, garlic reduced the wilt incidence to the extent of 94%. Studies undertaken in North Western Hills using 6 cropping sequences revealed that the reduction in wilt incidence ranged between 25 to 81% by following 2 years rotations. Potato-finger millet-finger millet-potato gave maximum reduction in wilt incidence (81%) (Table 3.2). Roots of finger millet were free from *R. solanacearum* infection, whereas paddy, maize, wheat and beans carried the infection. However, rhizosphere population of the pathogen was found to be reduced.

**Table 3.2. Effect of crop rotation on bacterial wilt incidence and yield of potato in North Western Hills (Bhowali)**

Crop rotation	Wilt incidence (%)	Yield loss (%)	Popn. of <i>R. solanacearum</i> in cfu/root system of different crops
Potato-Potato-Potato- Potato	51.7 (+ 92)	56.9	9.0 x 10 <sup>6</sup> (Potato)
Potato-Bean-Bean- Potato	19.7 (-25)	18.3	9.2 x 10 <sup>4</sup> (Bean)
Potato-Paddy-Paddy- Potato	12.0 (-53)	29.7	1.0 x 10 <sup>5</sup> (Paddy)
Potato-Wheat-Wheat- Potato	9.2 (-63)	18.8	4.2 x 10 <sup>4</sup> (Wheat)
Potato-Maize-Maize- Potato	8.7 (-66)	13.1	1.0 x 10 <sup>6</sup> (Maize)
Potato-Finger millet-Finger millet- Potato	4.7 (-81)	7.1	0.0 (Finger millet)

**Root-knot Nematode, *Meloidogyne* spp.:** Following 2 years crop rotational sequence of maize-wheat-potato-wheat reduces root-knot damage significantly. Crop rotation with non-host crops like maize, wheat, barley, etc. reduces nematode population.

**Cyst Nematode, *Globodera rostochiensis*:** Growing non-host crops like radish, garlic, beet root, French bean, cruciferous vegetables, turnip or green manuring crops bring down the cyst nematode population by more than 50%. A crop rotation pattern (using potato-French bean-peas), wherein potato is grown once after 3-4 other crops, decreased the nematode population by 98 to 99% and increased yields of potato. In Nilgiris, crop rotation with cabbage and carrot gave effective control of cyst nematodes.

### *Okra*

**Root-knot Nematodes, *Meloidogyne* spp.:** Crop rotation with cereals and marigold helps in reducing the nematode population in soil. Rotation of okra with sweet potato (cv. Sree Bhadra) reduced the root-knot nematode population by 51% and increased the fruit yield by 21%. Crop rotation with non-host crops such as cabbage, sesame, onion, mustard, marigold and wheat significantly reduced the root-knot nematode population.

### *Cabbage & Cauliflower*

**White Rot or Stalk Rot, *Sclerotinia sclerotiorum*:** Crop rotation with cabbage / cauliflower – paddy is effective in reducing the disease incidence.

### **Ornamental Crops**

#### *Gladiolus*

**Root-knot Nematodes, *Meloidogyne* spp.:** Crop rotation with marigold helps in reducing the nematode population.

### **Medicinal crops**

#### *Betelvine*

**Root-knot Nematode, *Meloidogyne incognita*:** Crop rotation with rice helps to reduce the nematode population in soil.

### **Spice crops**

#### *Ginger & Turmeric*

**Nematodes, *Meloidogyne incognita*, *Radopholus similis*:** Crop rotation with cereals and millets should be practiced, preferably with rice at least once in 3 years.

## Chapter 4

# BIOFERTILIZERS

Of late, there is an increasing awareness in favour of adopting biological routes of soil fertility management for preventing soil degradation and for sustaining production. The atmosphere over an hectare of land consists of 80,000 tonnes of N. Though atmospheric N is present in sufficient quantity (80%), it is not available to plants since it exists in inert form. Biological nitrogen fixation (BNF) is the conversion of atmospheric N by living organisms into forms that plants can use. This process is carried out by a group of bacteria and algae which fix or convert the element of N into assimilable forms either in association with plants or free-living state. The conversion of inert N is facilitated by the enzyme nitrogenase, present in the N fixing micro-organisms which are marked with 'nif' genes. They synthesize nitrogenase enzymes responsible for converting inert  $N_2$  to plant usable  $NH_3$ .

Biofertilizers or microbial fertilizers or more appropriately 'microbial inoculants' are preparations containing live or latent cells of efficient strain of N fixing micro-organisms used for seed or soil application with the objective of increasing the numbers of such micro-organisms in soil or rhizosphere and consequently improve the extent of microbiologically fixed N for plant growth. They are used to either to fix N or to solubilize plant nutrients like phosphates or to otherwise stimulate plant growth through synthesis of growth promoting substances (PGPR) or to collect available P from remote places out of reach of plant root hairs by sending elongated filaments (AMF). Biofertilizers on application remain in soils, multiply and keep benefiting the growing crops.

Use of cost effective and eco-friendly biofertilizers with suitable integration of organic manures will restore the soil health and keep

the soil productive and sustainable. Biofertilizers are inputs containing micro-organisms which are capable of mobilizing nutritive elements from non usable form to usable form through biological processes. The beneficial microbes in the soil which are of greater significance to horticultural crops are the biological nitrogen fixers, phosphate solubilizers and the mycorrhizal fungi.

Biofertilizers convert the unavailable form of nutrients into forms easily accessible to the plants. They improve soil physical properties and sustain soil fertility by providing aeration, biomass and nutrients. They not only make atmospheric N available but also solubilize and mobilize soil fixed P and improve P uptake in plants. They enhance plant growth due to release of hormones, vitamins, auxins, etc. They also help to proliferate beneficial micro-organisms which in turn suppress soil-borne pathogens.

## **Types of Biofertilizers**

There are 6 types of biofertilizers:

- Biological N-fixing micro-organisms.
- Phosphate solubilizing and mobilizing micro-organisms.
- Potash solubilizing micro-organisms.
- Sulphur mobilizing micro-organisms.
- Arbuscular mycorrhizal fungi.
- Growth promoting substance excreting micro-organisms.

### **4.1. Biological Nitrogen - Fixing Micro-organisms.**

Biological N-fixing micro-organisms helps in reduction of atmospheric N<sub>2</sub> to NH<sub>3</sub>. Biological N-fixation contributes more than 175 million tonnes of N out of which legume N-fixation account for almost 40%.

The N- fixing organisms associated with horticultural crops are the *Rhizobium* spp. which live in symbiotic association with roots of leguminous vegetables forming nodules and free living fixers – *Azotobacter* spp. and *Azospirillum* spp. which live in association with root system of crop plants. There are 2 types of rhizobia; (a) the slow growing *Bradyrhizobium* and (b) the fast growing *Rhizobium*. *Azospirillum* fix N from 10 to 40 kg per ha and saves N fertilizer inputs by 25 to 30%. *Azotobacter* inoculation saves N fertilizers by 10 to 20%.

### 4.1.1. *Rhizobium* and *Bradyrhizobium*

They symbiotically fix N with leguminous plants increasing the amount of available N for uptake by plants. The quantum of N fixation ranges from 50-300 kg N/ha/crop under most optimum conditions (Table 4.1). An increase in yield of about 10 to 20% has been observed in pulses treated with *Rhizobium*.

**Table 4.1. Quantity of N fixed by legume crop root nodules.**

Legume pulse crop	Nitrogen (kg/ha)
Cowpea	80 – 85
Bengal gram	85– 100
Red gram	168 – 200
Soybean	60 – 88
Groundnut	50 – 60
Lucerne	100 - 300
Black gram/green gram	50-55
Clover	100-150
Cluster bean	37-196
Fenugreek	44
Lentil	90-100
Pea	52-57

**Table 4.2. Estimates of N fixed by different N-fixing systems.**

N-fixing systems	N fixed (kg N/ha)
<b>Non-symbiotic:</b> Rice – Blue green algae	10 – 80
Rice – Bacterial association	10 – 30
Sugarcane - Bacterial association	20 - 160
<b>Symbiotic:</b> Rice – <i>Azolla</i>	
Legume – <i>Rhizobium</i>	
<i>Leucaena leucophila</i>	100 – 300
<i>Glycine max</i>	0 – 237
<i>Trifolium repens</i>	13 – 238
<i>Sesbania rostrata</i>	320 - 360
Non-legume – <i>Frankia</i> – <i>Casuarina</i> sp.	40 - 60

#### 4.1.2. *Azolla*

Blue green algae contributes 25 kg N/ha/season. Biological N-fixation through *Azolla* – *Anabena* complex is considered a potential biological system for increasing rice yield at comparatively low cost. *Azolla* – *Anabena* complex can fix 70 kg N/ha (20 to 150 kg N/ha) and has a biomass of 2.1 tonne dry matter/ha (0.8 to 5.2 t dry matter/ha). Fern has a potential of accumulating more than 10 kg N/ha/day.

#### 4.1.3. *Azotobacter*

*Azotobacter* is a free living aerobic N-fixing bacterium (fixes about 10-25 kg N/ha/season) which is commonly found to be involved in close association with crops. 50% of N fertilizer application can be reduced through *Azotobacter* inoculation along with FYM. *A. chroococcum* is the dominant species in arable soils which rarely exceeds a population of  $10^4$  to  $10^5$ /g of soil. *A. chroococcum*, *A. vinelandii*, *A. beijerincki* and *A. paspali* are known to form cysts to withstand adverse conditions. With the onset of favourable conditions, the cysts give rise to vegetative cells. These bacteria are also known to produce plant growth substances (IAA, gibberallins, Vitamin B, nicotinic acid, pantothenic acids, biotin and heteroauxin) which have beneficial effect on crop growth. It also acts as a crop protectant, since it releases antimetabolites which protect from root pathogens (*Fusarium*, *Alternaria* and *Trichoderma*). Vegetable crops in general (tomato, brinjal and cabbage) responded better to *Azotobacter* inoculation than other crops. It can also be used in fruit, plantation, spice and flower crops.

#### 4.1.4. *Azospirillum*

Azospirilla are a group of bacteria found in association with the root system of many crop plants. *Azospirillum* is known to fix nitrogen from 15 to 40 kg/ha. *Azospirillum* inoculation helps the plants in better vegetative growth and also in saving inputs of nitrogenous fertilizers by 25-30%. Four species of *Azospirillum* have been identified (*A. lipoferum*, *A. brasiliense*, *A. amazonense* and *A. irakense*). *A. lipoferum* and *A. brasiliense* are common in Indian soils. A reduction in the requirement of N by 25% to the crops receiving *Azospirillum* treatment is reported besides favourable effect on yield. The yield increase due to *Azospirillum* is mostly attributed to its capacity to produce hormones which establish early seedling vigour. *A. bangaloreense* can fix 40 kg N/ha in the cortical cells of tomato cv. Pusa



Ruby. *Azospirillum* biofertilizer can be used in fruit, vegetable and flower crops in which 11% yield increase can be obtained.

#### 4.1.5. *Beijerinckia*

Its production is high in acidic soils. *B. indica* is a common species. *B. flumineuris*, *B. mobilis* and *B. derxii* are other species found in the tropical soils. It is generally present in the rhizosphere of plantation crops such as coconut, arecanut, cashew, cocoa and pepper.

### 4.2. Phosphate Solubilizing and Mobilizing Micro-Organisms

It is known that Indian soils are very poor in phosphorus (P) content. Only about 25-30% of the applied P becomes available to the crop and the remaining part gets converted into insoluble/unavailable forms. It has been estimated that about 130 million tonnes of low grade P deposited (non-available) in our soil, but plant can not utilize this P directly. There are specific microorganisms which can solubilize this P from non-available form to available form.

Several soil bacteria (*Pseudomonas*, *Bacillus*) and fungi (*Pencillium*, *Aspergillus*) possess the ability to bring insoluble phosphates in soil into soluble forms. Addition of these organisms (*Bacillus megaterium*, *B. arcuans*, *B. subtilis*, *Pseudomonas striata*, *Aspergillus awamori*, *Pencillium digitatum*) to the soil increases the availability of phosphorus thereby saving the input of P. Bacteria and fungi solubilize bound phosphates in the soil by secreting organic acids such as formic, acetic, propionic, lactic, glycolic, fumaric and succinic acids which contribute about 10–25 kg  $P_2O_5$ /ha/season. These acids lower pH and bring about dissolution of bound form of phosphate. Some acids chelate with Ca and Fe resulting in effective solubilization and utilization of phosphate by crop plants.

The organic forms of P are phytin, phospholipids and nucleic acids which are added to the soil by way of decaying vegetation. Soil containing high organic matter are rich in organic forms of P. Large amount of P applied to various soils get fixed which is unavailable to the plants.

Microbial agents that regulate the availability of P in the rhizosphere have greater importance in organic farming. They help to convert the fixed forms of P –  $Al(OH)_2H_2PO_4$ ,  $Fe(OH)_2H_2PO_4$ ,  $Ca_{10}(PO_4)_6F_2$  into ionic available forms –  $HPO_4^{2-}$ ,  $H_2PO_4^-$  that can be then taken up by plants. Indigenous and cheap source of P like rock phosphate can be more effectively used with these bio-inoculants. The most important mineral phosphate solubilizers are *Pseudomonas*

*striata*, *P. flourescens*, *Bacillus polymyxa* among bacteria, and *Aspergillus awamori*, *A. flavus*, *A. niger* and *Pencillium* spp. among fungi. In compost pits, the decaying plant materials release organic acids and other acids that can release the bound P in rock phosphate in the soil solution. Seed or soil inoculation with phosphate solubilizing organisms are known to increase the uptake of P by plants, increased growth and yield of beet root, cabbage and tomato to the extent of 10-20%. Field trials conducted have revealed that application of rock phosphate at 50 kg P<sub>2</sub>O<sub>5</sub>/ha to soil and inoculation with phosphate solubilizing organisms can give yield equivalent to those obtained with application of 50 kg as super phosphate.

Arbuscular Mycorrhizal Fungi (AMF) are also responsible for converting fixed P into available P. Through inoculation of efficient strains of AMF, 25 to 50% of P fertilizer can be saved.

#### 4.3. Potash Mobilizing Micro-organisms.

It is known that Indian soils are moderate in potash (K) content. It is generally known that, directly and indirectly, K is a factor in the assimilation of CO<sub>2</sub> by plants. The plants well supplied with K contain more carbohydrates than plants deficient in this element.

Chandra *et al.* (1998) have isolated K mobilizing bacterium for the first time which is capable of mobilizing elementary or fixed K into a usable form to the plants. The mobilizing power is so high that it can save up to 50-60% of the cost of K fertilizer. The bacterium, *Frateuria aurantia* (Family: Pseudomonadaceae) was isolated from banana plant from Orissa soil. The bacterium has a solubilizing power of 90% within 22 days when the mineral source of K is in fixed form. The bacterium was tested on banana and paddy which increased the yield by 20 and 25%, respectively. It can be used as soil application for all types of crops at 2.5 kg/ha. It has to be mixed with 200-500 kg FYM in furrows before sowing. The bacterium can save up to 50-60% of the cost of chemical K fertilizer. *F. aurantia* has been reported to increase maximum level of K availability to the magnitude of 5-60 kg/ha.

#### 4.4. Sulphur Mobilizing Micro-organisms

Chandra *et al.* (1998) isolated the bacterium, *Acetobacter pasteurianus* which secretes the sulphur and makes it available to the plants in usable form. Sulphur present as insoluble sulphate form, are formed 30-35 cm deep in soil and are associated with oxides of Iron and Aluminium. *A. pasteurianus* helps in converting this non-usable form to usable form. The use of 625 g/ha of *A. pasteurianus* influenced

the levels of sulphur in crops like vegetables, cabbage, turnip, onion, etc.

#### 4.5. Arbuscular Mycorrhizal Fungi (AMF)

Arbuscular mycorrhizal fungi develop both intra and extra metrical hyphae that extends far areas away from the roots and increases the absorptive surface area of the P by mycorrhizal root system. AMF improve plant growth through better uptake of nutrients like P, Zn, Cu, etc. and make the root zone inimicable to root pathogens. They improve the activity of beneficial soil micro-organisms like N-fixers and P-solubilizers. AMF also help the plant to withstand water stress and transplant shock. They are obligate symbionts and can be used for transplanted crops like chilli, tomato, brinjal, potato, grapevine, apple, banana, tea, coffee, cocoa, rubber etc. AMF can be inoculated to nursery beds at 2 kg/sq. m. and pre-colonized seedlings can be transplanted to harness the benefits of mycorrhization. AMF saves 25 – 50 kg P/ha in addition to enhancement of yield to an extent of 10-12%.

The most common mycorrhizal fungi belong to the genera *Glomus*, *Gigaspora*, *Acaulospora* and *Scelero cystis* (Family-Endogonaceae, Order-Mucorales, Class-Phycomycetes). They produce vesicles and arbuscules inside the root system. Arbuscules are highly branched fungal hyphae while vesicles are the bulbous swellings of these hyphae. These AMF make more nutrients available to the host plant, improve soil texture, water holding capacity, disease resistance and help in better plant growth. Besides, AMF are also helpful in the biological control of root pathogens.

Seedling (tomato and chilli) inoculation with endomycorrhiza help better colonization, plant growth, nutrient uptake and increased crop yields, besides saving of P by 50%.

#### Production of AMF Inoculum

**In Glasshouse:** Cement pots or tanks are filled with sterilized sand:soil (1:1 by volume) or soilrite:peat (1:1 by volume) mixture. A standard starter culture of AMF obtained from any authentic source is placed as a band 3 cm below the soil surface. The seeds of Rhodes grass/ragi/maize is sown on them and covered with soil. Pots are irrigated normally. When the plants are about 10-12 weeks old, the top shoots are cut off and the root system colonized by the fungus along with the soil containing chlamydospores is used as the inoculum.

**On-farm Production:** A suitable land (even waste land) is selected near the field where the fungus inoculum has to be used. The land is brought to the fine tilth by ploughing, harrowing and cultivator operations. A raised bed (20 cm height) of soil:sand (1:1 by volume) mixture is prepared on a even land surface. The raised bed is sterilized by soil solarization for 2 to 3 weeks using polythene sheet. The starter culture of AMF is applied at a depth of 3-4 cm from the top by removing the top soil. The seeds of Rhodes grass/ragi/maize is sown on them and covered with soil. Irrigation is done normally. When the crop attains a height of 10-15 cm, 12 weeks after sowing, the shoot portion is cut off at ground level. The soil is dug up to a depth of 20 cm along with root system is used as the inoculum.

### **Method of Inoculation**

**Fruit Crops:** Fruit crops are inoculated in the nursery. AMF inoculum is added to FYM + soil + sand mixture (1:1:1 by volume) at the rate of 50 g inoculum/ 500 g soil mixture in polythene bags. Seeds of papaya or rootstocks of mango, citrus, guava or sapota are planted in each bag. 45 days after sowing, the root system of seedlings would be colonized by the fungus and ready for transplantation in the field (in pits). Before planting, each pit should be inoculated with 250-500 g of the fungus along with FYM and neem cake. Two months after planting, the roots may be tested for colonization by the fungus. The plants get colonized up to 80-90% within 3-8 months. Inoculation of AMF helps in greater uptake of nutrients like P, Zn and Cu. It also increases stem girth, plant height and hastens flower initiation.

**Vegetable Crops:** Vegetable crops can be inoculated with AMF in the nursery beds. The AMF inoculum consisting of chlamydospores, soil and infected root bits is either spread uniformly in the nursery beds or placed in rows over which seeds of vegetable crops (tomato, chilli, capsicum, brinjal) are sown. The seedlings get colonized by the fungus in about 4-5 weeks after which they are transplanted in the main field. Inoculated plants show better growth and improved nutrient content.

## **4.6. Growth Promoting Substance Excreting Micro-organisms**

The specific strain of plant growth promoting rhizobacteria (PGPR) could colonize roots of crops like potato, beet root, apple and legumes. They enhance plant growth indirectly by depriving the harmful micro-organisms of iron ( $\text{Fe}^{+++}$ ) in their energy metabolism via production of extra cellular iron chelators, thereby allowing the

plant to achieve more of its growth potential. PGPR belong to many genera including *Agrobacterium*, *Arthrobacter*, *Azotobacter*, *Bacillus*, *Pseudomonas*, *Cellulomonas*, *Enterobacter*, *Erwinia*, *Florabacterium* and *Rhizobium*.

**Table 4.3. Field application of bio-fertilizers in different crops.**

Crop	Recommended bio-fertilizer	Method of application	Dose (kg/ha)
French bean, pea	<i>Rhizobium</i>	Seed treatment	2.5
Cowpea, pigeonpea	<i>Rhizobium</i>	Seed treatment	2.5
Beet root	<i>Azotobacter</i>	Seed treatment	4.5-7.5
Potato	<i>Azospirillum</i>	Soil/tuber treatment	10
Radish, spinach	<i>Azospirillum</i>	Seed treatment	10
Turnip, carrot, parwal	<i>Azospirillum</i>	Seed treatment	10
Tomato, brinjal, chilli, onion, cabbage, cauliflower	<i>Azospirillum</i>	Seedling treatment	10
Ornamental plants	<i>Azotobacter</i>	Seedling treatment	3.75-5
Ginger, turmeric, garlic, banana, gladiolus, rose	<i>Azotobacter</i>	Buds/tuber/set treatment	7.5-10
Coffee, tea	<i>Azotobacter</i>	Soil treatment	7.5-10
Coconut, rubber	<i>Azotobacter</i>	Soil treatment	20-30 g/plant

**Table 4.4. Effect of bio-fertilizers on yield of some crops.**

Crop	Yield (q/ha)		% increase over control
	Without biofertilizers	With biofertilizers	
Potato	32.5	44.5	52.30
Potato	190.7	335.0	75.00
Cabbage	180.9	182.8	1.05
Cabbage	153.5	224.4	46.18
Cabbage	144.8	195.0	20.80
Brinjal	82.8	106.0	28.00

**Table 4.5. Concentration of auxins produced by micro-organisms**

Micro-organisms	Auxin concentration (ppm)
<i>Trichoderma harzianum</i>	51
<i>Azospirillum brasiliense</i>	32
<i>Azospirillum lipoferum</i>	21
<i>Azotobacter</i> sp.	19

## Chapter 5

# WEED MANAGEMENT

Increased use of herbicides have, however, resulted in multiple problems. The environment safety has been doubted with increased pollution hazards. That apart, weed species are developing resistance to chemical toxicants. A black grass strain has been identified to be resistant to chlorotoluran and diclofop methyl. Similarly, groundsel has shown resistance to simazine. In India, continuous use of isoproturan in wheat has resulted in the development of resistance in *Phalaris minor*. Added to this there is also problem of resurgence of weeds. Weeds can be managed by the following methods:

### 5.1. Preventive Methods

Preventive methods of weed control include weed-free crop seed, weed-free manure, clean (weed-free) harvesting equipment and ploughing implements, and elimination of weed infestations in and around irrigation channels and cultivated fields.

#### 5.1.1. Weed-free Crop Seed

In vegetable seed production, weed seeds get mixed with crop seeds and get dispersed far and wide. Care is needed to separate weed seeds from crop seeds for better management of weeds. *Mirabilis jalapa*, a common weed of waste lands, has seeds similar to papaya and often get mixed unintentionally resulting in poor quality papaya seeds.

#### 5.1.2. Weed-free Manure

To get weed-free manure is a difficult task and much of the weed problems arise due to this factor. *Parthenium hysterophorous* grows

very well in and around manure pits where organic matter is in abundance. It produces innumerable number of seeds which get mixed with manure usually made up of cow dung, horse dung and poultry waste. When manure is brought from such places, the seeds are easily scattered and establish themselves in the new site along with the crop plants.

### **5.1.3. Clean (Weed-Free) Harvesting and Ploughing Equipment**

Harvesting and ploughing equipment are major means of dispersing underground nuts, stolons and bulbs of perennial weeds far and wide to other areas. Thus, these equipment need to be cleaned at regular intervals.

### **5.1.4. Weed Infestations in and Around Irrigation Channels**

Weed seeds are also carried far and wide through irrigation channels infested heavily with weeds. Seeds of *Portulaca oleracea* are carried through water channels from long distances into vegetable fields of okra, tomato, brinjal, onion, garlic, cluster beans, knol khol and radish in such large numbers that it becomes very difficult to control them. Same is true with seeds of *Mollugo pentaphylla* and *Urena lobata*.

To bring about preventive measures of weed control, it is necessary to enact seed laws in India.

## **5.2. Cultural Methods**

The cultural methods of weed control include the use of smother crops and crop rotation/intercropping/trap cropping.

### **5.2.1. Smother Crops**

Smother crops are highly competitive with the weed species infesting an area for light, nutrients and moisture. Examples of smother crops are barley, millet, rye, sorghum, alfalfa, clover, cowpea, sweet clover, sesbania and sunflower. Care must be taken to see that the smother crops do not become a problem by themselves.

### **5.2.2. Cover Crops**

Velvet bean puts up vigorous growth, accumulating greater biomass and covers the ground fairly well in a short period, smothering weeds and effectively conserving soil moisture.



*Calapogonium mucunoides* is a leguminous cover crop most effective to check soil erosion and the growth of obnoxious weeds in plantations of pepper, orange and coconut. *Centrosema pubescens*, *Macroptilium atropurpureum* (Siratoo), *Stylosanthus hamata*, *Pueraria phaseoloides* (Kudzu) and *Dolichos lab lab* var. *lignosus* are the other cover crops which smother the weed growth.

### **5.2.3. Crop Rotation/ Intercropping/ Trap Cropping**

Smother crops may be grown in rotation with less competitive crops. Intercropping is intended to protect the inter space from losses through weeds. Crop rotation is particularly effective against parasitic weeds and other crop associated weeds. The trap crops which induce germination of parasitic weeds without being parasitized also reduce weed intensity.

Certain weeds are closely associated with particular crops or cropping sequence. Important parasitic weeds are broom rape (*Orobanche* spp. parasitizes mainly solanaceous crops) and dodder (*Cuscuta* spp. parasitizes mainly leguminous crops). Parasitic weeds are host specific. Stimulus is required for triggering germination of weeds. Incidence of *Orobanche* spp. on solanaceous crops can be minimized by rotating with sorghum. Incidence of *Cuscuta* spp. on leguminous crops can be minimized by rotating with cereal crops.

### **5.2.4. Optimum Plant Density and Line Sowing**

Maintenance of plant population in any crop and its early establishment helps crops to compete better with weeds due to smothering effect. The required plant density per unit area has been worked out in most of the horticultural crops and that has to be adopted by growers for effective management of weeds. Line sowing facilitates intercultivation between plant rows.

### **5.2.5. Drip Irrigation**

Applying water only to rooting zone as in case of drip irrigation would curtail the growth of weeds in inter row spaces.

## **5.3. Mechanical Methods**

This method includes such practices as hand weeding, hoeing, mowing, flooding, smothering with non-living material, burning and machine tillage.

### 5.3.1. Tillage

Tillage operation is a common and important method of weed control in all parts of the world. The primary objective of tillage is to control weeds. Summer tillage has been age old practice to open the soil to desiccating temperatures to manage perennial weeds, soil-borne pests and diseases.

*Conservation Tillage* : The presence of crop residues suppressed weeds, increased organic C and total soil N in the top 5-15 cm of soil.

*Zero Tillage*: Zero tillage sowing reduces the incidence of weeds such as *Phalaris minor*, *Chenopodium album* and *Medicago hispida* to the tune of about 40 – 50% because of less soil disturbance. The organic matter content of zero tillage soils may stay higher because of slower decomposition. In zero tillage, anchored crop residues are left standing, which promote the population of beneficial insects (natural enemies) since it provides a good habitat for their survival and thereby less insect problems.

*Rotary Tillage*: Rotary tillage by rotavator is capable of cutting and incorporating the weeds as well as residues left by the previous crop. The incorporation of weeds and crop residues will increase the organic matter status of the soil and accompanying changes in the physical and chemical health of the soil resulting in the sustainability of the system.

*Ridge Tillage*: It is a form of conservation tillage that appears to overcome weed control problems.

*Night Tillage*: Germination of weed species whose seed requires light should be impeded if a no tillage system were implemented for crop production. Alternatively, it is possible that night cultivation also could result in significant reduction in weed density. The exclusion of light during seed bed preparation has been shown to reduce weed emergence. Covering an implement to prevent light reaching the soil at the point of cultivation may be sufficient to reduce weed emergence by up to 70%.

*Deep Tillage*: Deep tillage helps in controlling weeds by exposing underground parts of perennial weeds leading to dessication and destruction during hot summer, burying weed seeds and emerged weed seedlings deep into the soil, leaving the land rough to hinder weed seed germination. Deep ploughing has to be carried out before the onset of summer when the upper soil surface is dry and lower soil layer is moist so that big clods are raised. During hot summer months exposed stolons, rhizomes of perennial weeds (*Cynodon dactylon*) die

due to dessication and lose their viability. Frequent tillage operations provide opportunity for weed seeds to germinate to be destroyed by cultivation.

*Mechanical Tillage:* Machine tillage is similar to hoeing. The advantage of machine tillage is that various types of tools can be attached to machines and large areas can be weeded rapidly and economically. Cross cultivation can be done to remove much of the weeds. Machine tillage also helps in loosening of the soil which creates a suitable atmosphere for bacterial activity resulting in rapid decomposition of organic matter. Weed control by machine tillage is achieved by burial of small annual weeds with soil thrown over them, destroys close relationship between weed plant and the soil resulting in disruption of absorption of water by weed roots and death by dessication.

### **5.3.2. Stale Seed Bed**

Frequent pre-monsoon showers facilitate germination of weeds to be destroyed by cultivation. This is made use in stale seed bed where crop sowing is deliberately delayed under intense weed situation to reduce the impact of weeds.

### **5.3.3. Hand Weeding**

This practice is very effective for the control of young weed seedlings and established annual and biennial weed species in small garden area (nurseries and ornamentals) and in between or near crop plants grown in narrow rows where it is difficult to reach them with a hoe or cultivator (vegetable crops).

### **5.3.4. Hoeing**

Hoe still remains one of the principal tools for weed control. Hoeing is effective against annual and biennial weed seedlings in crops like vegetables, ornamentals and small fruits. Weed intensity is low in line sown and transplanted crop than in broadcast sown crop. The main objectives of intercultivation are weed control, aeration, soil moisture conservation and earthing up. Wider rows permit effective intercultivation for long period with reduced hand weeding cost.

### **5.3.5. Mowing**

It is primarily used to reduce weed seed production and to restrict unsightly weed growth especially in wide spaced fruit and plantation crops.

### **5.3.6. Flooding**

Flooding is done to control perennial weeds. Flooding deprives the plants of air resulting in their death due to suffocation. Thus, root absorption of oxygen to the plant is prevented which is so vital for the respiration process in roots. Similarly, when shoots are immersed, it prevents absorption of carbon dioxide by leaves from atmosphere which is essential for photosynthesis.

### **5.3.7. Mulching**

The principle behind this is to exclude light completely to the growing weed plants to prevent photosynthesis and further growth. Mulching also helps in moisture conservation and organic matter. Hay, manure, grass clippings, straw, saw dust, wood chips, rice hulls, paper, plastic film and even spent herbage from aromatic industry are generally used for this purpose. Black paper and black plastic films are used successfully in various horticultural crops. In Hawaii Islands, use of black plastic film has been found to be economical and effective for unirrigated pineapple crop.

### **5.3.8. Burning**

Selective burning or flaming in crop plants is done under special situations where crops attain certain heights where flames can not strike leaves or other tender parts, when their stems are woody and resistant to intense heat of flame and the weeds are small (5 cm), succulent and susceptible to the heat. The theory behind burning is to cause cell sap to expand resulting in rupture of cell walls to cause coagulation of cell protoplasm and inactivation of enzymes.

## **5.4. Soil Solarization**

Harvesting of solar energy through soil solarization will be the key proposition for controlling soil-borne pests including weeds. This is an eco-friendly technology used to kill weed seeds in soil. It involves mulching of the soil with clear plastic films so as to trap the solar heat in the surface soil. Sheets should be spread in such a way that there is no gap between sheet and soil surface. The resultant temperature increase would be lethal to soil pathogens, nematodes and weeds. The term 'soil solarization' denotes solar heating of the moistened soil by mulching (tarping or covering) with appropriate mulch (transparent polythene). This approach of killing weed seeds and propagules seems to have greater potential in tropical and sub-tropical regions where air

temperatures goes up to 45°C during summer months. It is efficient in areas where bright sun light is available for about 4-6 weeks.

The transparent polyethylene is permeable to short wave solar radiation received from the sun which results in trapping of the heat in the soil. Polyethylene also reduces heat convection and evaporation of water from the soil. As a result of the formation of water droplets on the inner side of the mulch will trap long-wave radiation and thus eliminate radiating cooling of the soil surface.

Solarization heats the soil through repeated daily cycles. At lower soil depths, the temperature is reached to maximum later in the day and maintained for longer period of time.

A novel method of weed control has been developed using solar radiation. This technique uses intense radiation of sun to heat the soil to raise the temperature that is lethal to weed seeds. This method has future in tropical and sub-tropical countries.

## 5.5. Biological Methods

This method involves utilization of natural enemies for the control of certain weeds. The aim is to reduce weed population below the level of economic injury. This can be achieved by direct or indirect action of biological control agents. In direct action, firstly the biocontrol agent bores into plant, weakens its structure leading to its collapse and secondly, consumes and destroys the vital plant parts. In indirect action, the biocontrol agent reserves the competitive ability of weed over other plants and enhances the condition favourable for plant pathogens.

### 5.5.1. Insects

For biocontrol of weeds, the insect selected should specifically attack the target weed without harming the other plants, especially useful to man. Control of obnoxious weeds like prickly pear cactus (*Opuntia inermis*) and spiny prickly pear (*Opuntia stricta*) by *Cactoblastis cactorum*; *Hypericum perforatum* by leaf feeding beetle, *Chrysolina quadrigemina*; *Parthenium hysterophorus* by *Zygogramma bicolorata*; water hyacinth (*Eichhornia crassipes*) by weevils (*Neochetina eichhorniae*, *N. bruchi*) and *Salvinia molesta* by leaf eating grass hopper (*Paulina acuminata*) are examples of biological weed control.

Elaborate studies have been carried out at the Indian Institute of Horticultural research, Bangalore, on suppression of water hyacinth

by *Neochetina eichhorniae* and *N. bruchi*. An increase in the larval population leads to drying up of the leaf laminae starting from the tips. This was followed by complete browning of the leaves and collapse of affected plants. The studies were conducted in 4 water tanks around Bangalore and achieved 75 to 95% success in suppressing water hyacinth (Table 5.1).

**Table 5.1. Biological control of water hyacinth in water tanks around Bangalore.**

Water tank	Area infested with water hyacinth (ha)	Suppression of weed (%)
Bellandur tank	172	50% in 24 months 90% in 36 months
Hebbal tank	20	95% in 32 months
Agram tank	20	90% in 38 months
Byramangala reservoir	250	75%

Biological control of water-fern (*Salvinia molesta*) has been achieved within 12-16 months by release of 50-100 exotic weevils imported from Brazil (*Cyrtobagus salviniae*) per spot (20 to 40 litres of weevil – infested *Salvinia*). The weevil has established in Kerala and Karnataka.

### 5.5.2. Plant Pathogens

Use of plant pathogens, especially fungi, to control weeds (mycoherbicides) is gaining importance in recent years (Table 5.2). The potential for weed control using foliar pathogens by pre-emergent application of granular formulation of *Alternaria macrospora* spores so that biocontrol agents are present when seedlings of *Anoda cristata* emerge. This technique holds promise because reduced quantities of spores are needed when seedlings are small and emerging. Also, granular formulations can be applied on a band over the crop drill which further reduces the quantity of spores needed per unit land area.

Devine is a liquid formulation consisting of chlamydospores of a pathotype *Phytophthora palmivora* and is used as a post-emergent mycoherbicide against Milk weed vine (*Morrenia odorata*). Nearly 100% control of the weed is usually obtained and control lasts for 2 years. Collego is a wettable powder formulation of *Colletotrichum gloeosporioides* f. sp. *aeschynomene* and is used for controlling

Northern jointvetch (*Aeschynomene virginica*). It is applied aerially or with land based equipments when the weeds have just emerged. Control reported was as high as 90%.

**Table 5.2. Mycoherbicides registered world-wide to control various notorious weeds**

Mycoherbicide	Formulation of fungus	Weed controlled
De Vine	<i>Phytophthora palmivora</i>	Milk weed vine ( <i>Morrenia odorata</i> )
Collego	<i>Colletotrichum gloeosporioides</i> f. sp. <i>aeschynonene</i>	Northern joint vetch ( <i>Aeschynomene virginica</i> )
Caset	<i>Alternaria cassiae</i>	Sickle pod ( <i>Cassia obtusifolia</i> )
Biomal	<i>C. gloeosporioides</i> f. sp. <i>malvae</i>	Round leaf mallow ( <i>Malva</i> f.sp. <i>malvae pusilla</i> )
Biochon	<i>Chondrostereum purpureum</i>	Black cherry
Velgo	<i>Colletotrichum coccodes</i>	Velvet leaf
Luboa 2	<i>C. gloeosporioides</i> f.sp. <i>cuscutae</i>	Dodder ( <i>Cuscuta</i> sp.)
ABG-5003	<i>Cercospora rodmanii</i>	Water hyacinth ( <i>Eichhornia crassipes</i> )

**Table 5.3. Fungi possessing mycoherbicidal properties**

Pathogen	Weed controlled
<i>Colletotrichum furarioides</i>	<i>Asclepias sericea</i> (Common milk weed)
<i>C. oriculare</i>	<i>Xanthium spinosum</i> (Spiny cocklebur)
<i>Alternaria</i> sp.	<i>Crisum avenae</i> (Canana thistle)
<i>A. crassa</i>	<i>Datura stramonium</i>
<i>A. helianthi</i>	<i>Xanthium strumarium</i>
<i>Phomopsis convolvulus</i>	<i>Convolvulus arvensis</i> (Field bind weed)
<i>Bipolaris halapense</i>	<i>Sorghum halepense</i> (Johnson grass)
<i>Puccinia abrupta</i> var. <i>parthenicola</i>	<i>Parthenium hysterophorus</i>
<i>P. chondrillus</i>	<i>Condrilla juncea</i> (Skeleton weed)
<i>P. spegazzinii</i>	<i>Mikania micrantha</i>

**Table 5.4. Use of fungi and insects for control of parasitic weeds**

Parasitic weed	Fungi	Insects
<i>Orobanche</i> sp.	<i>Fusarium oxysporum</i> f. sp. <i>orthoceras</i>	Fly- <i>Sipha maidis</i> , <i>Scotia segetum</i> , <i>Phytomyza orobanchia</i> , <i>Aphis tabae</i> , <i>Agriote</i> sp., <i>Lygus pratensis</i> , <i>Agrojrotalmia pulchella</i>
<i>O. crenata</i>	—	<i>Tropinate squarildo</i> , <i>Smicronix cyaneus</i>
<i>Cuscuta</i>	<i>Colletotrichum gleosporoides</i> (Lubao II – Mycoherbicide)	Midge – <i>Melar agromyza</i>

*Trichoderma* sp. has been reported to suppress *Phalaris minor*, an important weed in farmer's fields, if applied through compost.

**Nematodes:** *Ditylenchus phyllobia* is a specific leaf gall nematode which naturally suppress the weed, *Solanum eleagnifolium* along the railway tracks and sides of the roads.

## 5.6. Allelopathy

Inter-weed competition determined by allelopathy can be manipulated to our advantage in the natural control of weeds. Natural compounds released by some plants inhibit or prevent the growth of nearby plants. Known as allelopathic substances, they may be released from roots, leaves or other plant parts. Black walnut trees inhibit the growth of certain plants near them and thistles exude a substance that interferes with the growth of oats. Most of the inhibitors belong to phenolic group of compounds except *Oxalis corniculata* which belong to organic acids. *Parthenium hysterophorus* contains parthenin along with phenolic compounds.

Marigold flowering plant is found to suppress the growth of *Parthenium hysterophorus* when planted in the ratio of 1:2 and 1:4 (*Parthenium* : Maigold). In these plots, second generation of *Parthenium* could not get re-established and very few plants left could not develop further. The recycling of marigold plants inhibits the establishment of *Parthenium*.

A few crops have been found to inhibit weeds in different cropping systems and the major sources of allelochemicals are root exudates and leachates of growing crops. Wheat, oats, peas and buckwheat suppress the growth, accumulation of above ground biomass and leaf



surface of *Chenopodium album*. Oats suppressed the growth of *Erysium cheiranthoides*. When rye was used as a cover crop in no tillage cropping system, it suppressed certain weeds like *Chenopodium album* and *Amaranthus retroflexus*. Rye also inhibited other weeds like *Digitaria sanguinalis*, *Arena fatua*, *Echinochloa crusgalli* and *Ambrosia artimisiifolia*. Crop residues from alfalfa and sunflower are toxic to weeds. The growing plants such as wheat, corn and soybean and their crop residues are also toxic to weeds.

### 5.7. Integrated Methods

Integrated weed management system (IWMS) involves co-ordinated efforts towards development of a long lasting and environment friendly practice of weed management. IWMS includes all preventive, crop husbandry and direct control measures aimed at reducing and maintaining weed population at sub-economic level. In this, all weed control methods like preventive, cultural, mechanical and biological are included in different permutation and combinations to achieve maximum weed control which is not possible in any one single method. IWMS is well suited for adoption in different cropping systems of fruit crops.

For nearly complete and eradivative water hyacinth control, *Cercospora rodmanii* was used in integration with other biotic agents such as weevils (*Neochetina eichhorniae* and *N. bruchi*).

In raspberry, reduced cultivation system like rotary cultivation + hoeing outyielded non-cultivation system which depended on herbicide alone.

## Chapter 6

### PEST MANAGEMENT

The use of synthetic chemicals to manage pests has a number of disadvantages which cause environmental pollution, phytotoxicity, ground water contamination and adversely affect the soil and its biotic environment. Indiscriminate use of synthetic pesticides resulted in insecticide resistance (Table 6.1), resurgence (Table 6.2) and accumulation of hazardous pesticide residues in fruits, vegetables and food chain. In the 1960s and 70s, there were only a few insects showing insecticide resistance, but presently there are at least 283 agricultural pests showing resistance against at least one group of insecticides.

**Table 6.1. Pests showing high degree of resistance to pesticides**

Sl. No.	Common name of pest	Scientific name of pest
1	Diamondback moth	<i>Plutella xylostella</i>
2	Tomato fruit borer	<i>Helicoverpa armigera</i>
3	Tobacco caterpillar	<i>Spodoptera litura</i>
4	Serpentine leaf miner	<i>Liriomyza trifolii</i>
5	Brinjal fruit and shoot borer	<i>Leucinodes orbonalis</i>
6	Red spider mite	<i>Tetranychus urticae</i>
7	Whitefly	<i>Bemisia tabaci</i>
8	Fruitfly	<i>Bactrocera dorsalis</i>
9	Thrips	<i>Scirtothrips dorsalis</i>
10	Root grub	<i>Holotrichia</i> spp.

*Helicoverpa armigera* had developed over 150–225 fold resistance to synthetic pyrethroids leading to failure of cotton crop during 1987–88 in Andhra Pradesh. To a lesser extent, *Spodoptera litura*, *Lipaphis erysimi* and *Myzus persicae* have also developed resistance to pyrethroids. Three common stored grain pests viz., *Tribolium castaneum*, *Rhizopertha dominica* and *Sitophilus oryzae* have developed resistance to several insecticides.

**Table 6.2. Resurgence of pests due to pesticides**

Pest	Pesticides
<i>Helicoverpa armigera</i>	DDT, Carbaryl, Organo-phosphates
<i>Spodoptera littoralis</i>	Methomyl
<i>Bemisia tabaci</i>	DDT, Organo-phosphates, Fenvalerate, Permethrin
<i>Tetranychus urticae</i>	DDT, Organo-phosphates, Pyrethroids
<i>Icerya purchasi</i>	DDT, Malathion
<i>Aonidiella aurantii</i>	Temephos, Dioxathion
<i>Myzus persicae</i> on brinjal	Cypermethrin, Deltamethrin, Fenvalerate
<i>Eutettix phycitis</i> & <i>Aphis malvae</i> on bitter gourd	Cypermethrin, Deltamethrin, Fenvalerate
<i>Amrasca biguttula biguttula</i> on brinjal	Cypermethrin, Fenvalerate
<i>Polyphagotarsonemus latus</i> on chilli	Monocrotophos, Methyl demeton, Thiometon, Phophamidon, Formothion, Cypermethrin, Fenvalerate, Decamethrin, Acephate
<i>Tetranychus urticae</i> on okra	Ethion
<i>T. cinnabarinus</i> on brinjal	Endosulfan, Fluvalenate, Decamethrin
Pink mite on tea	Synthetic pyrethroids

## Problems Associated with the Use of Chemical Pesticides

Use of pesticides is bereft with many problems such as:

- The development of pest resistance to pesticides.
- Environmental pollution.
- Disruption in biodiversity.
- DBCP was found to adversely affect the fertility of workers in a factory manufacturing and packaging DBCP.

- Aldicarb, carbofuran, DD, DBCP and EDB were found in ground water.
- DD affects a number of soil organisms including suppression of nitrifying bacteria with consequent accumulation of  $\text{NH}_3$  to phytotoxic levels.
- Avian toxicity with cabofuran.

Excessive chemicalization of horticultural eco-system with various agro chemicals has affected the soil bio-diversity adversely tilting the balance in soil flora and fauna. This deleterious alteration has increased soil sickness in the absence of natural suppression by antagonistic and useful organisms. This scenario resulted in increase in the pest population.

There has been a growing awareness to develop such management practices, which alone or in combination with other practices could bring about a reasonably good degree of reduction of the pest incidence and at the same time ensure sustainability of production, cost effectiveness and healthy ecosystem.

There is an urgent need to shift from the 'Chemical intensive' to 'Bio-intensive' cropping system with a view to restore the viability, sustainability and health of our agro-ecosystems. There is a need for development and adoption of IPM in agriculture because of the economic and environmental benefits it brings to us. Major emphasis must be given to non-chemical methods of control, such as regulatory, physical, cultural and biological methods. Pest resistant varieties of important crops must be evolved as these would be most useful tools of IPM for our resource poor farmers.

Many fumigants are broad spectrum pesticides used as nematicides, fungicides, insecticides or herbicides. These may be detrimental to non-target or potential biocontrol organisms. DBCP, EDB and DD have been detected in ground water and are banned for use. In 1977, dependance on nematicides received a serious set back. Many of the employees at a chemical plant at Lathrop, California, USA, who handled DBCP, a soil fumigant, were found to be either azoospermic or oligozoospermic. Low sperm counts were found among formulators, applicators, farmers and salesmen. The US EPA banned production and sale of DBCP. Several regulatory measures followed as most of the pesticides were found to be the cause of environmental concerns and human health risks.

Non-fumigant nematicides (organophosphates and carbamates) have high mammalian toxicities. There are several alleged cases of pest resistance and a number of significant environmental concerns.

All current non-fumigant pesticides have been detected in ground water.

Pesticides cause soil pollution and adversely affect useful microflora and fauna which interact with pathogens at the soil-root interface. They are harmful to endomycorrhizae, rhizobia, actinorhyza and other micro-organisms normally contributing to the nutritional economy of the plants and possibly bring about disturbance in the microbial equilibrium. Pesticides pollute water and deteriorate water quality. Most of them have been detected in ground water.

Pests can be managed by adopting the following methods:

## **6.1. Physical Methods**

### **6.1.1. Soil Solarization**

Soil solarization by mulching the soil with polythene cover for 3-4 weeks during summer months results in killing of soil-borne pathogens and weed seeds.

### **6.1.2. Mechanical Control**

Hand picking of egg masses, gregarious larvae and sluggish adults, and their destruction helps in reducing pest populations in certain situations. Grown up larvae of *Helicoverpa armigera* and red headed hairy caterpillar can be hand collected and destroyed. Fixing of tin bands over coconut trunks prevents damage by rats. In cabbage, scouting and mechanical destruction of gregarious early instar larvae of *Spodoptera litura* and leaf webber is very effective.

### **6.1.3. Light and Pheromone Traps**

Light and pheromone traps can be used to monitor and suppress certain pest species. Yellow sticky traps can be used to monitor aphids and whiteflies. In cabbage and cauliflower, light traps are useful in reducing diamondback moth incidence. A 100 watt bulb is hung in front of a thin gunny bag or polythene sheet (90 cm x 120 cm) smeared with oil or grease (6-8/ha). A bucket with water can also be kept below the light trap.

Traps baited with insect sex pheromones play a crucial role in monitoring and early detection of an infestation, before build up of pests to destructive population levels. When pheromones are used for monitoring pest populations, 13 traps are generally used/ha. By increasing the number of traps/ha, pheromones serve as a device for

mass trapping with the aim of catching most of the males present so that majority of females remain unmated and lay infertile eggs. Pheromones can be combined with insecticides to kill the attracted adults. Pheromones can also be used for mating disruption and ultimately reduce pest damage. Brinjal fruit and shoot borer can be effectively checked by erecting 75 pheromone traps/ha and practicing clean cultivation by destroying infested shoots and fruits. Lures like methyl eugenol and cue-lure can also be used to suppress fruitflies. Red palm weevil in coconut can be controlled by using sex pheromone traps.

#### 6.1.4. Use of Nylon Net

Growing of vegetable nurseries under nylon nets drastically reduces pest populations and virus/mycoplasma diseases by preventing the entry of vectors.

#### 6.1.5. Hot Water Treatment of Planting Material

**Table 6.3. Time and temperature recommendations for hot-water treatment for denamatizing planting stock**

Nematode	Planting stock	Time min.	Temp. °C
<i>Tylenchulus semipenetrans</i>	Citrus rooted cuttings	10	46.7
		25	45.0
<i>Radopholus similis</i>	Banana suckers	25	55.0
		30	43.0
<i>Meloidogyne</i> spp.	Grape rooted cuttings	10	50.0
		30	47.8
<i>Meloidogyne</i> spp.	Peach and Cherry rootstocks	5-10	50-51
<i>Meloidogyne</i> spp., <i>Pratylenchus penetrans</i> , <i>Ditylenchus dipsaci</i> , <i>Aphelenchoides fragariae</i>	Strawberry roots	15	48
<i>Meloidogyne</i> spp.	Potato tubers	120	46.0-47.5
	Sweet potatoes	65	46.7
	Yam tubers	30	51.0
	Ginger rhizomes	10	50
	Begonia tubers	30	48.0
	Tuberose bulbs	60	49.0
	Caladium tubers	30	50.0
	Gladiolus corms	30	57.8

## 6.2. Cultural Methods

The suppression of pest populations through adoption of common and simple farm practices are called cultural methods. The following cultural practices can be adopted in different cropping systems to suppress certain pest populations:

### 6.2.1. Field and Plant Sanitation

Regular removal of weeds, pest affected plant parts, crop stubbles and their destruction will eliminate the sources of infestation of the pest. Destruction of borer affected shoots and fruits of brinjal, tomato and okra prevents further build up of the pest population. Many virus/mycoplasma diseases like tomato leaf curl, little leaf of brinjal, YVMV of okra, bunchy top of banana, etc. can be minimized by uprooting the infected plants.

Diseases spread through irrigation water. Hence, bottom leaves touching the soil should be removed periodically to reduce the disease incidence and spread. Many virus diseases like leaf curl and spotted wilt of tomato have been minimized by this method.

### 6.2.2. Crop Rotation

Growing of a non-host crop after a host crop of the pest will break the breeding cycle of pest species and reduces their populations. Likewise, crop rotation prevents the build up of plant pathogens in soil.

### 6.2.3. Trap Cropping

Growing of susceptible or preferred hosts as trap crops along with the main crop will attract the pests in large numbers and these can be selectively killed. This will minimize the damage on main crop. Sunflower, marigold and maize trap crops are raised for the management of *H. armigera*. Similarly, sunflower and border castor trap crops are useful for minimizing loss by *S. litura*. Planting of cowpea as a bund crop attracts *Cheilomenes* spp.; maize as intercrop is known to encourage *Chrysoperla carnea*; growing cowpea as trap crop increases the parasitization of *H. armigera* larvae and predation of eggs by coccinellids; growing *Tagetes* spp. as border crop attracts heavy egg laying by *H. armigera* which in turn attracts parasitization by *Trichogramma* spp.

Marigold is grown as a trap crop for tomato fruit borer and mustard for cabbage and cauliflower pests.

Cowpea can be used as a trap crop, since cowpea varieties CO 2 and CO 4 harboured highest population of legume aphid, *Aphis craccivora* and whiteflies which are attracted by predatory ladybird beetles in large numbers. Similarly, cowpea cultivars CO 2, CO 4 and C 152 harboured aphids and leaf hopper, *Empoasca kerri* which are attracted by ladybird and spider predators which fed on aphids and nymphs of leaf hoppers.

*S. litura* larvae and nymphs of jassids and whiteflies were preyed upon by red ant, *Oceophylla smarygdina* on cowpea and castor (raised as bund/border/companion crops) and taken to sub colonies for feeding to the grubs. Effective control (removal of 97.6 to 100% larvae) of *S. litura* on crop plants was obtained within few hours, indicating the high predatory potential of the red ant.

**Table 6.4. Trap cropping for the management of horticultural crop pests**

Main crop	Trap crop	Pest/s controlled
Cabbage	Mustard	Diamondback moth
	Cauliflower	Diamondback moth
Tomato	Pumpkin	Whitefly
	Marigold	<i>Helicoverpa armigera</i>
	Maize	<i>Helicoverpa armigera</i>
Chilli	Marigold	<i>Helicoverpa armigera</i>

#### **6.2.4. Tillage Operations**

Ploughing or hoeing helps to expose stages of soil inhabiting pests to sun's heat or to the predatory birds.

#### **6.2.5. Water Management**

Flooding of fields wherever possible kills root grubs, termites and soil borne plant pathogens.

#### **6.2.6. Adjusting the Time of Sowing**

The simultaneous sowing of crops in a locality helps in reducing pest damage. Many a times early sown crops escape pest attack. Gherkin crop raised in January suffers less damage from fruitfly incidence. Vegetables grown during winter months do not have leaf miner and nematode damage.



Planting of potato during third or fourth week of March in Shimla Hills would reduce the damage due to *M. incognita*. The yields were maximum which was concomitant with the lowest tuber infestation and lowest larval population in the soil at harvest.

#### **6.2.7. Wider Spacing Between Plants**

Wider spacing between rows and plants and lesser crop density often prevent build up of populations of certain pests and also incidence of some diseases. In tomato, spacing of 1 m x 75 cm reduces the disease incidence (early blight and powdery mildew) and its spread. Likewise, a spacing of 60 cm x 60 cm in cabbage minimizes the disease incidence (*Alternaria* black spot, black rot and downy mildew).

#### **6.2.8. Growing of Barrier Crops**

Maize is traditionally used by farmers around many vegetable crops. It acts as a barrier for pest and vector species.

#### **6.2.9. Stalking/Training**

This practice reduces buckeye rot in tomato fruits and is also helpful in easy harvesting of fruits.

### **6.3. Biological Methods**

By keeping in view the adverse effects of chemical control, it becomes imperative to concentrate on alternate methods of pest control without the negative impact of pesticides on the ecosystem. Among various methods of pest control, biological control of crop pests is found to be the most important and practically feasible one by considering the present scenario of Indian agriculture. This eco-friendly measure of pest management is of certain importance in the era of organic farming.

Biological control basically means “The utilization of any living organism for the control of insect pests, diseases and weeds”. This means use of any biotic agents for minimizing the pest population either directly or indirectly. The natural enemies of crop pests do exist in nature and work against crop pests, which is called as Natural control. The efforts aimed at increasing the naturally occurring biotic agents against the pests, both quantitatively and qualitatively can be termed as Biological control.

Biological control refers to reduction of the amount of inoculum or disease producing activity of a pathogen accomplished by or through one or more organisms other than man. Maximum emphasis for developing biocontrol programmes was given to fungal and bacterial biocontrol agents primarily because of ease of their mass multiplication and formulation. In recent years, successful use of fungal biocontrol agents like *Trichoderma* spp. and *Gliocladium* spp. for the control of soil-borne diseases in several crops have been reported. Among the bacterial antagonists, the fluorescent pseudomonads are under intensive investigation because of their wide spread natural occurrence, biocontrol potential against fungal and nematode diseases as well as host defence inducing and plant growth promoting activities. The biocontrol agents provide protection against plant diseases either by direct action against the pathogen by mycoparasitism or antibiosis and indirectly by competing with pathogen for nutrients, oxygen or space. The soil-borne diseases such as pre- and post-emergence damping off, root rots, wilts, collar rots or other complex diseases have been successfully suppressed by biocontrol agents under glasshouse/field conditions. Pioneering work on this aspect was done at G.B. Pant university of Agriculture and Technology, Pantnagar and at Tamil Nadu Agricultural University, Coimbatore.

### **Advantages of Biopesticides**

- As effective as broad spectrum chemical pesticides and thus can replace them to a considerable extent.
- Extremely target specific, hence no effect on non-target organisms, including mankind.
- Biodegradable and consequently do not pose any environmental hazards.
- Due to their nature of action, the possibility of development of resistance is less.
- Some of them are known to enhance plant growth after application.

The most commonly used bioagents are broadly classified into 3 categories:

- Predators
- Parasitoids
- Pathogens

### 6.3.1. Predators

These insects are generally bigger than the host and feed on several of the pests by predating upon them externally. They will be consuming several of the insect pests during their life cycle and hold a key role in minimizing pest population under field conditions. The common predators observed include spiders, anthocorids, dragonflies, ladybird beetles, lacewing flies, ground beetles, ants and assassin bugs. In vegetable crops, the common predators observed are ladybird, *Cheilomenes sexmaculata*; hoverfly, *Syrphus indicus*; green lacewing fly, *Chrysoperla carnea*. The increased population of general arthropod predators is possible by inclusion of pollen and nectar yielding intercrops to increase the natural enemy diversity and abundance. Ecofeast crops such as maize and cowpea enhance predatory populations. Maize aphids, *Rhopalosiphum maidis* and *Logiunguis sacchari* and cowpea aphid, *Aphis craccivora* enhanced populations of lacewing fly, *Chrysoperla carnea* and ladybird beetle, *Cheilomenes sexmaculata* predators to control sucking pests and fruit borer eggs and early stage larvae. Fixing of live bird perches in the field helps the birds to feed upon moths of fruit borers.

The important predators put to use in biological control are:

- The green lacewing fly, *Chrysoperla* spp. against several soft bodied insects such as aphids, leaf hoppers etc.
- Lady bird beetle against aphids and mealy bugs.
- Spiders against a varied number and types of insects.
- Predatory coccinellid beetles against scales and mealy bugs in horticultural crops.

#### 6.3.1.1. Coccinellids

The Australian Lady Bird Beetle, *Cryptolaimus montrouzieri* was introduced from Australia for the control of green scale, *Coccus viridis* on citrus. It has been successfully used for the suppression of mealy bugs on citrus and coffee, *Planococcus citri*; grapes, *Maconellicoccus hirsutus*; guava mealybug, *Ferrisia virgata* and green shield scale, *Chloropulvinaria psidii*, several other fruit crops and ornamentals. A grub could prey on 881.3 eggs or 259 nymphs or 27.55 adults of grape mealy bug.

*Chilocorus nigrita* has been recorded on California red scale *Aonidiella aurantii* and coffee green scale, *Coccus viridis*. The release rate recommended for this predator is at 1500 adults/ha.

*Pharoscymnus horni* is a major predator of the tea scale, *Chrysomphalus aonidium*. The predator has been recommended for field release at 1500 adult beetles/ha.

*Cheilomenes sexmaculata* was seen predating on several species of aphids like *Lipaphis erysimi*, *Brevicorne brassicae*, *Aphis craccivora*, *Acyrtosiphon pisum* and *Myzus persicae*. *C. sexmaculata* can consume 24 adults and 176 nymphs of aphids/day.

*Scymnus coccivora* has proved effective against the grape mealybug, *M. hirsutus*; guava mealybug, *Ferrisia virgata* and mango mealybug, *Rastrococcus iceryoides*. This predator has been recommended for field release at 600-2500 /ha.

*Coccinella septempunctata*: It is used for suppression of black aphid, *Aphis craccivora* in citrus. Field releases of beetles in apple crop are most effective against woolly aphid, *Eriosoma lanigerum* during early phase of pest infestation.

#### 6.3.1.2. Chrysopids

*Chrysoperla carnea* and *Mallada boninensis* have been used for the management of lepidopteron pests, whiteflies and aphids on fruit crops. *C. carnea* could control aphids on chillies very effectively when releases were made at a predator:prey ratio of 1:5.

#### 6.3.1.3. Anthocorids

Anthocorids are useful for the protection of crops from lepidopteron pests, aphids, thrips, mites, etc. *Orius maxidentex* attacks whiteflies on chilli and thrips on croton, *Thrips palmi*.

*Cardiastethus exiguus*, *C. affinis*, *C. nazarensis* and *C. pygmaeus paulinae* are important predators on coconut leaf eating caterpillar, *Opisania arenosella*.

#### 6.3.1.4. Predatory Mites

*Amblyseius* spp. feed on coconut mite, *Raoiella indica*; cucurbit mite, *Tetranychus neocaledonius*; tea mite, *Acaphylla theae* and *Calacarus carinatus* and on citrus mite, *Eutetranychus orientalis*.

### 6.3.2. Parasitoids

These insects are generally either equal or lesser than the size of host insect and always require passing at least one stage of their life cycle inside the host system. They can kill only one host insect during their life cycle. However, due to their high multiplication rates they

are of vital importance in the biological control of insect pests. The parasitoids successfully being used are:

- *Trichogramma* egg parasite against eggs of tomato fruit borer, cabbage diamondback moth etc.
- *Bracon hebetor* against insect pests of coconut.
- *Brachymeria* against the pupae of several pests of plantation crops.
- *Goniozus nephantidis* and *Bracon brevicornis* against coconut black headed caterpillar.

Semiloopers such as *Cosmophitta indica*, *Anomis flava* and *Tarache nitidula* on border or intercrops such as cowpea and sunflower, enhanced general parasitoids like species of *Apanteles*, *Cotesia*, *Bracon* which shifted to fruit borers. *Bracon brevicornis* parasitized semilooper on cowpea cv. C 152 and shifted to the same pest on okra and fruit borer, *Earias vitella* on okra. Parasitoid cocoons are commonly seen on vegetable cowpea first and then on okra even after the harvest of cowpea.

#### 6.3.2.1. *Trichogrammatids*

The tiny wasps, *Trichogramma* spp. are egg parasitoids found parasitizing on fruit borers of vegetable crops. *T. embryophagum* was observed to parasitize pomogrenate butterfly, *Deudorix epijarbas*; apple codling moth, *Cydia pomonella* and tomato fruit borer, *Helicoverpa armigera*.

#### 6.3.2.2. *Braconids*

*Bracon brevicornis* and *B. hebetor* are gregarious ecto-parasitoids of many lepidopteran pests. They are effective on *Adisura atkinsoni*, *Earias* spp., *H. armigera* and *Opisania arenosella*. *B. brevicornis* has been used against the coconut leaf eating caterpillar, *O. arenosella* and stem borer. *B. hebetor* is also a parasitoid of *O. arenosella*; cabbage stem borer, *Hellula undalis* and *H. armigera* on several crops.

*Chelonus blackburni* is an egg-larval parasitoid introduced from USA. It is used against potato tuber moth, *Phthorimaea operculella* in Maharashtra and *H. armigera* on several crops. It is becoming an important component in IPM systems on potato ecosystem.

*Cotesia plutellae* is an important parasitoid of cabbage DBM, *Plutella xylostella* and is keeping the pest population under check in many parts of South India.

### 6.3.2.3. *Eulopids and Scelionids*

*Telenomus remus* is an exotic egg parasitoid introduced from New Guinea against *Spodoptera litura*. Its inundative releases have been recommended in cauliflower, cabbage, beet root and okra where it could effectively parasitize *S. litura* eggs. Release of *Telenomus remus* at weekly interval gave 60% parasitism of *Spodoptera litura* in cauliflower. Release of *T. remus* at a ratio of 1 eggmass:200 parasitoids gave 100% parasitism of *S. litura* in cabbage.

*Tetrastichus israeli* was found to parasitize 90% pupae of coconut leaf eating caterpillar, *O. arenosella*.

### 6.3.2.4. *Parasitoids of Coconut Leaf Eating Caterpillar, Opisania arenosella*

The larval parasitoid, *Goniozus nephantidis*; pre-pupal, *Elasmus nephantidis* and pupal, *Brachymeria nosatoi* have greater searching ability, capacity to withstand high temperature, production of female progeny, occurrence throughout the year, abundance during the peak period of the host and presence in all the coconut leaf eating caterpillar infested areas. *Xanthopimpla punctata* is a pupal parasitoid of *O. arenosella* in Tamil Nadu and Kerala active during September-October.

### 6.3.2.5. *Ichneumonids*

*Campoletes chlorideae* was found to reduce the population of *H. armigera* on potato.

*Diadegma semiclausum* is a dominant parasitoid of cabbage and cauliflower DBM, *P. xylostella* in Kodaikanal, Nilgiris and Himalayan hills. It can tolerate temperature up to 28°C.

### 6.3.2.6. *Encyrtids and Aphelinids*

*Encarsia periniciosi* is an exotic parasitoid introduced from USA, China and Russia. It has been established in most of the apple growing areas on San Jose Scale, *Quadraspidiotus periniciosus*. It is host-specific, monophagous ecto-parasitoid of San Jose Scale. *E. periniciosi* gave 89% parasitism on *Q. periniciosus* in Himachal Pradesh and 95% in Kumaon hills in Uttar Pradesh.

*Coccidoxenoides peregrina* was found causing 10-20% parasitism of citrus mealybug, *Planococcus citri* in Karnataka.

Field releases of *Leptomastix dactylopii* resulted in the control of citrus mealybug, *P. citri* within 3-4 months.

Potato tuber moth, *P. operculella* can be completely controlled by *Copidosoma koehleri*.

**Fruit Crops:** A few examples of the use of biocontrol agents (predators and parasitoids) for the management of insect pests in fruit crops are given in Table 6.5.

**Table 6.5. Biological control of fruit crop pests using predators and parasitoids**

Fruit crop/ Pest	Biocontrol agent /Dosage/ha	Frequency of application	Remarks
<b>Apple</b>			
Woolly aphid, <i>Eriosoma</i> <i>lanigerum</i>	<i>Aphelinus mali</i> , 1000 adults or mummies/ infested tree.	Once, as soon as infestation is noticed.	Parasitoid is effective against aerial popn. It is more effective in valleys than in slopes.
San Jose Scale, <i>Quad-</i> <i>raspidiotus</i> <i>perniciosus</i>	<i>Encarsia</i> <i>periniciosi</i> , 2000 adults/ infested tree.	Once, in spring.	In endemic areas, repeat release if necessary.
	<i>Chilocorus</i> <i>infernalis</i> 20 adults or 50 grubs/tree.	Once in April- May.	In endemic areas, repeat release if necessary.
Codling moth, <i>Cydia</i> <i>pomonella</i>	<i>Trichogramma</i> <i>embryophagum</i> 2000 adults/ tree.	Releasing at weekly interval.	First release to be initi- ated once the first moth is caught in pheromone traps or eggs noticed.
<b>Citrus</b>			
<i>Icerya</i> <i>purchasi</i>	<i>Rodolia cardinalis</i> 10 beetles/ infested plant.	Once on noticing adults or infestation.	Adopt ant suppression operations in the orchard.
Mealy bug, <i>Planococcus</i> <i>citri</i>	<i>Cryptolaemus</i> <i>montrouzieri</i> 10 beetles/ infested plant.	After the blossom.	Adopt ant suppression operations in the orchard.
	<i>Leptomastix</i> <i>dactylopii</i> 3000 adults.	Need based, under expert supervision.	Adopt ant suppression operations in the orchard.

<i>Aonidiella aurantii</i>	<i>Chilocorus nigrita</i> 15 adults/ infested tree	Single application for each generation.	Adopt ant suppression operations.
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### Grapevine

Mealy bug, <i>Maconellicoccmontrouzieri</i> <i>us hirsutus</i>	<i>Cryptolaemus</i> 2500-3000 beetles/ha or 10 beetles/ vine.	Once, as soon as the infestation is noticed.	Adopt ant suppression operations. Repeat release in case necessary.
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### Guava

Green shield scale, <i>Chloropulvinaria psidii</i>	<i>Cryptolaimus montrouzieri</i> 10-20 beetles/ infested plant.	Once, as soon as the infestation is noticed.	Adopt ant suppression operations. One release is enough since the beetle prefers guava ecosystem.
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**Vegetable Crops:** Several biocontrol agents (predators and parasitoids) have been effectively used for the management of insect pests in vegetable crops (Table 6.6).

**Table 6.6. Biological control of vegetable crop pests using predators and parasitoids**

Vegetable crop/Pest	Biocontrol agent / Dosage/ha	Frequency of application	Remarks
<b>Beans</b>			
<i>Tetranychus</i> spp.	<i>Phytoseiulus persimilis</i> , 10 adults /plant or release 1-6 leaves with predatory mites.	Once, 30 days after germination or as and when infestation is noticed.	Release 30 days after germination or as and when infestation is noticed.
<b>Tomato</b>			
<i>Helicoverpa armigera</i>	<i>Trichogramma brasiliense</i> / <i>T. chilonis</i> / <i>T. pretiosum</i> , 50,000	Weekly intervals / 6 times from 25 <sup>th</sup> day after transplanting or during egg laying period.	First release to be initiated when first moth is caught in pheromone traps or eggs are noticed.
<b>Brinjal</b>			
<i>Coccidohystrix insulata</i>	<i>Cryptolaemus montrouzieri</i> , 2 beetles/plant.	Once, as soon as infestation is noticed.	Release only in endemic areas.



**Plantation Crops:** Several biocontrol agents (predators and parasitoids) have been used for the management of insect pests of plantation crops (Table 6.7).

**Table 6.7. Biological control of plantation crop pests using predators and parasitoids**

Plantation Pest	Biocontrol agent /Dosage / ha	Frequency of application	Remarks
<b>Coconut</b>			
Black headed caterpillar, <i>Opisina arenosella</i>	<i>Goniozus nephantidis</i> 3000 adults.	Need based or for each generation.	Parasitoid:host ratio of 1:5 to be maintained. In case <i>G. nephantidis</i> , <i>Elasmus</i> & <i>Brachymeria nosatoi</i> are put together, the ratio should be 2:5
<b>Arecanut</b>			
<i>Ischanaspis longirostris</i>	<i>Chilocorus nigrita</i> 20 to 50 adults/ plant	Release as soon as infestation is noticed.	Identify endemic areas, mark the infested trees and release.
<b>Coffee</b>			
Mealybugs, <i>Planococcus</i> & <i>Pseudococcus</i> spp.	<i>Cryptolaemus montrouzieri</i> 2-10 beetles / infested plant.	After the blossom.	Adopt ant suppression operations.

### 6.3.3. Pathogens

These micro-organisms are capable of causing diseases in pests as a result the pest lose their appetite, subjected to several physiological disturbances, leading to the ultimate death of the pest. The micro-organisms exploited in biological control of pests are:

**Bacteria:** The most commonly and widely used bio-pesticide in pest control operations is *Bacillus thuringiensis*. The bacterium is highly effective against several insect pests of Lepidoptera. They cause disease due to which insect turns black and die. The bacterium come in several commercial formulations such as Dipel, Delfin, Halt, Spicturin, Biolep, Bio-Asp etc. It is used at a dosage of 1 g or ml/litre of water (1 kg/ha).

The most commonly used bacteria for the biocontrol of plant diseases include *Bacillus subtilis* and *Pseudomonas fluorescens* which

are used to control the diseases caused by *Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp. and *Fusarium* spp.

**Table 6.8. Bacterial biocontrol agents for the management of diseases of horticultural crops**

Horticultural Disease crops		Biocontrol agent	Mode of application
Banana	Panama wilt, <i>Fusarium oxysporum</i> f. sp. <i>cubense</i>	<i>Pseudomonas fluorescens</i> , <i>T. viride</i> + <i>P. fluorescens</i>	Sucker treatment Pseudostem injection Soil treatment
	Nematodes: <i>Radopholus similis</i> , <i>P. coffeae</i> , <i>H. multinctus</i> , <i>M. incognita</i>	<i>B. thuringiensis</i> var. <i>kurstaki</i> <i>P. fluorescens</i> , <i>Streptomyces avermitilis</i>	Soil treatment
Mango	Bacterial canker, <i>Xanthomonas compestris</i> pv. <i>mangiferaeindicae</i>	<i>Bacillus coagulans</i>	Foliar spray
Citrus	Butter fly, <i>Papilio demoleus</i>	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	Foliar spray
Tomato	White rot, <i>S. sclerotiorum</i>	<i>P. fluorescens</i>	Soil treatment
	Wilt, <i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i>	<i>Pseudomonas fluorescens</i>	Seed treatment Seed & soil treatment
	Bacterial wilt, <i>Ralstonia solanacearum</i>	<i>P. fluorescens</i>	Soil treatment
Potato	Bacterial wilt, <i>Ralstonia solanacearum</i>	<i>B. cereus</i> , <i>B. subtilis</i>	Soil treatment
	Tuber rot, <i>Erwinia carotovora</i>	<i>P. fluorescens</i>	Seed/tuber treatment
Chilli	Fruit rot & Dieback, <i>Colletotrichum capsici</i>	<i>P. fluorescens</i>	Seed & seedling treatment Foliar spray
	Wilt, <i>F. oxysporum</i>	<i>P. fluorescens</i>	Soil treatment
	<i>Macrophomina phaseolina</i>	<i>P. fluorescens</i>	Soil treatment
	Powdery mildew, <i>Oidium taurica</i>	<i>P. fluorescens</i>	Foliar spray

Brinjal	Collar rot, <i>Sclerotinia</i>	<i>Bacillus subtilis</i>	Soil treatment
	Root rot, <i>R. solani</i>	<i>P. fluorescens</i>	Soil treatment
	Blight, <i>Pythium vexans</i>	<i>P. fluorescens</i>	Seed treatment
Onion	Tip blight, <i>Alternaria</i> sp.	<i>P. fluorescens</i>	Foliar application
Cabbage	Diamondback moth, <i>Plutella xylostella</i>	<i>Bacillus thuringiensis</i>	Foliar spray
Coconut	Basal stem rot, <i>Ganoderma lucidum</i> / <i>G. applanatum</i>	Phophobacteria	Stem & soil treatment
Arecanut	Fruit rot, <i>Phytophthora arecae</i> , <i>Colletotrichum capsici</i>	<i>P. fluorescens</i>	Soil treatment Foliar spray
	Foot rot & Root rot, <i>Phytophthora capsici</i>	<i>P. fluorescens</i> , <i>Bacillus</i> sp.	Spray
Black pepper	Quick wilt, <i>Phytophthora</i> sp.	<i>T. harzianum</i> (IISR P-26) + <i>P. fluorescens</i> (TNAU PF-1)	Soil treatment
	Slow decline, <i>Radopholus similis</i> , <i>Meloidogyne incognita</i> , <i>Phytophthora capsici</i>	<i>Pasteuria penetrans</i>	Soil treatment
	Anthracnose, <i>Colletotrichum gloeosporoides</i>	<i>P. fluorescens</i>	Spray
	Rhizome rot, <i>Pythium pleroticum</i> , <i>P. myriotylum</i> , <i>P. aphanidermatum</i> , <i>F. solani</i> , <i>F. equiseti</i>	<i>P. fluorescens</i>	Seed treatment
Ginger	Bacterial wilt, <i>Ralstonia solanacearum</i>	<i>P. fluorescens</i> Endophytic bacteria	Soil treatment
Fenugreek	Root rot, <i>R. solani</i>	<i>P. fluorescens</i>	Seed treatment
Coriander	Root rot/wilt, <i>Fusarium oxysporum</i> f. sp. <i>corianderii</i>	<i>Streptomyces</i> sp.	Seed treatment
Vanilla	Root rot, <i>Phytophthora meadii</i> , <i>F. oxysporum</i> f.sp. <i>vanille</i>	<i>P. fluorescens</i>	Soil treatment

**Entomopathogenic Fungi:** Several fungi such as *Beauveria bassiana*, *Metarrhizium anisopliae*, *Nomurea rileyi*, *Paecilomyces* spp. and *Verticillium lecanii* are used against important pests like gram pod borer, tobacco caterpillar and sucking pests like thrips, aphids and mealy bugs. The fungi develop hyphae inside insect system as a result of which insect dies due to mechanical congestions. This mode of action makes these organisms to perfectly suit to the needs of organic farming. In certain cases they produce toxins to kill the insect.

**Entomopathogenic Nematodes:** The entomopathogenic nematodes harbour certain bacteria which act as toxins to insect systems. Mainly exploited entomopathogenic nematodes in insect control operations are *Heterorhabditis* spp. and *Steinernema* spp.

**Table 6.9. Biological control of horticultural crop pests using entomopathogens (fungi and nematodes)**

Hortil. crop/ Pest	Biocontrol agent / Dosage/ha	Frequency of application	Remarks
<b>Citrus</b>			
<i>Coccus viridis</i>	<i>Verticillium lecanii</i> 16 x 10 <sup>4</sup> spores /ml + 0.05% Teepol.	Single application with knapsack sprayer just before the onset of rains.	Use permitted spreaders, spray in the afternoon, ensu- re proper coverage.
<b>Guava</b>			
Aphid, <i>Aphis</i> <i>gossypii</i>	<i>Verticillium lecanii</i> , 10 <sup>9</sup> spores /ml + 0.1% Teepol.	First spray before onset of rainy sea- son, subsequent need based.	Spray in the evening hours.
<b>Potato</b>			
Cutworm, <i>Agrotis</i> spp.	<i>Steinernema</i> <i>carpocapse</i> , 5 billion infective juveniles.	Soil application through irrigation water on detection of cutworm larvae.	Entomophilic nema- todes are highly su- ceptible to desicca- tion, so apply throu- gh irrigation water.

**Antagonistic Fungi:** The most extensively used antagonistic fungi for the biocontrol of plant diseases affecting seed, root and aerial plant parts include *Trichoderma viride*, *T. harzianum*, *T. virens*, *Pochonia chlamydosporia* and *Paecilomyces lilacinus* which are used to control the soil-borne diseases caused by *Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp., *Sclerotinia* spp., *Macrophomina* spp. and *Fusarium* spp. (particularly *Fusarium oxysporum*).

In vegetable crops, diseases like damping off, root rots and wilts in nurseries and main fields can be effectively managed by seed treatment with talc formulations of *Trichoderma viride* / *T. harzianum*/*Pseudomonas fluorescens* (4 g/kg seed) followed by field application of FYM/compost enriched with the above antagonists (250 kg/ha). In the rainfed pigeonpea and cowpea, seed treatment with *T. viride* (4 g/kg seed) reduced the incidence of dry root rots and wilts caused by *Macrophomina phaseolina*, *Fusarium* spp., *Rhizoctonia solani* and *Sclerotium rolfsii*. In case of plantation crops, raising seedlings/cuttings in *T. harzianum*/ *P. fluorescens* amended compost and soil application of *T. harzianum*/ *P. fluorescens* along with neem cake/compost in the main field was useful in minimizing the incidence of foot rot of pepper, damping off and root rots of cardamom, rhizome rot of ginger, basal stem rot of coconut and arecanut and stem bleeding disease of coconut.

*Trichoderma* spp. are favoured by the presence of high level of plant organic matter and plant roots, which they colonize readily. These versatile fungi are highly efficient producers of many extra-cellular enzymes like cellulases, chitinases, glucanases, proteases, etc. They are being exploited in a variety of ways like source of chitinases (generating disease-resistant transgenics), in plant disease control (through their anti-fungal and anti-nematode activity in plant defence induction), improvement of plant growth, straw/compost decomposition and suppression of some weeds.

Mechanism of action of *Trichoderma* spp. include i) directly killing the pathogen by mycoparasitism and/or antibiosis, ii) adversely affecting the growth and development of the pathogen either by antibiosis or by competing for the nutrients, oxygen and space, iii) altering fitness of the pathogen, iv) induction of plant resistance, v) enhancing plant growth and its tolerance to stress, vi) metabolizing the plant exudates supporting the pathogen, and vii) inactivating the enzymes produced by the pathogen.

*Aspergillus niger* (strain AN 27 of Indian Agricultural Research Institute, New Delhi) can kill *Fusarium oxysporum* f. sp. *melonis*, several other *formae speciales* of *F. oxysporum*, *F. solani*, *F. udum* as well as *Macrophomina phaseolina*, several species of *Pythium*, *Rhizoctonia solani*, *Sclerotinia sclerotiorum*. It did not permit formation of resting structures in any of the above cultures.

*A. niger* could not inhibit the growth of *Sclerotium rolfsii*. It is known to cause seedling blight in cotton and groundnut.

*A. niger* prefers a pH range of 4 to 8. It is effective both in acidic and alkaline soils, can act even at 43°C and competent both in low and

high soil moisture conditions. It has a shelf life of 2 years and 6 months. It is formulated as 'Kalisena SD' and 'Kalisena SL'. It releases ethylene which causes fungistasis. *A.niger* exhibits hyperparasitic activity on *R. solani* (collar rot in coffee seedlings).

### Enrichment of FYM with *Trichoderma harzianum*

Commercial formulation of *T. harzianum* was mixed with moist FYM (1 kg/ton). Mixture was spread 15 cm high heap under shade, covered with polyethylene sheet and incubated for 3 weeks at 25 to 30°C and sprayed with water regularly to maintain moisture. Colonized FYM can be used at 6 g/kg soil in pot culture experiments (12 g/2 kg soil in 15 cm diameter pots).

*T. harzianum* colonized compost significantly enhanced germination and growth of both tomato and okra as compared to non-colonized FYM. Population of *T. harzianum* in colonized compost was several folds higher ( $48.6 \times 10^{12}$ ) than non-colonized FYM ( $3 \times 10^4$ ).

**Table 6.10. Population of *Trichoderma harzianum* in colonized FYM (21 days after inoculation)**

Treatment	CFU/g air dried FYM
<i>Trichoderma harzianum</i> colonized FYM (Unsterilized)	$48.6 \times 10^{12}$
FYM only (Unsterilized)	$3.0 \times 10^4$
<i>Trichoderma harzianum</i> colonized FYM (Sterilized)	0
FYM only (Sterilized)	0

**Table 6.11. Total nutrient content of colonized/non-colonized, sterilized/unsterilized FYM**

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Control(UN)	2.75	1.60	0.075	0.28	6.66	1.22	213.49	31.04	2457.42	402.38
TH (UN)	3.50	2.97	0.149	0.31	9.67	1.66	292.09	47.77	3142.14	531.68
Control(ST)	2.87	1.84	0.055	0.33	7.60	1.21	236.49	29.67	2686.43	475.50
TH (ST)	3.44	1.90	0.140	0.48	10.64	2.32	422.12	49.75	3183.10	580.35
CD at 5%	0.09	0.51	0.005	0.01	0.26	0.38	51.65	4.31	12.80	11.38

Colonization of FYM by *T. harzianum* helps to improve the quality of compost. It significantly enhanced total and water soluble

humic matter. A number of macro and micro-nutrients like P, K, S, Zn, Cu and Fe (both total and water soluble content) were significantly higher in *T. harzianum* colonized compost. Six times increase in water soluble humic content due to colonization of *T. harzianum* seems quite important as it is reported to enhance the plant growth (Tables 6.10 to 6.12).

**Table 6.12. Water soluble nutrient content of colonized/non-colonized, sterilized / unsterilized FYM.**

Treatment	HM (g/100g)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (mg/ kg)	Cu (mg/ kg)	Fe (mg/ kg)	Mn (mg/ kg)
Control(UN)	0.020	0.086	0.0098	0.0156	0.407	0.10	0.57	0.04	2.73	1.07
TH (UN)	0.124	0.210	0.0133	0.0019	0.304	0.20	0.63	0.08	3.33	1.00
Control(ST)	0.045	0.095	0.0115	0.0185	0.493	0.08	0.57	0.06	2.39	3.69
TH (ST)	0.133	0.077	0.0151	0.0179	0.445	0.14	0.86	0.05	5.34	2.97
CD at 5%	0.020	0.074	0.0005	0.0004	0.014	0.05	0.02	0.01	0.38	0.03

**Arbuscular Mycorrhizal Fungi (AMF):** AMF are helpful in the biological control of root pathogens.

**Fruit Crops:** A few examples of the use of antagonists (*Trichoderma* spp., *Aspergillus niger*, *Pencillium citrinum*) for the disease management (wilts, root rots) in fruit crops are given in Table 6.13.

**Table 6.13. *Trichoderma* spp. and other antagonistic fungi for the management of diseases of fruit crops**

Fruit	Crop Disease/Pathogens	Potential biocontrol agents	Mode of application
Apple	White root rot, <i>Dematophora necatrix</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Soil treatment
	Scab, <i>Venturia inequalis</i>	<i>Chaetomium globosum</i> , <i>Cladosporium</i> spp., <i>Trichothecium roseum</i>	Foliar spray
Banana	Panama wilt, <i>Fusarium oxysporum</i> f. sp. <i>cubense</i>	<i>T. viride</i> , <i>Aspergillus niger</i> , <i>T. viride</i> + <i>P. fluorescens</i>	Sucker treatment Pseudostem injection Soil treatment

	Nematodes: <i>Radopholus similis</i> , <i>P. coffeae</i> , <i>H. multicinctus</i> , <i>M. incognita</i>	<i>Paecilomyces lilacinus</i> , <i>T. viride</i> , <i>G. mosseae</i> , <i>G. fasciculatum</i> , <i>Gigaspora margarita</i>	Soil treatment
Citrus	<i>Phytophthora</i> spp.	<i>Trichoderma viride</i> / <i>T. harzianum</i> at 100 kg/ha.	Soil treatment
Citrus (Mandarin)	Root rot, <i>Phytophthora nicotianae</i> pv. <i>parasitica</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Soil treatment
Citrus (Orange)	Blue mold, <i>Pencillium italicum</i>	<i>T. harzianum</i>	Fruit treatment
	Root rot, <i>Macrophomina phaseolina</i>	<i>Glomus fasciculatum</i> , <i>Gigaspora gigantia</i>	Soil treatment
	Root rot ( <i>Phytophthora</i> sp.)	<i>Trichoderma</i> spp.	Soil treatment
Grapevine	Powdery mildew	<i>Ampelomyces quisqualis</i>	Foliar spray
	Grey rot, <i>Botrytis cinerea</i>	<i>T. viride</i>	Aerial spray
Guava	Anthracnose, <i>Pestalotia psidii</i> , <i>Colletotrichum gloeosporoides</i>	<i>T. harzianum</i>	Spray
	Fruit rot, <i>Lasiodiplodia theobromae</i> , <i>Phomopsis psidi</i> , <i>C. gloeosporoides</i> , <i>Pestalotiopsis versicolor</i> , <i>Rhizopus arrhizus</i>	<i>Trichoderma</i> sp.	Fruit treatment
	Wilt, <i>Gliocladium roseum</i> & <i>F. solani</i>	<i>Pencillium citrinum</i>	Soil treatment
		<i>Aspergillus niger</i> (AN 17)	Soil treatment
		<i>T. harzianum</i>	Soil treatment
Mango	Fruit rot, <i>Rhizopus arrhizus</i> , <i>Lasiodiplodia theobromae</i>	<i>Trichoderma</i> sp.	Fruit treatment
	Anthracnose, <i>Colletotrichum gloeosporoides</i>	<i>T. harzianum</i>	Foliar spray
		<i>Streptosporangium pseudovulgare</i>	Foliar spray
	Powdery mildew, <i>Oidium mangiferae</i>	<i>S. pseudovulgare</i>	Foliar spray
Strawberry	Grey mold, <i>Botrytis cineria</i>	<i>T. harzianum</i>	Through honey bees
Mulberry	Leaf spot, <i>Cercospora moricola</i>	<i>T. viride</i> , <i>T. harzianum</i>	Foliar spray



	Stem canker & Die-back, <i>Botryodiplodia</i> spp.	<i>T. virens</i> , <i>T. harzianum</i> , <i>T. pseudokoningii</i>	Cutting & soil treatment
	Cutting rot, <i>F. solani</i>	<i>T. virens</i> , <i>T. harzianum</i> , <i>T. pseudokoningii</i>	Cutting & soil treatment
	Collar rot, <i>Phoma sorghina</i>	<i>T. virens</i> , <i>T. harzianum</i> , <i>T. pseudokoningii</i>	Cutting & soil treatment
Passion fruit	Collar rot, <i>R. solani</i>	<i>T. harzianum</i> , <i>Trichoderma</i> sp.	Seed treatment
Amla	Bark splitting, <i>Rhizoctonia</i> <i>solani</i>	<i>Aspergillus niger</i>	Soil treatment

**Vegetable Crops:** *Trichoderma* spp. have been successfully used for the control of nursery diseases (damping off, collar rot, root rot, wilt) of various vegetable crops by seed treatment (*Trichoderma* spp. at 5g/kg seed) and nursery bed treatment. The same bioagents are also used for the control of wilts and root rots in the main field. Mycoparasites like *Ampelomyces quisqualis* and *Veticillium lecanii* can be used for the management of powdery mildews (Tables 6.14 to 6.17).

**Table 6.14. *Trichoderma* spp. and other biocontrol agents for the management of diseases of vegetable crops**

Crop	Disease / Pathogen/s	Potential biocontrol agent	Mode of application
French bean	Seedling rot, <i>Pythium</i> sp., <i>Sclerotinia sclerotiorum</i> , <i>Botrytis cineria</i> , <i>Rhizoctonia solani</i>	<i>T. koningii</i>	Seed treatment
	Root rot, <i>R. solani</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. virens</i> , <i>T. hamatum</i>	Seed treatment- 4 g/kg, Forrow appln. 130-160 kg/ha
	Dry root rot, <i>Macrophomina phaseolena</i>	<i>T. harzianum</i>	Forrow appln. 130-160 kg/ha
	Wilt, <i>Fusarium oxysporum</i>	<i>T. harzianum</i>	Soil appln. 160 kg/ha

	Wilt, <i>Sclerotium rolfsii</i>	<i>T. viride</i>	Seed treatment-4 g/kg, Forrow appln. 130-160 kg/ha
Pea	Seed & Collar rot, <i>Pythium</i> sp., <i>R. solani</i>	<i>T. harzianum</i> , <i>T. hamatum</i>	Seed treatment
	White rot, <i>Sclerotinia sclerotiorum</i>	<i>T. harzianum</i>	Soil treatment
	Wilt, <i>Fusarium oxysporum</i> f. sp. <i>pisi</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
Cabbage	Blight, <i>Alternaria brassicola</i>	<i>T. longibrachiatum</i> , <i>T. virens</i>	Seed treatment
	Damping-off, <i>R. solani</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. koningii</i>	Seed treatment
Cauliflower	Damping-off, <i>R. solani</i> , <i>Pythium aphanidermatum</i>	<i>T. harzianum</i> , <i>Aspergillus niger</i>	Seed & soil treatment
Okra	Wilt, <i>Pythium</i> sp.	<i>Aspergillus niger</i>	Soil treatment
	Stalk rot, <i>Sclerotinia sclerotiorum</i>	<i>Aspergillus niger</i>	Soil treatment
Tomato	Damping-off, <i>Pythium aphanidermatum</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. koningii</i> , <i>T. pseudokoningii</i>	Seed & soil treatment
	<i>Pythium</i> spp.	<i>Trichoderma viride</i> / <i>T. harzianum</i> at 4 g/l.	Soil treatment
	Wilt, <i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>Aspergillus niger</i>	Seed treatment Seed & soil treatment
	Wilt, <i>Sclerotium rolfsii</i>	<i>T. viride</i>	Seed treatment-4 g/kg, Forrow appln. 130-160 kg/ha
	Root-knot, <i>Melodogyne incognita</i> , <i>M. javanica</i>	<i>T. harzianum</i>	Soil treatment
	White rot, <i>S. sclerotiorum</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment

	Root rot, <i>R. solani</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
	Grey mold, <i>Botrytis cineria</i>	<i>T. harzianum</i>	Foliar spray
	Bacterial wilt, <i>Ralstonia solanacearum</i>	<i>Glomus mosseae</i> , <i>G. fasciculatum</i>	Soil treatment
Potato	Black scurf, <i>R. solani</i>	<i>T. viride</i> , <i>T. virens</i> , <i>T. harzianum</i> , <i>Epicoccum purpurescens</i>	Tuber treatment
	Scab, <i>Streptomyces scabies</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
	Charcoal rot, <i>Macrophomina phaseolina</i>	<i>Aspergillus niger</i>	Soil treatment
Bell pepper	<i>Phytophthora capsici</i>	<i>T. viride</i> , <i>T. harzianum</i>	Fruit treatment
Chilli	Damping-off, <i>Pythium aphanidermatum</i>	<i>T. harzianum</i> ,	Seed & soil treatment
	<i>Sclerotium rolfsii</i>	<i>T. harzianum</i>	Soil treatment
	Fruit rot & Dieback, <i>Colletotrichum capsici</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. pileatus</i> , <i>T. koningii</i> , <i>T. pseudokoningii</i> , <i>T. hamatum</i> , <i>T. longibrachiatum</i>	Seed & seedling treatment
	Wilt, <i>F. oxysporum</i>	<i>E. purpurescens</i> , <i>T. viride</i> , <i>T. harzianum</i> , Non-pathogenic <i>F. oxysporum</i>	Soil treatment
	Stem rot, <i>S. sclerotiorum</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
	Blight, <i>Phomopsis vexans</i>	<i>T. viride</i> , <i>T. harzianum</i>	Seed treatment
Brinjal	Damping-off, Wilt, <i>Phytophthora</i> sp., <i>Pythium aphanidermatum</i> , <i>F. solani</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. koningii</i>	Seed & soil treatment
	Collar rot, <i>Sclerotinia sclerotiorum</i>	<i>T. viride</i> , <i>T. virens</i>	Soil treatment

	Charcoal rot, <i>Macrophomina phaseolina</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
Radish	Seedling rot, Damping-off, <i>Pythium</i> sp., <i>R. solani</i>	<i>T. harzianum</i> , <i>T. hamatum</i>	Seed treatment
Beet root	Wilt, <i>Sclerotium rolfsii</i>	<i>T. viride</i>	Seed treatment- 4 g/kg, Forrow appln. 130-160 kg/ha
Cucurbits	Seed rot, <i>R. solani</i>	<i>T. harzianum</i>	Seed treatment
	Anthrachnose, <i>Colletotrichum capsici</i>	<i>E. purpurescens</i>	Foliar spray
	Powdery mildew, <i>Sphaerotheca fuligena</i>	<i>Ampelomyces quisqualis</i>	Foliar spray
Cucumber	Charcoal rot, <i>Macrophomina phaseolina</i>	<i>E. purpurescens</i>	Soil treatment
	Wilt, <i>Fusarium oxysporum</i> f. sp. <i>cucumerinum</i> , <i>R. solani</i>	<i>Aspergillus niger</i>	Soil treatment
	Root rot, <i>R. solani</i>	<i>T. viride</i>	Seed treatment- 4 g/kg, Forrow appln. 130-160 kg/ha
Bottlegourd	Powdery mildew	<i>Ampelomyces quisqualis</i>	Foliar spray
	Wilt, root rot, <i>Fusarium oxysporum</i> , <i>F. solani</i>	<i>Aspergillus niger</i>	Soil treatment
Water melon	Wilt, <i>Fusarium oxysporum</i> f. sp. <i>solani</i> , <i>F. o. f. sp. niveum</i>	<i>T. viride</i> , <i>Aspergillus niger</i>	Seed & soil treatment
Musk melon	Wilt, <i>F. oxysporum</i> , <i>F. solani</i> , <i>R. solani</i>	<i>T. harzianum</i> , <i>Aspergillus niger</i>	Seed treatment
Onion	Leaf blight, <i>Botrytis cineria</i>	<i>Gliocladium roseum</i>	Foliar application
	Wilt, <i>Erwinia carotovora</i>	<i>T. viride</i>	Seed treatment

**Table 6.15. Field efficacy of antagonists on diseases of vegetable crops**

Antagonist	Crop	Disease	Pathogen	% Control
<i>T. harzianum</i>	Cauliflower	Sclerotinia rot	<i>Sclerotinia sclerotiorum</i>	72
		Damping off	<i>Pythium aphanidermatum</i>	83
	Cabbage	Sclerotinia rot	<i>Sclerotinia sclerotiorum</i>	70
		Damping off	<i>Pythium aphanidermatum</i>	80
	Tomato	Sclerotinia rot	<i>Sclerotinia sclerotiorum</i>	73
		Damping off	<i>Pythium aphanidermatum</i>	85
	Chilli	Dieback	<i>Colletotrichum capsici</i>	61
		Fruit rot	<i>Colletotrichum capsici</i>	64
<i>T. viride</i>	Cauliflower	Sclerotinia rot	<i>Sclerotinia sclerotiorum</i>	70
		Damping off	<i>Pythium aphanidermatum</i>	80
	Cabbage	Sclerotinia rot	<i>Sclerotinia sclerotiorum</i>	68
		Damping off	<i>Pythium aphanidermatum</i>	78
	Tomato	Sclerotinia rot	<i>Sclerotinia sclerotiorum</i>	71
		Damping off	<i>Pythium aphanidermatum</i>	83
	Chilli	Dieback	<i>Colletotrichum capsici</i>	60
		Fruit rot	<i>Colletotrichum capsici</i>	62

**Table 6.16. Biological control of Crown, Root and Fruit rot of bell pepper (*Phytophthora capsici*)**

Bioagent	Plant mortality (%)	Fruit rot lesion length (cm)	Reduction in fruit rot lesion length (%)
<i>Trichoderma viride</i> (PDBC TV 6)	40.0	1.10	79.7
<i>T. viride</i> (PDBC TV 6)	30.0	3.82	29.7

<i>T. viride</i> (PDBC TV 23)	16.7	0.52	90.4
<i>T. viride</i> (PDBC TV 31)+	43.3	4.84	11.0
<i>T. viride</i> (PDBC TV 32)	33.3	0.78	85.6
<i>T. viride</i> (PDBC TV 33)	36.7	1.32	75.7
<i>T. harzianum</i> (PDBC TH 10)	16.7	1.54	71.7
<i>T. harzianum</i> (PDBC TH 18)	30.0	4.20	22.7
Ridomil MZ 72 WP at 2 g/l	33.3	1.04	81.6
Control	46.7	5.44	0.0

**Table 6.17. Plant growth promotion in horticultural crops by *Trichoderma* spp.**

Crop	Biocontrol agents	Special features
Brinjal	<i>T. harzianum</i>	Promotion of shoot and root growth
Cauliflower	<i>T. harzianum</i>	Increase in shoot and root growth
Cucumber	<i>T. harzianum</i>	Increase in dry weight
Lentil	<i>T. harzianum</i> , <i>T. virens</i>	Increase in plant growth
Pepper	<i>T. harzianum</i>	Increase in seedling height, leaf area and plant dry weight
Tomato	<i>T. harzianum</i>	Promotion of shoot and root length and increase in seed germination by 10 – 31%

**Ornamental, Medicinal and Aromatic Crops:** Several biocontrol agents have been used for the management of diseases of ornamental, medicinal and aromatic crops (Table 6.18).

**Table 6.18. *Trichoderma* spp. and other antagonistic fungi for the management of diseases of ornamental, medicinal and aromatic crops**

Crop	Disease / Pathogens	Biocontrol agent	Mode of application
Jasmine	Root rot, <i>Macrophomina phaseolina</i>	<i>T. viride</i> , <i>T. harzianum</i>	Cutting treatment
Rose	Grey mold, <i>Botrytis cineria</i>	<i>T. viride</i> , <i>T. harzianum</i>	Cutting treatment

Chinese Rose	Wilt, <i>Fusarium oxysporum</i>	<i>Aspergillus niger</i>	Soil treatment
Gladiolus	Yellows & corm rot, <i>Fusarium oxysporum</i> f. sp. <i>gladioli</i>	<i>T. virens</i> , <i>T. harzianum</i>	Corm and soil treatment
Chrysanthemum	Wilt, <i>Fusarium oxysporum</i>	<i>T. harzianum</i>	Soil appln. 160 kg/ha
Menthol Mint	Stolon decay, <i>Sclerotinia sclerotiorum</i>	<i>T. harzianum</i> , <i>T. virens</i>	Sucker treatment
Opium poppy	Sclerotinia rot and blight, <i>Sclerotinia sclerotiorum</i>	<i>T. harzianum</i> , <i>T. viride</i> , <i>T. koningii</i> , <i>T. virens</i>	Soil treatment
	Downy mildew, <i>Peronospora arborescens</i>	<i>Trichoderma</i> spp.	Seed treatment
Betelvine	Foot and root rot, <i>Phytophthora parasitica</i> pv. <i>piperina</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
	Collar rot, <i>Sclerotium rolfsii</i>	<i>T. harzianum</i> , <i>T. viride</i> , <i>T. koningii</i> , <i>T. virens</i> ,	Soil treatment

**Plantation Crops:** Bioagents like *Trichoderma harzianum*, *T. viride*, *T. virens* and arbuscular mycorrhizal fungi are successfully used for the control of some of the devastating diseases like stem bleeding and basal stem rot of coconut (Table 6.19). Locally available cheap plantation crop wastes like coffee husk, tea wastes, composted coir pith are being used for mass production of *Trichoderma* spp.

**Table 6.19. *Trichoderma* spp. and other antagonistic fungi for the management of diseases of plantation crops.**

Crop	Disease / Pathogens	Biocontrol agent	Mode of application
Coconut	Stem bleeding, <i>Thelaviopsis paradoxa</i>	<i>T. virens</i>	Stem spray
	Basal stem rot, <i>Ganoderma lucidum</i> / <i>G. applanatum</i>	<i>T. harzianum</i>	Stem & soil treatment

Arecanut	<i>Phytophthora</i> spp.	<i>Trichoderma</i> spp.	Fruit treatment
	Fruit rot, <i>Phytophthora arecae</i> , <i>Colletotrichum capsici</i>	<i>Trichoderma</i> spp.	Soil treatment
	Foot rot/Anabe, <i>Ganoderma lucidum</i>	<i>Trichoderma harzianum</i>	Soil treatment
Coffee	Collar rot, <i>R. solani</i>	<i>T. harzianum</i>	Seed & soil treatment
	Red root, <i>Poria hypolateratia</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
	Brown root, <i>Fusarium noxius</i>	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
Rubber	Brown rot, <i>Phellinus noxius</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. hamatum</i>	Soil treatment

**Spice crops:** Bioagents like *Trichoderma harzianum*, *T. viride*, *T. virens* and arbuscular mycorrhizal fungi are successfully used for the control of some of the devastating diseases like foot rot of black pepper, capsule and rhizome rot of cardamom, damping off of cardamom and rhizome rot of ginger (Tables 6.20 to 6.22).

**Table 6.20. *Trichoderma* spp. and other biocontrol agents for the management of diseases of spice crops**

Crop	Disease / Pathogens	Potential biocontrol agent	Mode of application
Black pepper	Foot rot & Root rot, <i>Phytophthora capsici</i>	<i>T. harzianum</i> , <i>T. virens</i> , <i>Glomus fasciculatum</i> (AMF)	Spray
	Quick wilt, <i>Phytophthora</i> sp.	<i>T. harzianum</i> (IISR P-26) + <i>Pseudomonas fluorescens</i> (TNAU PF-1)	Soil treatment
	<i>Phytophthora</i> spp.	<i>Trichoderma viride</i> / <i>T. harzianum</i> at 100 kg/ha.	Soil treatment
	Slow decline, <i>Radopholus similis</i> , <i>Meloidogyne incognita</i> , <i>Phytophthora capsici</i>	<i>T. harzianum</i> , <i>T. virens</i> , <i>Pecilomyces lilacinus</i> , <i>Pochonia chlamydosporia</i>	Soil treatment



Cardamom	Damping-off, <i>Fusarium moniliforme</i> , <i>Pythium vexans</i> , <i>P. aphanidermatum</i> , <i>Rhizoctonia</i> sp.,	<i>T. viride</i> , <i>T. harzianum</i>	Soil treatment
	Capsule rot, <i>Phytophthora meadii</i> , <i>P. nicotianae</i> var. <i>nicotianae</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. virens</i> , <i>T. hamatum</i>	Soil treatment
	Clump rot / rhizome rot, stunting, <i>Pythium vexans</i> , <i>Rhizoctonia solani</i> , <i>Meloidogyne incognita</i>	<i>T. harzianum</i>	Soil treatment
Ginger	Rhizome rot, <i>Fusarium oxysporum</i> f. sp. <i>zingiberi</i>	<i>T. virens</i> , <i>T. harzianum</i>	Rhizome treatment
	Rhizome rot, <i>Pythium pleroticum</i> , <i>P. myriotylum</i> , <i>P. aphanidermatum</i> , <i>F. solani</i> , <i>F. equiseti</i>	<i>T. viride</i> , <i>T. harzianum</i> , <i>T. virens</i> , <i>Aspergillus niger</i>	Seed treatment
	Yellows, <i>Fusarium oxysporum</i> f. sp. <i>zingiberi</i> , <i>M. incognita</i>	<i>T. virens</i> , <i>T. harzianum</i> , <i>T. hamatum</i>	Seed treatment
	Rhizome rot, <i>Sclerotium rolfsii</i> , <i>F. solani</i> , <i>Pythium</i> sp.	<i>Trichoderma</i> sp., <i>T. virens</i> , <i>T. harzianum</i>	Soil treatment
	Dry rot, <i>Pratylenchus coffeae</i> , <i>Fusarium</i> complex	<i>T. harzianum</i>	Soil treatment
Turmeric	Rhizome rot, <i>Fusarium</i> sp., <i>Pythium graminicolum</i> , <i>P. aphanidermatum</i> , <i>R. similis</i> , <i>M. incognita</i>	<i>T. harzianum</i> , <i>T. viride</i>	Soil treatment
Fenugreek	Root rot, <i>R. solani</i>	<i>T. viride</i>	Seed treatment
Coriander	Root rot/wilt, <i>Fusarium oxysporum</i> f. sp. <i>corianderii</i>	<i>T. viride</i> , <i>T. harzianum</i>	Seed treatment
Cumin	Wilt, <i>F. oxysporum</i> f.sp. <i>cumini</i>	<i>Trichoderma</i> spp.	Soil treatment
Vanilla	Root rot, <i>Phytophthora meadii</i> , <i>F. oxysporum</i> f.sp. <i>vanille</i>	<i>T. harzianum</i>	Soil treatment

**Table 6.21. Effect of antagonists on seedling infection in cardamom nursery**

Antagonist / strain	Disease / Pathogen	% disease control in pot culture
<i>Trichoderma harzianum</i> (ICRI-T-12)	Seedling rot, <i>Phytophthora meadii</i>	98
<i>T. viride</i> (ICRI-T-14)	Seedling rot, <i>Phytophthora meadii</i>	100
<i>Bacillus subtilis</i> (PDBC)	Seedling rot, <i>Phytophthora meadii</i>	98
<i>Pseudomonas fluorescens</i> (PDBC)	Seedling rot, <i>Phytophthora meadii</i>	96
<i>Trichoderma harzianum</i> (ICRI-T-12)	Rhizome rot, <i>Pythium vexans</i>	82
	<i>Rhizoctonia solani</i>	66
	<i>Fusarium oxysporum</i>	58
<i>T. viride</i> (ICRI-T-14)	Rhizome rot, <i>Pythium vexans</i>	80
	<i>Rhizoctonia solani</i>	65
	<i>Fusarium oxysporum</i>	53
<i>Bacillus subtilis</i> (PDBC)	Rhizome rot, <i>Pythium vexans</i>	84
	<i>Rhizoctonia solani</i>	61
	<i>Fusarium oxysporum</i>	80
<i>Pseudomonas fluorescens</i> (PDBC)	Rhizome rot, <i>Fusarium oxysporum</i>	64

**Table 6.22. Effect of antagonists on capsule rot disease of cardamom in plantation**

Antagonist / strain	Disease	Pathogen	% disease control in plantation
<i>Trichoderma harzianum</i> (ICRI-T-12)	Capsule rot	<i>Phytophthora meadii</i>	64.8
<i>T. viride</i> (ICRI-T-14)	Capsule rot	<i>Phytophthora meadii</i>	62.3
<i>Bacillus subtilis</i> (PDBC)	Capsule rot	<i>Phytophthora meadii</i>	34.8

**Viruses:** The Nucleo Polyhedrosis Viruses (NPV) cause typical “Tree top disease” in insects. The infected insect lose appetite, becomes restless and reaches the apical portion of the plant due to O<sub>2</sub> depletion inside the insect system. Later, the infected insect will die

hanging itself in an inverted 'V' shape on the apical portion of the plant.

Other than NPV, viruses like Granulosis Virus (GV) and Cyto Plasmic Virus (CPV) are also used in cropping systems. Entomopathogenic viruses are highly host specific which makes them exceptionally safe to non-target organisms and nature. *Ha* NPV is used for the management of *Helicoverpa armigera*, while *Sl* NPV is meant for *Spodoptera litura*. Similarly, castor semilooper is managed by *Ach* NPV and red hairy caterpillar by *Am* NPV. NPV's are used at a dosage of 250 LE/ha along with 1.25 kg jaggery and 200 ml teepol. This dosage is on the basis of  $1.5 \times 10^{12}$  POB's/ha.

**Table 6.23. Entomopathogenic Viruses for the management of insect pests of horticultural crops.**

Horticultural crops	Insect pest	Biocontrol agent	Dose*
Tomato	<i>Helicoverpa armigera</i>	<i>Ha</i> NPV	250 LE/ha
Chilli	<i>Helicoverpa armigera</i>	<i>Ha</i> NPV	250 LE/ha
Pigeon pea	<i>H. armigera</i>	<i>Ha</i> NPV	250 LE/ha
Chick pea	<i>H. armigera</i>	<i>Ha</i> NPV	250 LE/ha
Coconut	<i>Oryctes rhinoceros</i>	Baculovirus	10 infected beetles.

\* Add 0.5% jaggery and 0.1% Tinopal or 0.25% boric/tannic acid to increase the efficacy.

### Development of Mixed Formulations of Biocontrol Agents

*T. harzianum* and *P. fluorescens* exhibit better efficacy against soil-borne plant pathogens in acidic and neutral to alkaline soils, respectively. In general, *P. fluorescens* suppressed the growth and sporulation of *T. harzianum*. But the combination of *T. harzianum* strain PBAT-43 and *P. fluorescens* strain PBAP-27 were used to develop a mixed formulation (Plant Biocontrol Agent – 3 of GBPUA&T, Pantnagar), which was equally or more effective than individual formulations both under greenhouse and field conditions.

### Mass Multiplication

Various grain seeds (sorghum, minor millets) and meals (wheat, sorghum, soyabean, barley), bagasse, straws, wheat bran, saw dust,

spent tea leaf waste, coffee husk, diatomaceous earth granules impregnated with molasses, cow dung, FYM, *Sitotroga* (mushroom) spent meal, *Corcyra* spent meal and peat individually or in combination have been used as substrates in solid fermentation. In liquid fermentation, most commonly used substrates are molasses, brewer's yeast, corn steep liquor, sugar syrup, sulfite wastes liquor, whey, cotton seed, jaggery, yeast, soya flours, etc. Solid fermentation product is primarily conidia, whereas liquid fermentation results in mixture of chlamydospores, hyphal fragments and conidia.

## Formulation

Formulation is the blending of active ingredients (*Trichoderma* propagules and hyphae) with inert carriers (talc, peat, peat + additives, coal, coal + additives, inorganic soils), plant materials (compost made from bagasse, saw dust, soya, coir dust, rice husk, plant compost, FYM powder, corn cob, cow dung powder, cellulose) or inert materials (vermiculite, vermiculite + additives, perlite, ground rock phosphate, Ca phosphate, polyacrylamide gel, entrapped alginate beads). Modern formulations are liquid based in mineral oil along with emulsifiers.

Different types of formulations available are WP, pellets, alginate granules, ST, peat-based dried biomass and microgranules. WP formulations are less efficient and environmentally hazardous particularly when used as foliar sprays. Liquid formulations are better for foliar application. Requirement of humid conditions for the fungus to work can be avoided by spraying fungal spores in mineral oil.

Drying the formulation should be quick and safe without compromising on the bioagent viability and efficacy. Ideally moisture content of formulated product should be 6-8%.

**Formulation of Alginated Pellets of *Trichoderma* spp.:** *Trichoderma* sp. is multiplied on broth medium, mycelium is harvested and mixed with 1% Na alginate solution (1 litre) and 2 g wheat bran and pipetted in 0.25 M Ca Cl<sub>2</sub> solution drop wise. The fungus mycelium in the form of alginated pellets are harvested, rinsed in water after 10 min. and dried on blotting paper. Alginated pellets can be used for soil application at 400 to 800 pellets/sq.m.

## Shelf Life

The final formulation must have a minimum shelf life of 2 years at room temperature, be easy to handle, insensitive to abuse and must be stable over a range of -5° to 35°C. This is the ideal situation and

should be kept as an ultimate aim for developing a formulation. Chlamydo-spores-based formulations of *Trichoderma* spp. exhibited longer shelf life (80% viability for 9 months) than conidia-based formulations (80% viability for 4 months) at room temperature. Shelf life of *T. harzianum* was longer when kaolin and talc were used as carrier than bentonite. Addition of FYM powder to talc + CMC-based formulation of *T. harzianum* enhanced temperature and UV radiation tolerance of the bioagent. *Trichoderma* spp. on coated seeds of radish and chickpea stored at 5°C have shown shelf life of 9 months. Mixed formulations exhibit longer shelf life compared to individual ones when stored at room temperature.

## Application

All horticultural crops at seedling stage are prone to attack by one or more soil-borne bacterial/fungal/nematode pathogens. It is inevitable to manage plant health from seedling stage itself by using bioagents for seed treatment, nursery bed treatment, seedling bare root dip treatment, treatment of substrates or treatment of the main field. Bioagents such as *Pseudomonas fluorescens*, *Trichoderma harzianum* and *T. viride* are effective for the management of soil-borne plant pathogens.

**Seed Treatment with Antagonists:** In case of soil application of the antagonist, the biopesticide should be applied in huge quantities. It has been found that protection of rhizosphere (area surrounding the root portion and having the highest microbial activity) in soil is sufficient to control the disease. When applied through seeds, antagonists not only colonize spermioplane and spermosphere, but also rhizoplane and rhizosphere. The propagules of biocontrol agents germinate on seed surface and colonize the roots of germinated seedlings. The mechanisms involved are that the antagonists form a physical barrier on the seed as well as around the root zone thereby preventing the plant parasite entering the rhizosphere zone. The antagonist directly attack the pathogens and produces antibiotic which is inhibitory to the plant pathogens. The antagonist completely utilizes the available nutrients in the rhizosphere and thereby competing with the plant pathogens for nutrients. Crops in which biopesticides have been successfully exploited are cucurbits, cauliflower, tomato, brinjal, potato, tea, coffee, cardamom, black pepper, betelvine, ginger, gladiolus, pointed gourd, beet root, etc.

Directly sown vegetable seeds (okra, French bean, cowpea, pea, field bean, gourds, melons, etc.) have to be treated with talc-based

formulations of *P. fluorescens*/ *T. harzianum* /*T. viride* at 10 g/kg of seeds.

**Seed Biopriming:** Seed biopriming (treatment of seeds with biocontrol agents and incubating under warm and moist conditions until just prior to radicle emergence) has potential advantages over simple coating of seeds as it results in rapid and uniform seedling emergence. *Trichoderma* conidia germinate on the seed surface and form a layer around bioprimed seeds. Such seeds tolerate adverse soil conditions better. Biopriming could also reduce the amount of biocontrol agents that is applied to the seed. Population of *T. harzianum* and *T. virens* on the surface of treated seeds of tomato and brinjal increases from  $10^4$  cfu per seed up to  $10^6 - 10^7$  cfu per seed after biopriming.

**Nursery Bed Treatment:** Treatment of nursery beds with *P. fluorescens*/ *T. harzianum* /*T. viride* at 50 g/sq.m. + neem cake at 200 g/sq. m. before sowing seeds of transplantable crops like tomato, chilli, brinjal, capsicum, cabbage, cauliflower, etc. gives effective control of seed and soil-borne pathogens and nematodes.

**Seedling Bare Root Dip Treatment:** Seedling rots can be controlled by dipping the roots in the bioagent (spore or cell) suspension before transplanting. Seedling bare root dip in antagonist's suspension not only reduced nematode and soil-borne disease severity but also enhances seedling growth in tomato, brinjal, chilli and capsicum. Root dipping of tomato seedlings in suspension of antagonists reduces the severity of root-knot caused by *Meloidogyne incognita*.

**Treatment of the Substrates (Coir pith, Soil, etc.):** The coir pith/substrate used for raising seedlings in plastic trays / polybags / protrays should be treated with *P. fluorescens*/ *T. harzianum* /*T. viride* at 1 kg/tonne before filling. The soil mixture (used for raising seedlings in polybags in a conventional manner) should be treated with *P. fluorescens*/ *T. harzianum* /*T. viride* at 1 kg/tonne + neem cake at 50 kg/tonne before sowing.

**Soil Treatment in the Main Field:** *Trichoderma* is capable of colonizing FYM. Therefore, for soil application, first it is added to moist FYM, incubated for 10-15 days to allow colonization and colonized FYM is distributed in field followed by irrigation.

The bioagent enriched FYM (mixing of FYM with *P. fluorescens*/ *T. harzianum* /*T. viride* at 1 kg/tonne + neem cake at 50 kg/tonne, covering it with polythene sheet, watering at regular intervals and left

in shade for 15 days) should be applied to the main field at 5 tonnes/ha before sowing seeds/transplanting seedlings.

For fruit crops (banana, acid lime, papaya, pomegranate, grapes) and roses, bioagent enriched FYM at 2 kg/plant + neem cake at 400 g/plant should be applied once in every 6 months after planting.

**Foliar Application:** There are several reports showing effectiveness of biocontrol agents applied as foliar spray against different plant pathogens. Environmental factors like humidity, temperature and sun light affect the colonization of biocontrol agents on leaf surface and thereby bioefficacy of antagonists. Hence, foliar application is preferred during evening hours and it is more successful in rainy season crops.

### Factors Affecting the Field Efficacy

- Strains: Strains of resident biocontrol agents are more effective.
- Soil factors: *T. harzianum* is more effective than *P. fluorescens* in acidic soils against pre- and post-emergence damping off and root rots in a number of vegetable crops, whereas *P. fluorescens* is more effective in neutral and alkaline soils. Performance of *Trichoderma* spp. is better in soils with low organic matter content and microbial activity. Adequate moisture is needed in soil for *Trichoderma* propagules to germinate and act as antagonist. *Trichoderma* is not effective in flooded condition (e.g. rice).
- Inoculum load.

### Increasing the Efficiency of Biocontrol Agents

Employing the eco-friendly pest management agents like botanical pesticides can conserve natural enemies. Eco-feast crops like maize can be grown as an intercrop in horticultural crops to attract and encourage many entomophagous insects. Nector yielding plants attract many natural enemies. *Tagetes* sp. as border crop attracts heavy egg laying of *Helicoverpa armigera*, which leads to increased parasitization by *Trichogramma* spp. on tomato. Planting cowpea on bunds attracts *Cheilomenes sexmaculata* and growing maize as an intercrop encourages *Chrysoperla carnea*. Establishing crop habitat diversity encourages biodiversity of biocontrol agents and the multi-tier cropping of plantation and horticultural crops can ensure adequate action by natural enemies – predators and parasitoids.

Release of quality biocontrol agents with high temperature and pesticide tolerance with good host searching ability and fecundity will increase the efficiency of biocontrol agents. Monitoring the pest through pheromone traps is useful for the timely release of biocontrol agents. Usage of adjuvants will increase the efficiency of microbial agents. Use of virulent strain with prolonged shelf life and high colony forming units will increase the efficiency of microbial agents. Timing and method of release of biocontrol agents play a major role in increasing their efficiency against pests in the field. Providing adequate moisture will improve the efficacy of entomopathogenic fungi and nematodes (EPN) against different species of cutworms and white grubs.

The antagonistic fungi (*Trichoderma* spp., *Pachonia chlamydosporia*, *Paecilomyces* spp.) and bacteria (*Pseudomonas fluorescens*, *Bacillus* spp., *Pasteuria penetrans*) are effective against soil-borne pathogens. Enhancing the soil health and organic C-content through organic manuring, soil amendment and plant residue recycling enrich the soil with beneficial micro-organisms antagonistic to plant diseases as well as predatory fauna. Application of antagonistic organisms along with vermicompost and FYM can boost the efficacy of the antagonistic fungi and bacteria, EPN as well as nematode-trapping fungi and increase the crop yields. Compost prepared from banana leaves was found to be highly suppressive to fusarial wilt of tomato. Neem cake amended soils showed lesser incidence of basal stem rot and stem bleeding diseases of coconut. Oil cakes from different plant species were often used not only as organic soil amendments but also for suppression of soil-borne plant pathogens. Reduction in wilt incidence by 80% in musk melon by soil amendment with mustard cake has been observed. Neem, gingelly and pinnai oil cakes were reported to cause sclerotial disintegration of *Macrophomina phaseolina* and *Rhizoctonia solani*.

Enhancing the potential of biocontrol agents through various manipulations can lead to production of pesticide-free, quality horticultural produce which is in high demand for domestic consumption and export, contributing to greater profitability to the farmers.

### **Areas requiring Attention of Scientists and Policy Makers with Respect to Biological Control**

- Improvement in mass multiplication, shelf life and delivery system should be under taken. Fermentation technology should be popularized for large scale production of biopesticides.



- Integration of biocontrol with other management practices under field conditions should be taken up.
- The quality parameters for registration of commercial formulations of biocontrol agents must be framed and quality control measures are to be implemented strictly by Governmental regulatory agencies.
- Research on biocontrol of foliar diseases including powdery mildews should be strengthened.
- Emphasis should be given for the exploratory survey in undisturbed natural ecosystems of the country for collection and exploitation of the microbial wealth of nature in agriculture.
- Improvement of biocontrol agents by using molecular tools with regard to their efficacy, field adaptability and tolerance to agrochemicals should be under taken.

## Development of Transgenics

Genes encoding a serine protease and endochitinase (Th En-42, Ech-42, Chit-42) have been cloned and characterized. Recently, transgenic potato plants expressing Chit-42 from *Trichoderma* were shown to be highly tolerant or resistant to foliar pathogens (*Alternaria alternata*, *A. solani* and *Botrytis cineraria*) and to the soil-borne pathogen, *Rhizoctonia solani*.

### 6.4. Botanicals

Compost prepared from banana leaf was found to be highly suppressive to fusarial wilt of tomato and the compost from weed plants and pearl millet wastes were reported to reduce the incidence of dry root rot of cowpea. Neem, gingelly and pinnai oil cakes were reported to cause sclerotial disintegration of *Macrophomina phaseolina* and *Rhizoctonia solani*. Neem cake amended soils showed lesser incidence of fusarial wilt of pigeonpea, basal rot and stem bleeding diseases of coconut. Mustard cake reduces the wilt incidence in muskmelon.

#### 6.4.1. Neem Seed Kernel Extract (NSKE)

The use of 4% neem seed kernel extract (NSKE), along with the Indian mustard as a trap crop for the management of the insect pests of cabbage is recommended. Though many commercial formulations of

neem are available in market, they are not consistent in giving uniform control and only freshly prepared NSKE is recommended in cabbage and cauliflower. NSKE was found effective for the management of bean fly, *Ophiomyia phaseoli* in beans; serpentine leaf miner, *Liriomyza trifolii* and fruit fly, *Bactrocera cucurbitae* in cucurbits. The neem extract was also found to reduce many insect pests like tomato fruit borer, *Helicoverpa armigera*; brinjal shoot and fruit borer, *Leucinodes orbonalis*; thrips, *Thrips palmi* in water melon and yellow mite, *Polyphagotarsonemus latus* in chilli .

The first large scale demonstration of the use of neem seed kernel extract (NSKE) 4% in cabbage was demonstrated in a fully mechanised farm near Coimbatore. It is presently being recommended against all the pests of cabbage after evaluation under the All India Coordinated Vegetable Improvement Project (AICVIP) at different centres in India. However, NSKE preparation is not easy. The seed has to be crushed, winnowed to separate kernel, then wet ground using a blender or grinding stone, soaked overnight, filtered through a fine cloth, made to volume and sprayed. One spray to one hectare requires 40 kg of neem seed kernel. For this, about 70-75 kg of neem seed is required.

#### **6.4.2. Neem Seed Kernel Powder**

In view of the above difficulties experienced, powdered neem seed kernel extract was tested. In this process, the kernels were separated, powdered, soaked and filtered and tested for its effectiveness at 4% concentration on DBM larvae of different instars. It was found effective and recommended to IVLP farmers. This method of neem extraction was readily accepted by farmers as the difficulty in wet grinding and obnoxious smell were reduced substantially.

#### **6.4.3. Neem Seed Powder**

By using neem seed kernel powder, though the difficulty of wet grinding was overcome, the difficulty in separating the kernel and powdering still remained. This was overcome by powdering the whole seeds using local flour mill. Thus, the difficulty in powdering was reduced. However, only few flour mill owners permit the powdering of neem seeds due to the persistent bitterness in the grinding stone after grinding neem seeds. Hence, this required further simplification. Some requested the local oil mill to give them the crushed neem seeds without removing its oil. However, the powdering was coarse and fine enough to get good extraction. Hence, powdering of neem seeds

remained a problem at farmers level. Therefore it was found essential to have a neem seed powder supplier for sustaining the technology.

#### **6.4.4. Pulverised Neem Seed Powder**

In flour mill, seeds are passed between grinding stones and are powdered. In the process, the temperature raises  $>80^{\circ}\text{C}$  and we presume that the active ingredients responsible for the insecticidal and other properties of neem may get affected. To overcome this limitation, pulverisers were used. Pulverisers use beaters instead of stones. These beaters beat the seeds and powder them. Due to this action, the temperature of the powder does not go beyond  $1-2^{\circ}\text{C}$  above room temperature. The powder is also very fine and about 300 micron size.

Studies conducted at the Indian Institute of Horticultural Research (IIHR), Bangalore, have shown that pulverised 4% NSPE is as effective as pulverised 4% NSKE after 72 hours on DBM larvae. Hence, the seed requirement was also reduced considerably. In view of the above studies, the pulverised neem seed extract (NSPE) alone can be used for insect pest management than NSKE. Spraying of pulverised neem seed powder at 6% caused scorching of leaves of cabbage, brinjal and cucumber. Therefore, only 4% pulverised neem seed powder is now recommended on all the crops.

#### **6.4.5. Soluble Neem Formulations**

The performance of commercial neem formulations consisting primarily azadirachtin in the management of insect pests of cabbage is not consistent. Recently, a powder formulation of neem (Soluneem) was tested on cabbage and its performance was at par with NSKE in controlling DBM. It was also found effective in reducing fruit borer in tomato. Now many companies are bringing formulations with high azadirachtin content. These formulations are effective on serpentine leaf miner, *Liriomyza trifolii* in many crops.

#### **6.4.6. Oils**

Use of non-edible oils against insect pests is very common. The use of pongamia (*Pongamia pinnata*) oil is found effective against many insect pests such as chilli thrips, whitefly, aphids, etc. However, high doses have to be used and they may be toxic to leaves at high temperatures. Again, the performance is not consistent. Perhaps the quality of oil, whether extracted by solvent or expeller may decide the efficacy of oils. In addition, the oil has to be made into an emulsion and sprayed. Hence, the use of oils in plant protection has not picked up.

### 6.4.7. Soaps

Recent advance in the use of botanicals is the use of neem and pongamia soaps. These were developed at IIHR to overcome the problems associated with NSKE and oil sprays.

A few farmers near Bangalore have been using neem and pongamia oils though they cause yellowing of cabbage leaves due to the high doses and improper emulsion. As oil sprays are effective on DBM, it was felt that soaps prepared from them may also be effective. Further, it was felt that, as the soaps being readily soluble in water they may not be toxic to cabbage leaves. Hence, Potassium soaps from neem and pongamia oils were prepared and tested against DBM. Laboratory studies indicated that 1% soap sprays caused mortality of the third instar DBM larvae within 24 hours. Further, field experiments also showed that the soaps are effective and better than many synthetic insecticides on DBM and did not cause yellowing of cabbage leaves. Experiments were also conducted on the efficacy of the soap sprays for the control of fruit borer (*Helicoverpa armigera*) in tomato and fruit fly (*Bactrocera cucurbitae*) in gherkins.

Field experiments also show that the soap sprays were highly effective on jassids, aphids, red spider mites and whiteflies in many vegetables, but moderately effective on thrips in watermelon and chillies (Table 6.24).

**Table 6.24. Insect pests on which soaps were found effective.**

Crop/s	Insect pests
Cabbage & cauliflower	DBM, leaf webber, aphids, young <i>Spodoptera</i> larvae
Tomato	Whitefly, red spider mites, fruit borer (egg laying stage), leaf miner
Okra	Leaf hopper, whitefly, aphids
Cucurbits	Fruitfly, leaf miner
Mango	Leaf hopper
Ornamental crops	Mites, whitefly

**Limitations of Neem and Pongamia Soaps:** There are two main limitations while using soaps i.e. thorough coverage of the leaf area where insect or mites are feeding is essential and the efficacy may get reduced due to rapid loss of residual toxicity at high temperatures. However, there is great potential to use them in the IPM of many vegetables like cabbage, tomato, okra, chilli and cucurbits. They

can be used as a component in IPM of pigeon pea for controlling borers.

#### 6.4.8. Oil Cakes

Another important development is the use of neem and pongamia cakes in the IPM of many crops like okra, brinjal, cabbage, tomato and vegetable pigeonpea. Though neem and pongamia cakes are used for the supply of nutrients and for the management of soil borne insect and nematode pests, their role in control of other insect pests was not explored. At IIHR, for the first time, the use of neem and pongamia cakes in IPM was demonstrated in many crops like okra, brinjal, tomato, cabbage, cauliflower and cucurbits. The good quality fresh cakes with good smell and 4% oil were utilized for the study.

However, the main limitation in the use of cakes is that their effect is rapidly lost during hot summer months and also due to high wind velocity and excessive rains. Good crop canopy is another requirement for delaying the loss of volatiles. Burying cake-containing pots in soil during summer and rainy season is one of the strategies devised to reduce this loss. Thus, the use of neem cake is a real boon for pest management by organic means in many crops.

#### 6.4.9. Enemy Crops

**Table 6.25. Enemy crops used to reduce nematode population.**

Crop	Nematode	Enemy crop
Brinjal	<i>Meloidogyne incognita</i>	<i>Tagetes patula</i>
	<i>M. javanica</i>	<i>Sesamum orientale</i>
Tomato	<i>M. incognita</i>	<i>Tagetes patula</i>
Castor	<i>Pratylenchus</i> sp.	Chrysanthemum
Okra	<i>Meloidogyne</i> spp.	<i>Tagetes patula</i>
Soybean	<i>Rotylenchulus</i> sp.	<i>Tagetes minuta</i>
	<i>Pratylenchus</i> sp.	<i>Crotalaria spectabilis</i>

### 6.5. Host Resistance

Plant resistance is regarded as an extremely feasible method for controlling pests. It is an effective, economical and environmentally safe means of reducing losses from pests. Use of resistant plants enables the grower to control pests without increasing production

costs associated with the purchase of expensive chemicals, applicators and in numerous mechanical operations that go into the production of a crop. Resistance is especially valuable in controlling pests in low value crops and minor crops which can increase crop yields equal to that obtained by chemical methods. The use of varieties resistant to pests may be the only method of control available, which is economical on a field scale, for certain pests (Tables 6.26 to 6.28). At present, largely because of limited research in this area, a few pest-resistant varieties of plants are available to the commercial grower.

**Table 6.26. Horticultural crop varieties resistant to diseases.**

Vegetable crop	Diseases	Resistant varieties
Acid lime	Bacterial canker	Rasraj.
Citrus	Gummosis, leaf fall, fruit rot ( <i>Phytophthora</i> spp.)	Cleopatra mandarin, Rangpur lime, Trifoliate orange rootstocks.
Banana	Panama wilt ( <i>Fusarium oxysporum</i> f. sp. <i>cubense</i> )	Robusta, Dwarf Cavendish.
Papaya	Ring spot virus	Rainbow.
Grapevine	Anthraco nose	Pusa Navrang
Tomato	<i>Fusarium</i> wilt	Meenakshi, Menaka, Mohini, S-110, Sel-28.
	<i>Fusarium</i> & <i>Verticillium</i> wilt	Pant Bahar, Rishi, Maitri, Manmohan, Rasika, Ratna, Lercia.
	Bacterial wilt	Arka Abha, Arka Alok, Arka Shreshta, Arka Abhijit, Megha, Shakthi, Sonali, Swaraksha, Utkal Pallavi, Utkal Deepti, Utkal Kumari, Sun 7610, Sun 7611, BT-1, BT-10, LE 79-5.
	Bacterial wilt & TL CV	Arka Ananya, All Rounder.
	Leaf curl virus	Avinash-2 (T), Hisar Anmol (H-24), Hisar Gaurav, JK Asha, Nandi, Abhinav, Vaibhav, Sankranti, Sungro-501, Mruthyunjaya-3, Akash, Utpan, Chandini, Ruchi, Khasi Amrit, Arka Ananya, H-44, H-36, H-86, H-88.
	Powdery mildew	Arka Asish.
	<i>Phytophthora</i> fruit rot	A-2.

	Late blight	Punjab Kesari.
	Late blight, <i>Verticillium</i> & <i>Fusarium</i> wilts	Sonali, Pant Bahar.
	Early blight	Sungro-830, Abhiman.
Brinjal	Bacterial wilt	Arka Nidhi, Arka Keshav, Arka Neelkant, Swarna Shree, Swarna Mani, Swarna Shyamali, Surya, Pant Rituraj, Pusa Purple Cluster, Pusa Anupam, Utkal Tarini, Swetha, Haritha, SM 6-6, SM 6-7, BB-7, BB- 44.
	Little leaf	Pusa Purple Cluster (Field resistant), Pusa Purple Round, T-3.
	<i>Phomopsis</i> blight	Pusa Bhairav.
	Bact. wilt & <i>Phomopsis</i> blight	Pusa Samrat.
Chilli	TMV, CMV& Leaf curl	Pusa Sada Bahar, Pusa Jwala, Punjab Lal, Punjab Surkh.
	TMV, CMV, Leaf curl, wilt & Dieback	Punjab Lal, Punjab Surkh.
	Mosaic & leaf curl	Pant C-1.
	Powdery mildew	Arka Suphala (T), Arka Meghana, Arka Harita (T), Andhra Jyoti.
	PM & viruses	Arka Harita, Arka Meghana.
	Bacterial wilt	Utkal Rashmi.
	Anthracnose	Vardan.
	Fruit rot, <i>Colletotrichum capsici</i>	K-2 (Kovilpatti)
	TMV	Kranti, Krishna, Bijli, Agni.
Capsicum	Bacterial wilt	Arka Gaurav.
	TMV	Green Gold.
	TMV& PVY	Indira.
Potato	Late blight	Kufri Sutlej, Kufri Badshah, Kufri Jawahar (in plains), Kufri Jyothi, Kufri Giriraj, Kufri Kanchan, Kufri Meghad (in hills)

French bean	Rust	Arka Bold, Swarna Priya, Swarna Latha.
	Angular leaf spot & mosaic	Pant Anupama.
	Rust & <i>Alternaria</i> leaf spot	Arka Bold.
	Rust & bacterial blight	Arka Anoop.
	PM & mosaic	Contender, Pusa Parvathi.
	Rust & mosaic	Pant Bean-2.
Cowpea	Bacterial blight	Pusa Komal.
	Golden Mosaic Virus	Arka Graima, BCKV-1.
Pea	Powdery mildew	Pusa Pragati, Rachna, Pant-5, Jayanti, Uttara, JP-4, JP-93, JP-50-I, FC-1, PRS-4, NDVP-4, JM-5.
	PM & Rust	Arka Ajit, Arka Karthik, Arka Sampoorna.
	<i>Fusarium</i> Wilt	JP Batri Brown 3, JP Batri Brown 4
	PM & <i>Fusarium</i> wilt	VL-3.
Field bean	Viral diseases	Pusa Sem-2, Pusa Sem-3.
Cluster bean	Bacterial blight, powdery mildew & <i>Alternaria</i> leaf spot	Gomah Manjari.
Pigeonpea	<i>Fusarium</i> wilt	Maruti , Pusa-33 (T).
	<i>Alternaria</i> leaf blight	Pusa-9.
Hyacinth bean	Yellow Mosaic Virus	Wal Konkan-1.
Okra	YVMV	Pusa Sawani, Pusa Makhmali, Arka Abhay, Arka Anamika, Hisar Unnat, Hisar Barsati, Varsha Uphaar, Kiran, DVR-1, DVR-2, IIVR-10, Punjab-7, Pusa A-4, Parbhani Kranti (T), Punjab Padmini, Punjab Kesari, Utkal Gaurav, Azad Kranti, Panchali, Adhunik, Supriya, Tara, Varsha, Vijay, Vishal.
Muskmelon	Powdery mildew (PM)	Arka Rajhans, Punjab Hybrid, Pusa Madhuras (MR), Hara Madhu, RM-43.



	PM & red pumpkin beetle	Pant Khira-1.
	PM & downy mildew	Punjab Raseela.
	Downy mildew	Madhumati.
	<i>Fusarium</i> wilt	Pusa Madhuras, Durgapura Madhu, Arka Jeet, Punjab Sunehari (MR), Harela.
Watermelon	PM, DM & anthracnose	Arka Manik.
	<i>Fusarium</i> wilt	Amruth.
Ridge gourd	PM & DM	Swarna Manjari, Swarna Uphaar, Surekha.
	DM	Arka Sujat.
Ash gourd	Mosaic	Indu.
Bottle gourd	Blossom end rot	Arka Bahar (T).
	Powdery mildew	Pant Shankar Lauki-2.
	PM & DM	Narendra Rashmi.
	CMV	Punjab Long, Punjab Komal.
Cucumber	PM	Swarna Poorna (T).
	PM, anthracnose & epilachna beetle	Swarna Swetha, Swarna Ageti.
	PM, DM, Anthracnose & Angular leaf spot	Poinsette.
	Cucumber green mottle virus	DURM-1.
Cabbage	Black rot	Pusa Mukta, Bahar, Pragati.
	Black rot & yellows	Head Rani Gol, Kranti Ganesh Gol, Geetanjali.
	<i>Fusarium</i> wilt	Swathi, Sarita, Bajrang, Shanti, Swarna, Sonali, Quisto, Bishwas.
	Black leg	Pusa Drum Head.
Cauliflower	Black rot	Pusa Shubra, Pusa Snowball, Early Himlata, K-1.
	Black rot & Curd blight	Pusa Shubhra.
	DM	Pusa Hybrid-2.

	Curd blight	Pusa Synthetic.
	<i>Fusarium</i> wilt	Sujata.
	<i>Xanthomonas</i> , <i>Pseudomonas</i> & DM	Pawas.
Carrot	PM	Arka Suraj.
Radish	<i>Alternaria</i> blight	Kashi Sweta.
Onion	Purple blotch & basal rot	Arka Pitamber, Arka Kirtiman, Arka Lalima.
	Purple blotch, <i>Alternaria</i> <i>pori</i>	Arka Kalyan, Pusa Red, Pusa Ratnar, Nasik Red, Red Creole, Patna Red.
	Brown rot	Poona Red, Bellary Red, Telagi Red, Patna Red, White Large, Udaipur- 1037.
Garlic	Purple blotch, <i>Stemphylium</i> disease	Agri-found White (G-41), G-1, G-50, G-51
Amaranth	White rust	Arka Arunima, Arka Suguna (MR).
Palak	<i>Cercospora</i> leaf spot	Arka Anupama.

MR – Moderately Resistant    T – Tolerant

**Table 6.27. Horticultural crop varieties resistant to insect pests**

Vegetable crop	Insect pests	Resistant varieties
Tomato	Fruit borer	Angurlata, Punjab Chhuhara, Sabour Prabha.
Brinjal	Shoot & fruit borer	Punjab Bahar, Gulabi Doria, Pusa Purple Cluster, Pusa Purple Long, Pusa Purple Round, Pusa Barsati, Pusa Samrat, Pusa Uphar, Bara- masi, Jalgaon Local, Arka Shirish,
	Jassids	Pusa Purple Round, Pusa Anmol, Punjab Chamkila, Pant Brinjal, Manjri Gota, Dorli Jymbli Malayaum.
	Epilachna beetle	Uonuma Purse.
	Mites	Long Green, Pusa Purple Long.

	Fruit and shoot borer & jassid	Pusa Purple Cluster, Chaklasi Doli, Doli-5.
	Whitefly	Pusa Purple Cluster.
	Epilachna beetle, whitefly & Aphid	Punjab Chamkila.
Chilli	Mites	Pusa Jwala, Kalyanpur Red, Punjab Lal, Goli Kalyanpur, Pant C-1.
	Thrips	Pusa Jwala, Chamtkar, Pant C-1, K-2, Andhra Jyoti.
	Thrips & Mites	Punjab Lal, X -235.
	Aphids	Kalyanpur Red, Pusa Jwala, Pant C-1, Punjab Lal.
Capsicum	Whitefly	California Wonder, Yolo Wonder, Koral.
Pea	Stemfly	Sophia-135, Sutton Phinonena.
Field bean	Pod borer, jassid & aphid	Pusa Sem-2, Pusa Sem-3.
Onion	Thrips	Arka Pitamber, Arka Kirtiman, Arka Lalima, Bombay White, Ludhiana Selection, Hisar-2, Pusa Ratnar, Kalyanpur Red Round, Udaipur-103, Safed Gol, Mathewad-1, Shirwal-2, Kagar-2, Peth-1.
Okra	Leaf miner	Nath Shobha-111.
	Fruit borer	Parkins Long Green, Karnal Special, Clemson's Spineless, Red Bhindi, Pusa A-4.
	Leaf hopper	Punjab Padmini, Early Long Green, Clemson's Spineless, Siswal Local, White Velvet, Lucknow Special.
Cabbage	Diamondback moth	Green Acre.
	Aphids	Early Quin Glory, All Season, K K Cross.
	Butter fly	Green Acre, Red Pickling, Red Rock Momoth.
Cauliflower	Diamondback moth	Nasik-1.
	Aphids	Improved Japanese.
Radish	Aphids	Pusa Chetki.

Musk melon	Mites	Durgapura Selection-1, Early Gold, Hara Madhu.
	Red pumpkin beetle	Kasawa.
Tinda	Fruitfly, <i>Dacus cucurbitae</i>	Arka Tinda.
Bottle gourd	Red pumpkin beetle	Narendra Rashmi.
Bitter gourd	Fruitfly, <i>Dacus cucurbitae</i>	Short Green Kerala, Phule BG-4, Faizabad Collection-17.
	Red pumpkin beetle	Pant Karela-1.
Pumpkin	Fruitfly	Arka Suryamukhi.

**Table 6.28. Nematode-resistant cultivars of horticultural crops.**

Crop	Nematode	Resistant cultivars
Banana	<i>Radopholus similis</i>	Kadali, Pedalimoongil, Ayiramkapoovan, Peykunnan, Kunnan, Pisang Seribu, Tongat, Vennettu Kunnan, Anaikomban
Citrus	<i>Tylenchulus semipenetrans</i>	Trifoliate orange, Swingle citrumelo
Grapevine	<i>Meloidogyne incognita</i>	Black Champa, Dogridge, 1613, Salt Creek, Cardinal, Banquabad
	<i>Rotylenchulus reniformis</i>	Dakshi, Joazbeli, Mukchilani
Papaya	<i>R. reniformis</i>	Solo, Washington
Passion Fruit	<i>M. incognita</i>	Yellow, Kaveri
Tomato	<i>Meloidogyne</i> spp.	Nematox, Pusa-120, Pusa Hybrid-2, NTR-1, SL-12, Patriot, VFN-8, VFN Bush, Piersol, Radiant, Nemared, Ronita, Anahu, Bresch, Helani, Campbell-25, Punuui, Arka Vardan, Pelican, Hawaii-7746, Hawaii-7747, Hisar Lalit, Mangala Hybrid.
Brinjal	<i>M. incognita</i>	Giant of Banaras, Black Beauty, Gola, SM - 67
Chilli	<i>M. javanica</i>	579, CAP-63, Pusa Jwala
Potato	<i>M. incognita</i>	Kufri Dewa
	<i>Globodera rostochiensis</i>	Kufri Swarna
Carrot	<i>M. incognita</i>	Arka Suraj

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Sweet potato	<i>M. incognita</i>	Sree Bhadra, Sree Vardhini, Sree Nandini, Kanjangad
Cowpea	<i>M. incognita</i>	Barsati Mutant, Iron, New Selection, C-152, 92-1-B, IC 9642-B, TVU 2430-P
French bean	<i>M. incognita</i>	Banat, Blue Lake Stringless, Bountiful Flat, Brown Beauty, Cambridge Countess, Gallaroy, Kenya-3, Pinto W5-114, Seafarer, Suttan's Masterpiece
Muskmelon	<i>M. incognita</i>	Scarsol
	<i>M. javanica</i>	S-445
Watermelon	<i>M. incognita</i>	Shehjanpuri
Ridge gourd	<i>M. incognita</i>	Panipati, Meerut Special
Ash gourd	<i>M. incognita</i>	Jaipuri, Agra
Pumpkin	<i>M. incognita</i>	Jaipuri, Dasna
China aster	<i>M. incognita</i>	Shashank-Resistant Poornima-Mod. Resistant
Tuberose	<i>M. incognita</i>	Sringar-Resistant Suvasini-Tolerant
Mentha	<i>M. incognita</i>	Kukrail, Arka Neera, SS-1-4, SS-2-7, SS-18
Black pepper	<i>M. incognita</i>	Pournami (Tolerant)
Yam	<i>M. incognita</i>	Sree Latha, Sree Keerthi

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## 6.6. Integrated Methods

Integrated Pest Management (IPM) is an important principle on which sustainable crop protection can be based. IPM allows farmers to manage pests in a cost effective, environmentally sound and socially acceptable way. According to FAO, IPM is defined as “A pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods, in a compatible manner as possible and maintains the pest populations at levels below those causing economic injury”. While developing the IPM technologies, the following aspects are to be considered:

- The technologies developed should be economically viable. About 70% of our people depend on agriculture for their livelihood and more than 80% of them are small and marginal farmers. Hence, there is a need to develop low input crop

protection technologies. The inputs should be efficiently used. The input use efficiency should be given utmost importance.

- The technologies developed should bring down the pest population below economic injury level.
- The technologies developed should be environmentally safe as enough damage has already been done to the environment by indiscriminate use of chemical pesticides. It is heartening to note that the pesticide consumption in India has come down from 75,033 tonnes in 1990-91 to 47,020 tonnes during 2001-02.
- The technologies developed should conserve the natural enemies that are already present in the crop ecosystem. Hence, only safer and eco-friendly pesticides should be recommended. In this context, Avermectins, Strobilurin fungicides and pheromones are safe to natural enemies.
- The technologies developed should conserve the biodiversity. Hence, crop-mixes and variety-mixes should be adopted in the cropping system. In this context, use of trap crops like Indian mustard and African marigold in developing IPM technologies in cabbage and tomato, respectively are relevant.
- The technologies developed should not pose risk to human beings, animals, birds, honey bees, fishes and beneficial soil organisms including earthworms.
- The technologies developed should not come in the way of export, since there is a growing demand for organic food in western countries. There should not be any pesticide residues in the farm produce.

The use of 4% neem seed kernel extract (NSKE), along with the Indian mustard as a trap crop have been recommended for integrated management of the insect pests of cabbage. Similarly, integrated management of tomato fruit borer has been achieved by using marigold as a trap crop and spraying *Ha* NPV.

Integrated management of foot rot (*Phytophthora capsicii*) and nematodes (*Meloidogyne incognita* and *Radopholus similis*) on black pepper was achieved by (i) mixing VAM and *Trichoderma harzianum* in solarised nursery mixture to raise healthy and robust seedlings, (ii) application of *T. harzianum* and FYM in planting pit, (iii) field application of neem cake at 1 kg/vine mixed with 50 g of *T. harzianum* during August.

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Management of capsule rot (*Phytophthora spp.*) of cardamom was achieved by two applications of *T. harzianum* at 1 kg/plant (grown on decomposed coffee pulp and FYM in 1:1 ratio) during May and July integrated with foliar spray of Akomin (potassium phosphonate).

The root-knot and the burrowing nematode on banana were effectively managed by integration of neem cake at 500 g and FYM enriched with *T. harzianum* at 2 kg/plant. The above treatment increased the fruit yield to 45 kg/plant and bunches came to harvest 65 to 75 days earlier.





*PART - II*

**PACKAGE OF PRACTICES FOR  
ORGANIC FARMING  
IN HORTICULTURAL CROPS**



## Chapter 7

# FRUIT CROPS

### 7.1. Tropical Fruits

#### 7.1.1. *Mango*

**Nutrient Management:** FYM has to be applied at 25 kg/pit before planting and the same dosage every year during June-July. Growing of green manure crops like sunnhemp, cowpea or horse gram during rainy season and incorporating in soil at the time of flowering is recommended. Young plants have to be manured in August with liberal quantities of well rotten FYM along with 400 g each of *Azospirillum* and phosphobacteria. During the first 5 years, dhaincha can be raised as a green manure crop and ploughed *in situ* as an organic nutrient supplement. Groundnut can be grown as an intercrop and haulms can be incorporated into the soil as green leaf manure.

In a 10 year-old mango orchard (cv. Banganapalli), application of 200 kg green leaf + 10 kg vermicompost significantly increased fruit weight (465 g) and yield (56.2 kg/tree) as compared to control (40.2 kg/tree). TSS, reducing sugars, non-reducing sugars and total sugars also increased in the above treatment and acidity decreased. The shelf life of fruits was significantly higher (16 days) with the application of 50 kg FYM + 100 kg green leaf as compared to control (13 days).

To bring additional income to the grower until the trees begin to bear and to improve the health of trees, the intercrops are grown which are of the right type. The recommended intercrops in mango orchards for summer season are bottle gourd, bitter melon, onion, chillies, cowpea, black gram and green gram. For winter season, the intercrops suggested are peas, turnip, cauliflower, carrot, radish and chickpea. Intercropping of pre-bearing mango orchard with vegetables enrich the soil, land and space use efficiency, generate supplemental income during the initial unproductive phase, protect the inter-space

from losses through weeds, erosion, impact of radiation, temperature, wind and water and enrich it by N-fixing leguminous vegetable crops. Total available N (138.2 and 173.5 Kg N/ha) and gross total gain available N (19.5 and 45.9 kg N/ha) after 1 and 2 years was significantly maximum in Cluster bean-Chilli-Bottle gourd cropping. The gross total available P was significantly maximum in Colacasia-Amaranth-Cowpea (105.6 kg P<sub>2</sub>O<sub>5</sub>) after 1 year and Okra-French bean-Watermelon (158.0 kg P<sub>2</sub>O<sub>5</sub>) after 2 years. The gross gain in available P was significantly maximum in Okra-French bean-Watermelon (61.6 kg P<sub>2</sub>O<sub>5</sub>) after 1 year and Colacasia-Amaranth-Cowpea (115.4 kg P<sub>2</sub>O<sub>5</sub>) after 2 years. The total available K was significantly maximum in Potato-Cowpea-Amaranth (286 kg K<sub>2</sub>O/ha) after 1 year and Cowpea-Tomato-Okra (440 kg K<sub>2</sub>O/ha) after 2 years. Significant maximum gross total gain in available K is maximum in Cowpea-Tomato-Okra (144.6 kg K<sub>2</sub>O/ha) after 1 year and (161.9 kg K<sub>2</sub>O/ha) after 2 years. Intercropping vegetables in pre-bearing mango improved the available P and K content of orchard soil from low level in the beginning to medium and high levels after 2 years.

**Weed Management:** The major monocot weeds that occur in mango orchards are *Cynodon dactylon* and *Cyperus rotundus*, and dicot weeds are *Bidens pilosa*, *Tridax procumbens* and *Phyllanthus maderaspatensis*.

Usually manual method of weed control is practiced in young orchards by employing women labour. They use small hand tools (Khurupi) for removing weeds in basins and in between rows of plants. When the orchard comes of age (8-10 years), mechanical method of weeding by using bullock drawn implements or motor run tractors and tillers with special weeding tool attachments are employed for effective weed control. Cultivation of mango orchards at least twice a year is necessary to keep the weeds under check which otherwise may prove harmful to the growth and productivity.

Cover cropping with sunnhemp in light soils and sesbania in heavy soils is another practice followed in mango orchards to suppress the weed growth.

Drip irrigation should be preferred over flood irrigation to conserve moisture and to reduce the weed infestation.

## Pest Management

### Fruitfly, *Bactrocera dorsalis*

**Pre-harvest Management (starting 45 days prior to harvest):** Destroy all fallen fruits at weekly intervals. Rake/plough

between trees 1 or 2 times between flowering and harvest to expose pupae to sun. Avoid delay in harvesting.

**Post-harvest Management:** Within 24 hr after harvest, hot water treatment at 48°C maintained by thermostat for 1 hr, gave 100% fruitfly infestation free fruits in cvs. Banganapalli and Totapuri. Hot water treatment in 5% salt solution at 55°C for 30 min. without thermostat gave 100% control in cvs. Banganapalli, Totapuri and Alphonso.

**Stone Weevil, *Sternochetes mangiferae*:** Field sanitation including collection and destruction of all fallen fruits at weekly intervals till harvest will destroy adults which are source of infestation for the following year. Raking of soil below the tree in October/November and March destroy pupae and contributes partially to weevil management.

**Hoppers, *Amritodus atkinsoni*:** Orchard sanitation, regular ploughing, removal of weeds, dead, diseased and excess branches to increase sunlight penetration on various sides of the tree are found advantageous in reducing pest damage.

Two sprays of Azadirachtin at 3000 ppm at 2 ml/litre or Azadirachtin at 10,000 ppm at 1 ml/litre (first spray at early panicle emergence i.e. before flower opening and second spray at pea-size fruit stage) gave effective control of hoppers. Sprays of neem/pongamia soaps were also highly effective.

Biological suppression of hoppers was achieved by the release of predator, *Mallada boninensis* at 10-12 larvae/tree. The reduviid predator, *Irantha armiper* was found preying voraciously on hoppers. The white halo fungus, *Verticillium lecanii* is observed on mango hoppers in nature resulting in wiping out of hoppers around Lucknow.

**Mealybug, *Rastrococcus iceryoides*, *Drosicha mangiferae*:** Alkathene sheet (20 cm wide, 400 gauge) should be put around the tree trunk 0.5 to 1.0 m above the ground level and mud can be applied at the corners. Sanitary conditions should be maintained near the plants and the soil should be turned regularly up to August-September so that eggs are exposed and destroyed.

Raking of basin soil around the tree trunk was found effective. Mealybugs can be controlled by banding one foot width alkathene (400 gauze) around the tree fastened by twine with grease barrier at the lower end.

Application of karanj based biodynamic preparation resulted in 100% mortality of mealy bugs within 7 days, while neem based biodynamic preparation took 9 days for 100% mortality.

The release of the coccinellid predator, *C. montrouzieri* at 50 beetles/tree was found very effective in suppressing mealybug population.

**Scale Insect, *Chloropulvinaria polygonata*:** *C. montrouzieri* which feeds very well on ovisacs is recommended for the control of scale insects.

**Leaf Webber, *Orthaga eudrusalis*:** *Bacillus thuringiensis* is recommended at 1 kg/ha for the control of leaf webber.

**Leaf Gall Causing Midge, *Procontarinia matteiana*, *Amradiplosis* spp., *Erosomyia indica*:** Collection and destruction of the affected leaves prevent the population build up of the pest. Raking soil below the tree destroys pupae.

**Stem Borer, *Batocera rufomaculata*:** Borers can be destroyed by inserting a hard wire into the tunnel. They can also be pulled out by using a hook at the end of the wire and then destroyed. The tunnel should be sealed with wet clay after applying petrol/kerosene (10 ml).

**Seedling Wilt, *Sclerotium rolfsii*:** Select healthy stones, make them pulp-free and dress them. Collection and destruction of diseased seedlings. Avoid contaminated soil in future plantings. Spray 2% Bordeaux mixture.

**Gummosis and Bark Splitting, *Lasiodiplodia theobromae*:** Application of fresh cow dung to the cut surfaces of twigs pruned branches kept 93.33% mango plants completely free from the incidence of gummosis and bark splitting up to 6 months (Table 7.1). The positive response of fresh cow dung pasting on trees may be due to the presence of high population of Actinomycetes which are reported effective against anthracnose, stem end rot diseases and gummosis of mango.

**Table 7.1. Effect of pasting of fresh cow dung and copper oxychloride on cut surfaces of pruned mango trees.**

Treatment	Shoot emergence per pruned branch (No.)	% plants free from gummosis and bark splitting	Cost (Rs./tree)
Fresh cow dung	39	93.33	3.5
Copper oxychloride	36	88.88	34.0

**Stemend Rot, *Botryodiplodia theobromae*:** Harvesting of mangoes on clear dry day, preventing snapping of the pedicel and avoiding injury to the fruits at all stages of handling helps to reduce the disease incidence.

**Powdery Mildew, *Oidium mangiferae*:** The infected gardens should be kept free from weeds and other alternate hosts. Removal and burning of infected leaves, shoots and flowers helps to reduce the spread of the disease. Spraying with 0.3% wettable sulphur gave effective control. The first spray may be given soon after flowering, followed by 2 more sprays at fortnightly intervals. Mango cv. Totapuri is tolerant to powdery mildew.

**Bacterial Canker, *Xanthomonas compestris* pv. *mangiferae-indicae*:** Seedling certification, collection and burning of infected leaves and twigs and orchard sanitation have been recommended as preventive measures. Spraying 1% Bordeaux mixture is to check the disease. Mango cvs. Bombay Green, Jehangir, Fazli and Suvarna-rekha are reported to be resistant. *Bacillus coagulans* is a potential bioagent which reduced the disease incidence to the extent of 75%.

**Anthracnose, *Colletotrichum gloeosporoides*:** Prune affected branches and apply Bordeaux paste on cut ends. Spray 1% Bordeaux mixture on leaves. Hot water treatment of fruits at 50-55°C for 15 min. gave good control. *Bacillus subtilis* was found relatively effective by controlling 50% of the disease on fruits at post-harvest.

**Pink Disease:** Remove diseased parts. Spray 1% Bordeaux mixture 3 times. First spray be given in June followed by 2 more sprays at 15 days interval.

**Die-back, *Botryodiplodia theobromae*:** Pruning and destruction of infected twigs is foremost. Grafted plants should be pasted with Bordeaux paste at the graft union and extending down to the soil level. Spray 1% Bordeaux mixture before onset of winter. Give 2 more sprays in March and September.

## IPM

- Ploughing of orchard immediately after harvest and in Nov-Dec to expose pupae of fruitfly, midge, leaf webber and eggs of mealy bug to natural enemies.
- Heavy irrigation of orchard in October helps in destruction of eggs of mealy mealy bug, diapause pupae of midge and fruitfly.
- Avoiding dense planting, keeping orchard clean by regular ploughing, removal of weeds and pruning of over crowded and overlapping branches in December to control hoppers.
- Polythene banding (25 cm wide, 400 gauge) of tree trunk 30 cm above the ground level in Dec-Jan to prevent migration of freshly hatched first instar nymphs of mealy bugs on tree.

- Spraying 5% NSKE / 1% neem soap / *Verticillium lecanii* at bud burst stage (February) to control leaf hoppers, midges and mealy bugs. Repeat spraying during July for controlling next generation of pests.
- Fixing of plastic bottle traps with wooden blocks impregnated with methyl eugenol to capture fruitflies.
- Soil drenching with 5% NSKE/*Beauvaria bassiana* around the tree trunk to prevent migration of mealy bugs on tree.
- Collection and destruction of fruitfly and stone weevil infested fruits and die-back affected twigs from time to time.
- Mechanical removal of leaf webber larvae and webs from April to Sept-Oct by leaf web removing device developed by Central Institute for Sub-tropical Horticulture, Lucknow.
- Spraying of 2% starch to clear sooty mold.
- Early harvesting of matured fruits to avoid fruitfly infestation and anthracnose.

### 7.1.2. Banana

**Nutrient Management:** 45 days before planting, green manure crop (sunnhemp) can be grown and incorporated in the soil at the time of flowering. Application of FYM at 40 t/ha before planting is recommended. The important yield attributing characters showed a positive trend by the application of vermicompost as rhizome smear. The maximum bunch weight was recorded by the treatment which received rhizome coating with vermicompost and full NPK. The shelf life of the fruit at room temperature was highest in plants which received vermicompost (Table 7.2).

**Table 7.2. Effect of rhizome coating with organic manures and bio-fertilizers on yield and quality of banana**

Treatment	Bunch wt. (kg)	Shelf life (days)	Total sugars (Bricks)
POP of KAU	8.17	3.00	16.62
Full NPK + rhizome coating with <i>Azotobacter</i>	7.00	3.67	18.49
Full NPK + rhizome coating with vermicompost	10.47	4.00	19.18
Full NPK + rhizome coating with <i>Azotobacter</i> + vermicompost	10.08	6.18	22.19



½ N and P, full K + rhizome coating with <i>Azotobacter</i>	7.18	5.67	20.47
½ N and P, full K + rhizome coating with vermicompost	8.80	5.62	20.92
½ N and P, full K + rhizome coating with <i>Azotobacter</i> + vermicompost	8.67	6.00	22.10
Full NPK + vermicompost as organic manure	9.13	6.33	24.28
Full NPK + ½ vermicompost as organic manure	8.83	6.55	22.16
CD at 5%	1.32	0.82	1.17

Application of vermicompost at 5 kg/plant in 3 split doses at 3<sup>rd</sup>, 5<sup>th</sup> and 7<sup>th</sup> month after planting recorded the maximum pseudostem height, girth, number of leaves, total leaf area, number of hands, fingers, length, girth and weight of fingers and bunch weight. The organically grown banana fruits recorded the highest TSS, ascorbic acid and total sugars.

Maximum microbial activity in the rhizosphere of ‘Rasthali’ banana was noticed by application of 2.5 kg each of compost and poultry manure per plant along with 10 g each of *Trichoderma* and phosphate solubilizing bacteria and 20 g of *Azospirillum*.

In ‘Karpooravalli’ banana, combined application of 2.5 kg each of compost and poultry manure, 1 kg each of neem cake and vermicompost per plant at 3, 5 and 7 months after planting recorded maximum fruit yield which was on par with application of 100% inorganic fertilizer. The population of bacteria, fungi and actinomycetes was highest in the above treatment.

Application of neem cake at 1 kg, goat manure at 3 kg/plant 3 times (at planting, 2 and 5 months after planting) and wood ash at 0.5 kg/plant at planting and again 1.5 kg each twice produced banana cv. Nendran bunches weighing 15-20 kg.

Banana plants inoculated with *Glomus fasciculatum* recorded higher yield (33.88 t/ha) as compared to uninoculated ones. Similarly, these plants registered less number of days for shooting (205.96); harvest after shooting (124.69) and total crop duration (329.97) when compared to non AMF plants (Table 7.3).

**Table 7.3. Effect of *Glomus fasciculatum* on the yield of banana.**

Treatment	Yield (t/ha)	
	With <i>G. fasciculatum</i>	Without <i>G. fasciculatum</i>
75% RDF + Microbial consortia-I*	37.29	33.44
50% RDF + Microbial consortia-I	33.18	25.98
Microbial consortia-I	24.95	21.09
RDF (Recommended Dose of Fertilizer)	36.96	33.69
Microbial consortia-II**	37.04	33.41
CD at 5%	3.772	3.772

\***Microbial consortia-I:** Mixture of *Azotobacter chroococcum*, *Azospirillum brasiliense*, *Pseudomonas striata* and *Trichoderma harzianum*.

\*\***Microbial consortia-II:** Mixture of 15 local isolates of microbes in cow dung powder.

**Weed Management:** The major monocot weeds of banana fields are *Cynodon dactylon*, *Cyperus rotundus*, *Digitaria marginata* and *Eleusine aegyptium*, and dicot weeds are *Euphorbia* spp., *Polygonum plebejum*, *Portulaca oleracea* and *Mimosa pudica*.

Banana crop has a superficial root system and thus heavy machinery for its cultivation must be avoided. Manual method of weed control by women labour using hand operated tools is the common method of weed control. Nearly 5-6 hand weedings are essential to keep the field free from weeds. Mulching appears to be another effective method of weed control. Generally organic mulches like dried oak leaves and inorganic mulches like black polythene were most effective. Growing cover crops to suppress weeds is also another way of controlling weeds in this crop. Intercropping with ginger, cowpea, colocasia and tapioca in various varieties of banana have been reported. These intercrops did not have any adverse effect on the growth and yield of banana.

With closer spacing of 1.6 m x 1.6 m, only one intercrop of radish followed by short duration legume like green gram is possible during the initial 3-5 months after planting, the most remunerative combination being green gram-ginger for northern zone giving a net profit of Rs. 7312 and field beans-squashes for southern zone giving Rs. 3330 from intercrops. Intercropping with cowpea drastically reduced weed growth with corresponding higher yield in Robusta

banana. For Basrai banana spaced at 1.8 m x 1.8 m in medium black soil of Gujarat, the most economic intercrop was turmeric. Some farmers take early cauliflower, cabbage, yam and elephant foot yam in early growth period of ratoon crop which are harvested before flowering of banana. Onion was found to be the best intercrop in Orissa. Intercropping of banana with green gram, black gram, soybean, groundnut or cowpea had no significant adverse effect, whereas intercrops gave additional returns, black gram being the best intercrop. In Kerala, intercropping of banana with vegetables such as brinjal, colocasia, yam, dioscorea, chillies and okra in wet-land is common.

**Table 7.4. Intercropping schedules and profit earned in banana fields.**

Intercrops	Sowing time	Harvesting time	Crop duration (days)	Net income (Rs./ha)
<b>Assam, Bihar, West Bengal, Uttar Pradesh and Gujarat</b>				
Toria ( <i>Brassica campestris</i> cv. Pusa Toria)	September	December	70	1248
Radish	October	November	35	1200
Cucumber/Pumpkin	June	September	80	2200
Turmeric	August	March	240	6300
Ginger	August	March	240	6400
Coriander	September	December	95	3340
Groundnut	June	October	100	1025
Bottle gourd	October	January	100	2800
Okra (Pusa Savani)	June	September	105	1050
Maize (Composite)	June	September	102	1221
<b>Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Kerala</b>				
Field bean	September	December	100	1131
French bean (Contender)	September	December	90	2300
Groundnut	June	October	100	1025
French bean (Contender)	October	January	90	2300

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Green pea	September	December	90	1800
Radish	October	November	35	1200
Pumpkin	September	December	85	2200
Field bean	June	September	100	1131
Squash	September	December	45	1200
Radish	November	January	45	1200

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## Pest Management

**Panama Wilt, *Fusarium oxysporum* f. sp. *cubense*:** Flooding of wilt affected areas for 6 months has been reported to give satisfactory results. Use of healthy planting material, removal of infected plants at first sight and avoidance of root injury through intercultural operations helps in reducing the disease incidence. Crop rotation with rice or sugarcane helps in reduction of the disease incidence. Improvement in drainage is also recommended. Application of the capsule filled with *Pseudomonas fluorescens* at 60 mg/capsule is recommended at 2, 4 and 6 months after planting. The modified Panchagavya mixture at 10<sup>1</sup> dilution should be applied (soil drenching) at 2-3 litres/plant. Cvs. Giant Cavendish, Lacatan, Rajavazhai, Peyladen, Moongil, Poovan and Vamanakeli are reported to be resistant to wilt.

**Sigatoka Leaf Spot, *Cercospora musae*:** Removal and destruction of infected leaves, spraying 1% Bordeaux mixture mixed with 2% linseed oil, providing improved drainage, good weed control, removal of suckers and correct spacing helps in reducing the disease incidence.

**Anthraxnose, *Gloeosporium musarum*:** The distal bud should be removed when all the hands have opened to prevent infection. Protective spray of young bunches with 1% Bordeaux mixture controls the disease. Banana bunches should be harvested at correct stage of maturity. Bunches should be stored at 10°C. Cvs. Kothia and Muthia are reported to be fairly resistant.

**Bacterial Wilt, *Ralstonia solanacearum*:** Strict phytosanitary measures are necessary to prevent the spread of the disease. Better drainage can reduce the disease incidence. Growing cover crops like kudzu (*Pueraria phaseoloides*) and sorghum is helpful in reducing the soil inoculum. Bacterization of suckers with *Pseudomonas fluorescens* and use of antagonistic crops such as garlic and sorghum help in

reducing the disease. Bacterial wilt of banana was successfully controlled by incorporation of *Pseudomonas fluorescens*.

**Tip Over, *Erwinia carotovora*:** Seedling treatment (tissue cultured) with *Bacillus subtilis*/*Pseudomonas fluorescens* followed by 3 soil drenches at 15 days interval starting from 20 DAP gave 100% and 87.5% disease control and increased fruit yield by 85.71% and 70% over control.

**Bunchy Top:** Remove the affected plants periodically along with rhizomes and destroy. Select disease-free suckers for planting. Orchard should be kept free of weeds.

**Pseudostem Weevil, *Odioporus longicollis*:** Stem injection of Azadirachtin at 10 ml/litre above the last visible hole in the pseudostem is effective in reducing the weevil damage.

**Nematodes: Burrowing, *Radopholus similis*; Lesion, *Pratylenchus coffeae*; Spiral, *Helicotylenchus multicinctus* and Root-knot, *Meloidogyne* spp.:** Nematode-free suckers should be selected for planting. Corms of suckers should be trimmed carefully to remove the nematode affected necrotic tissue. Deep paring of infected banana suckers used for planting helps to reduce nematode population. The pared sets can be disinfected by dipping them in hot water at 55°C for 25 min. Fallowing for a period of 3 months after banana suppressed the population of *R. similis*. Flood fallowing for about 5 months destroyed not only *R. similis* but also *Fusarium* wilt pathogen. The land should be ploughed thoroughly in summer and left fallow or planted with cover crops/green manure crops (sunnhemp) not affected by nematodes at least for 6 months. Sugarcane has been shown to be a good alternate crop.

Intercropping with *Tagetes*, *Crotalaria* or radish significantly reduced the *R. similis* population. A significant reduction in *Pratylenchus* sp. population (85%) was observed in the banana field where *Tagetes erecta* was grown as intercrop. The yield of the plants significantly increased (12 kg/plant) when intercropped with *Tagetes* spp. compared with the untreated control (9 kg/plant). Intercropping with sunnhemp in banana field was found effective in reducing *R. similis*, *P. coffeae* and *H. multicinctus* population by 38.4%, followed by marigold and cowpea which recorded a 29.0 and 22.3% reduction, respectively.

Covering soil with black polyethylene, sugarcane trash and banana trash are reported to reduce *R. similis* and *Pratylenchus* sp. in banana roots. A significant reduction in the nematode population and increased yield in plants treated with press mud (15 t/ha) or neem

cake (1.5 t/ha) was recorded. Application of press mud is economical and eco-friendly. Neem formulations like Econeem and Nimbicidine showed maximum efficacy in reducing the nematode population with increased plant growth and yield. Application of distillery sludge at 2.5 kg + vermicompost 1 kg + neem cake at 1 kg + poultry manure at 2.5 kg/plant at 3, 5, and 7 months after planting significantly reduced *P. coffeae*, *M. incognita*, *H. multicinctus* and *Heterodera oryzicola* population. It was on par with distillery sludge at 2.5 kg + neem cake at 1 kg treatment. Neem cake at 200 g/plant recorded the maximum increase in plant growth parameters with significant reduction in lesion nematode (*P. coffeae*) population in banana cv. Nendran.

Crop rotation with rice in wetlands and with vegetables, cotton and cereals in garden lands and intercropping of banana with antagonistic crop such as marigold helps to reduce nematode population. Rotation with pangola grass, sugarcane, sorghum, tobacco, cassava significantly increased banana yield and controlled *R. similis*. Rice or green gram after banana suppressed the population of *R. similis*, *P. coffeae* and *H. multicinctus*. Banana intercropped with sunnhemp reduced *R. similis* population in root and increased plant growth and yield. After destroying the infested plantations, planting of sugarcane or cover crops like *Panicum maximum* var. *trichoglume* and *Phaseolus purpureus* did not support *R. similis* population.

Application of the fungal antagonists like *Paecilomyces lilacinus*, *Trichoderma viride*, *Pochonia chlamydosporia*; arbuscular mycorrhizal fungus like *Glomus fasciculatum* and bacterial antagonist like *Pasteuria penetrans* are effective in reducing the nematode population in soil and roots of banana. Application of *Trichoderma viride* at 20 g/plant at the time of planting and repeated 3 months after planting is effective in controlling *P. coffeae* and *M. incognita* as well as reducing the incidence of Panama wilt in banana.

Soil application of *Pseudomonas fluorescens* at 20 g/plant (2.5 x 10<sup>8</sup> cfu/g) was effective in increasing the plant growth parameters (pseudostem height and girth, number of leaves, root length and weight) and in reducing the nematode population in soil (62.34, 67.12 and 58.87% of *R. similis*, *P. coffeae* and *H. multicinctus*, respectively) and roots (60.35, 62.00 and 56.54% of *R. similis*, *P. coffeae* and *H. multicinctus*, respectively).

Integration of neem cake at 400 g per plant with *P. penetrans* at 100 g soil (300 spores/g)/*T. harzianum* / *T. viride* at 250 g / plant while planting was found effective in reducing nematode population both in soil and roots of banana by more than 50 per cent and increased plant growth parameters. Repeat the treatment 4 months after planting.

Application of neem cake at 500 g along with *G. mosseae* was found to be most effective in reducing the nematode population both in soil and roots of banana.

### 7.1.3. Citrus

## Nutrient Management

**Table 7.5. Requirement of FYM / compost in lime and lemon.**

Time of application	Requirement of FYM / compost	
	Kg / plant	Tonnes / ha
Before planting	15	4.1
After planting: First year	5	1.4
Second year	10	2.8
Third year	15	4.1
Fourth year	20	5.5
Fifth year	25	6.9
Sixth year & later	30	8.3

**Table 7.6. Requirement of FYM / compost in sweet orange and mandarin.**

Time of application	Requirement of FYM / compost	
	Kg / plant	Tonnes / ha
Before planting	50	13.8
After planting: Second year	10	2.8
Third year	20	5.5
Fourth year	30	8.3
Fifth year & later	40	11.1

**Weed Management:** The predominant monocot weeds of citrus fields are *Cynodon dactylon*, *Cyperus* spp., *Digitaria marginata*, *Eleusine indica*, *Setaria* spp. and *Imperata cylindrica*, and dicot weeds are *Amaranthus caturus*, *Bidens pilosa*, *Lagasca mollis*, *Acanthospermum hispidum*, *Euphorbia* spp., *Borreria articularis* and *Evolvulus alsinoides*.

In young citrus orchards, manual method of weed control using hand operated implements like khurupi and cutlasses is very popular with growers. In established orchards, cultivation and hoeing helps in eradication of weeds and conservation of soil moisture. In closely

planted orchards, cultivation is done by hoeing with the spade. Three to four ploughings in a year in a closely planted orchards is enough. Mulching the citrus basins with organic and inorganic materials is another common method of controlling weeds. Polythene mulch resulted in better growth of seedlings. In old orchards, weed control is carried out by ploughing or tillage. Growing cover crops to reduce the density of weeds in the inter-rows is also popular. Intercropping also brings more money to the grower and improves the health of the trees. For summer season, vegetables like tinda, bottle gourd, bitter gourd, onion, chillies, green gram, cowpea and cotton are recommended for growing in 3 to 4 years old citrus orchards. In winter season, vegetables like pea, turnip, cauliflower, carrot, radish and chickpea are grown. Intercropping of citrus with green manure crops is helpful in maintaining organic matter content and moisture in soil besides improving N content to a great extent. Growing of vegetables and fodder crops like bean, carrot, tomato, berseem and senji (*Melilotus parviflora*) in orchards near cities, whereas in those located away from the market, onion, potato, chilli, pulses and kohl rabi for rabi season and bottle gourd, bitter gourd and okra during kharif season were recommended. In soils deficient in organic matter and N content, berseem, senji, chickpea, pea, cluster bean and cowpea were suggested. Cost-benefit analysis of some intercropping systems revealed that potato was more profitable giving Rs. 42,000 net profit/ha followed by cabbage (Rs. 20,000/ha) and pea (Rs. 16,500/ha) compared with no intercropping (Rs. 12,516/ha). Cover cropping with leguminous forage crops like *Trifolium alexandrium* and *Phaseolus trilobus* was found highly profitable as short duration crops. For longer periods, Lucerne was of some value. *Stylosanthes* cover crop had no harmful effect on kinnow and lemon trees and gave 21.2 t/ha fodder.

Mulching with alkathene films, wheat bran, rice husk or paddy straw also helps in keeping the weeds under check.

## Pest Management

**Cottony Cushion Scale, *Icerya purchasi*:** It can be effectively controlled by the lady bird beetle, *Rodolia cardinalis*. The fascinating success of this scale control has established biological control as a valid method of pest control.

**California Red Scale, *Aonidiella aurantii*:** Release of the predator, *Chilicorus nigrita* at 10-15 beetles/tree controls red scale. Releasing of the parasitoid, *Aphytis melinus* at 2000/tree is recommended for the suppression of the red scale. Neem/pongamia oil 2% can be sprayed thrice at 15 days interval.



**Green Scale, *Coccus viridis*:** The parasitoids, *Aneristus ceroplastae* and *Encyrtus lecaniorum* cause up to 43% parasitism in the field. Two coccinellid predators, *Chilicorus nigrita* and *C. circumdatus* play a major role in bringing down the population of green scale on acid lime. *Verticillium lecanii* at  $3 \times 10^8$  spores/ml is found effective in reducing the population of green scale in humid areas. Release of *Cryptolaemus montrouzieri* at 10 beetles/tree was found to be highly effective in suppressing green scale.

In mixed planted orchards (citrus + coffee) with more shade and less light interception (900-1400 lux), spray of *V. lecanii* at  $10 \times 10^6$  spores/ml + 0.05% teepol was highly effective against green scale both in citrus and coffee. In pure citrus orchards, the combination was only effective during the rainy season.

**Blackfly, *Aleurocanthus woglumi*:** The pest is regulated by parasitoids like *Amitus hesperidium* and *Encarsia clypealis* up to 80-90% in Karnataka and Maharashtra. At Gawahati, *Prospaltella divergence* and *Encarsia merceti* are dominant parasitoids accounting for 90% of the total parasitoids. NSKE spray reduces blackfly population. *Chrysoperla carnea* or *Mallada boninensis* can also be released at 10-15 eggs/ 1<sup>st</sup> instar larvae/plant. Combined release of *M. boninensis* (30 larvae /tree) and *Tamarixia radiata* (40 adults /tree) resulted in 28-30, 42-45 and 23-26% reduction in blackfly, psylla and leaf miner population, respectively.

**Mealybugs, *Planococcus citri*, *P. lilacinus*, *Nipaecoccus viridis*:** Release of the parasitoid, *Leptomastix dactylopii* at 5000/ha is recommended for suppression of *P. citri* population. The parasitoid, *Tetracnemoidea indica* checks *P. lilacinus* population. Release of *T. indica* or *Cryptolaemus montrouzieri* at 10 beetles/tree is recommended for the suppression of *P. lilacinus*. *C. montrouzieri* is also recommended for the control of *N. viridis*. *Coccidoxenoides peregrina* was found to parasitize both male and female *P. citri* (nymphal stages including crawlers). The parasitoid was most effective at Hessaraghatta (Karnataka) in July-August. The mealybug was completely suppressed by end of April mainly due to the activity of *C. peregrina* which appeared in February. From acid lime fruits infested with *P. citri*, only *C. peregrina* emerged in large numbers.

**Citrus Butterfly, *Papilio demoleus*:** Collection and destruction of caterpillars and conservation of indigenous braconid larval parasitoid, *Distatrix papilionis* keeps the pest under check. The parasitoids, *Trichogramma chilonis* and *D. papilionis* account for a cumulative parasitism of 88%.

Application of *Bacillus thuringiensis* var. *kurstaki* at 1 ml/l + spreader is very effective for the control of citrus butterflies. The susceptibility of citrus caterpillar to 'Bactospeine' has been reported.

**Psylla, *Diaphorna citri*:** The eulopid, *Tamarixia radiata* is the most common parasitoid of citrus psylla causing up to 95% parasitism in Punjab and 30-90% in Maharashtra.

**Leaf Miner, *Phyllocnistis citrella*:** Spraying 4% NSKE gives control of leaf miner. Spraying with fish oil resin soap and nicotine sulphate (1:1) + 50 parts of water in the early stages of infestation or even sprinkling of neem cake solution (250 g neem cake in 5 litres of water) on trees helps in reducing the pest population. The parasitoid, *Tetrastichus phyllocnistoides* and *Ageniaspis* sp. cause up to 80% parasitism in Punjab. Release of *Mallada boninensis* at 20-50/plant is recommended for reducing the leaf miner infestation.

**Aphid, *Toxoptera aurantii*:** Release of *Cheilomenes sexmaculata* at 50/plant is recommended for the control of aphids.

**Whitefly, *Dialeurodes citri*:** Do not plant densely in the orchard. Provide good drainage. The parasitoid, *Encarsia lahorensis* along with the coccinellid predators and fungus, *Aschersonia papilata* keeps the whitefly population under check.

**Fruit Sucking Moth, *Otheris materna*. *O. fullonica*, *O. ancilla*, *Achoea janata*:** Clean cultivation and removal of alternate hosts are of primary importance. The fruit damage can be minimized by bagging the individual fruits with polmyrah baskets. Use light traps for attracting the adults and kill them.

**Bark Eating Caterpillar, *Inderbela* sp.:** Inject petrol or kerosene (10 ml) into the holes and plug the hole with mud.

**Stem Borer, *Chelidonium* sp., *Chloridolum* sp., *Nupserha* sp.:** Chip off the affected new shoots. Cut and burn the affected branches. Inject petrol or kerosene (10 ml) into the holes and plug the hole with mud. Beetles should be removed by jerking the trees, collected and destroyed. A wad of cotton is soaked in kerosene or petrol, so as to absorb about 10 ml and then pushed into the mouth and plugged with mud.

**Gummosis, Leaf Fall and Fruit Rot, *Phytophthora nicotianae* var. *parasitica*, *P. palmivora*:** Use of disease-free planting material, avoiding water stagnation in contact with susceptible portions of the bark above the bud union by providing good drainage, collection and burning of diseased leaves and fruits and use of resistant rootstocks such as Trifoliate orange, Troyer citrange, Rangpur lime and Cleopatra mandarin reduce the disease incidence.

Scrape off the affected parts and apply Bordeaux paste. Drench the soil around the tree covering 1 m diameter area with 20 litres of 1% Bordeaux mixture/tree at an interval of 1 month from July to September. Healthy trees should be protected by pasting the trunk with Bordeaux paste up to a height of 50-75 cm above the ground level once in a year.

Soil application of *Trichoderma* spp. along with organic matter in the ratio of 1:40 at 2 kg/plant or FYM enriched with *Trichoderma* spp. at 2 kg/plant and application of Bordeaux paste to the tree trunk before onset of monsoon also helps in reducing the disease incidence. The mycorrhiza, *Glomus fasciculatum* is effective against the pathogen.

**Anthracnose, *Colletotrichum gloeosporoides*:** Dead twigs should be pruned and destroyed during winter and sprayed with 1% Bordeaux mixture in February, March and September to reduce fruit drop. Cut ends should be protected with Bordeaux paste.

**Scab, *Elsinoe fawcetti*:** Spraying with 1% Bordeaux mixture gives effective control.

**Canker, *Xanthomonas compestris* pv. *citri*:** Pruning of infected twigs before monsoon and application of 1% Bordeaux mixture are found effective. Application of neem cake solution on the foliage can reduce the canker. Spraying 1% Bordeaux mixture is found effective for protecting the leaves and fruits. Acid lime cv. 'Rasraj' is resistant to canker. Seedless lime is also resistant to canker.

Application of 2 phylloplane antagonists i.e. *Bacillus subtilis* and *Aspergillus terreus* isolated from citrus leaves were effective in reducing the disease incidence.

**Soft Rot, *Aspergillus niger*:** In lemons treated with *Bacillus subtilis* (AF 1) cells, only 3-4% fruits showed development of soft rot in comparison to 100% in control.

**Greening:** Removal of greening affected trees and replanting with disease-free budded plants raised on improved rootstock. Locate citrus nurseries where psyllid vector is virtually absent. Certified pathogen-free bud wood should be used for propagating nursery stock. The bud wood can be exposed to 47°C for 2 to 4 hours.

**Tristeza Virus:** Use of disease-free planting material on tolerant rootstocks such as Rough lemon and Cleopatra mandarin, use of cross protected plants with mild strain and use of nucellar seedlings which are virus-free and true to type are some of the recommended practices to control the disease.

**Citrus Nematode, *Tylenchulus semipenetrans*:** Seedling bare root dips in hot water at 45°C for 25 min. eliminated *T. semipenetrans* infection. Irrigation of citrus orchards with sewage water reduced the citrus nematode population to a very low level. The rootstocks Trifoliate orange, Troyer Citrange and Swingle citrumello are resistant to *T. semipenetrans*.

Management of the citrus nematode based on the application of neem cake and castor cake both at 10 kg per plant along with a nematophagous fungus *Paecilomyces lilacinus* at 250 g (grown on paddy seeds) per plant 3 times in a year at 15 cm depth and 50 cm away from the trunk was found to be extremely effective in reducing the citrus nematode population with a consequent increase in the growth of acid lime trees. Integration of *Paecilomyces lilacinus* with neem cake/ castor cake gave effective control of *T. semipenetrans* on acid lime.

*Trichoderma harzianum* in combination with neem, karanj and castor oil cakes was effective in increasing the growth of acid lime trees and reducing the citrus nematode population both in soil and roots. The parasitization of citrus nematode females with *T. harzianum* increased in the presence of the oil cakes.

Incorporation *Verticillium lecanii* with neem cake facilitated the effective management of *T. semipenetrans* on acid lime.

Inoculation of endomycorrhiza, *Glomus fasciculatum* in the soils amended with neem cake was found effective for the management of *T. semipenetrans* on acid lime. This strategy can help in combating the menace of citrus nematode at nursery stage and also provide highly mycorrhizal seedlings of acid lime for transplanting in the main field for the management of *T. semipenetrans* under field conditions.

**Root-knot nematode, *Meloidogyne javanica*, *M. indica*:** Growing sunnhemp in tree basin reduced the population of root-knot nematodes. Neem cake at 20 kg/basin of acid lime trees reduced the population of *M. javanica* by 25% three months after application. Its repeated application once in 4 months significantly reduced the population of root-knot nematodes. The rootstocks Trifoliate orange, Troyer citrange, Rangpur lime, Cleopatra mandarin and Rough lemon are highly resistant to *M. javanica*.

#### 7.1.4. Sapota

**Nutrient Management:** Application of FYM/ compost at 50 kg/pit before planting (5 t/ha) and vermicompost every year at 25 kg/plant (2-3 t/ha) is recommended.

**Weed Management:** The predominant weeds of sapota fields are *Setaria glauca*, *Digitaria marginata*, *Andropogon* sp., *Heteropogon contortus* and *Cymbopogon caesius* among monocots, and *Bidens pilosa*, *Blumea* sp. and *Oxalis corniculata* among dicots.

The removal of weeds in young sapota orchards is done manually using small hand operated implements. In established orchards, with enough space in between plants, the removal of weeds and loosening of the soil is done by ploughing or harrowing once or twice a year either by bullock drawn implements or motor run tractors or tillers. Weed growth is generally poor under the dense spread and shade of trees. Intercropping with banana, papaya, pineapple, cocoa and vegetables like cowpea, French beans, tomato, brinjal, cabbage, cauliflower, cucurbits and peas in inter rows and turmeric and ginger in basins may also be taken up for the first 6 to 10 years.

## Pest Management

**Green Scale, *Coccus viridis* and Green Shield Scale, *Chloropulvinaria psidii*:** The green scale is suppressed by *Chilocorus nigrita* and *C. motrouzieri*, while green shield scale is controlled by *C. motrouzieri*.

**Mealybugs, *Planococcus citri*, *P. lilacinus*:** Spray 500 g nicotine sulfate (40%) and 2 kg soap mixed in 350 litres of water. The two encyrtids, *L. dactylopii* and *Coccidoxenoides perigrinus* are able to suppress the population of *P. citri*, while *C. montrouzieri* is highly effective in checking the population of *P. lilacinus*.

**Leaf Miner, *Acrocercops gemoniella*:** Spray 500 g nicotine sulfate (40%) and 2 kg soap mixed in 350 litres of water.

**Fruit Rot, *Phytophthora* sp.:** Clean the garden and burn the fallen leaves, fruits, etc. Drain out excess water. Spray 1% Bordeaux mixture.

**Dry Root Rot/Wilt, *Fusarium solani*:** Soil application of *Trichoderma harzianum* helps in managing the disease.

### 7.1.5. Papaya

**Nutrient Management:** Planting pits (1.8 x 1.8 m) are filled with red earth and FYM. Application of FYM/ compost at 10 kg/ plant (20-30 t/ha) is recommended.

Inoculation of *Glomus fasciculatum*, *Sclerocystis dussii* and *Acaulospora laevis* resulted in an increase in chlorophyll and leaf nutrient contents. The maximum leaf nutrient and chlorophyll

contents were noticed in *G. fasciculatum* inoculated plants followed by *S. dussii* and *A. laevis* (Table 7.7).

**Table 7.7. Effect of different AM Fungi on chlorophyll and nutrient contents.**

Treatment	Total chlorophyll (mg/g)	Nutrients (dry weight basis)					
		N (%)	P (%)	K (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)
Uninoculated control	2.27	0.57	0.04	0.37	57.00	43.00	86.40
<i>Glomus fasciculatum</i>	2.64	0.92	0.07	0.52	62.00	40.41	183.40
<i>Sclerocystis dussii</i>	2.63	0.93	0.07	0.42	67.10	53.60	108.66
<i>Acaulospora laevis</i>	2.20	0.74	0.06	0.38	60.90	25.00	91.10
CD at 5%	0.025	0.092	0.003	0.086	3.460	16.622	25.556

**Weed Management :** The important monocot weeds that occur in papaya field are *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Chloris barbata* and *Digitaria marginata* and dicot weeds are *Parthenium hysterophorus*, *Lagasca mollis*, *Croton bonplandianum*, *Euphorbia geniculata*, *Phyllanthus niruri* and *Evolvulus alsinoides*.

The main method of weed control practiced in papaya is by employing women labour to remove the weeds manually by using khurupi. Spades are used for hoeing in the basins. Even shallow ploughing by bullock drawn implements can be done. Six weeding are required to suppress weeds in papaya. The old dried leaves and other organic materials are used for mulching in the basins of papaya. Growing cover crops in papaya orchards is another way of controlling weeds. Low growing vegetables like chillies, onion, cabbage, cauliflower, radish and tomatoes can be grown as intercrops for about 6 months with advantage.

## Pest Management

**Damping-off, *Pythium aphanidermatum*, *Phytophthora parasitica*:** Seedlings should be raised in well drained nursery soil. Diseased plants should be removed and burnt. Soil drenching with 1% Bordeaux mixture reduce the disease incidence. Soil treatment with neem cake along with *T. harzianum* gave good germination and seedling stand.

**Collar Rot:** Disease intensity was minimum in *Glomus fasciculatum* inoculated plants (6.25%) followed by *Sclorocystis dussii* (25%). Plant mortality was least in *G. fasciculatum* + vermicompost (25%) followed by *G. fasciculatum* (31.35%). The least infection was recorded in *G. fasciculatum* + vermicompost (7.01 cm) which was at par with *S. dussii* (7.74 cm) and *S. dussii* + vermicompost (8.27 cm).

**Stem and Fruit Rot, *Rhizoctonia solani*:** Maintain good drainage system in the orchard. Remove the diseased plants and destroy them. Apply Bordeaux paste on the affected plant parts. Spraying with 6-6-50 Bordeaux mixture with sticker on stems and drenching the soil around the stem repeated at 15-20 days interval gave good stand of the crop.

**Anthracnose, *Gloeosporium papaye* (*Colletotrichum gloeosporoides*):** Removal of infected leaves is essential for sanitation. Hot water treatment of fruits at 45°C for 30 min protects the fruits from the disease.

**Powdery Mildew, *Oidium caricae*:** Spraying with 0.3% wettable sulphur at 8-10 days interval controls the disease.

**Blight, *Phytophthora nicotianae* var. *parasitica*:** Prompt and complete removal and destruction of infected plants and fruits from the orchard is very important.

**Mosaic :** Planting disease-free seedlings, rouging of diseased plants and spraying groundnut oil to inhibit transmission help in reducing the incidence of mosaic.

**Ring Spot:** Papaya nursery should be raised under insect proof net to avoid early infection on seedlings. Roguing must be followed right from the seedling stage. Infected plants should be uprooted and burnt. Yellow sticky traps should be placed along the borders to trap the aphid vectors. Rows of barrier crops like maize and sorghum should be raised along the borders to prevent horizontal movement of aphids. Spray 0.4% Nimbecidine, groundnut oil at 20 ml/l. Avoid cultivation of cucurbits in and around papaya orchards. Papaya cv. Rainbow is resistant to ring spot virus.

**Root-knot Nematode, *Meloidogyne incognita*:** Hot water treatment of root-knot infected seedling roots at 50°C for 10 min gave satisfactory control of root-knot nematodes.

**Reniform Nematode, *Rotylenchulus reniformis*:** Papaya cvs. CO-1, CO-2, CO-3, CO-4, CO-5, Thailand and Giant are resistant to the reniform nematodes.

### 7.1.6. Pineapple

**Nutrient Management:** Application of FYM/ compost at 30 t/ha is recommended.

**Weed Management:** The predominant weeds are *Cynodon dactylon*, *Cyperus* spp. and *Digitaria marginata* among monocots, and *Lagasca mollis*, *Portulaca oleracea* and *Mollugo pentaphylla* among dicots.

The spaces between inter-rows and plants are weeded by men and women labourers using hand operated implements like khurupi (hand hoe) and cutlasses. Mechanical weed control using spade is done by men labourers when earthing up operation is done to cover the shallow exposed roots of pineapple plants after 2-3 months of planting. Mulching with black polythene is a very effective method of weed control.

### Pest Management

**Mealybug, *Dysnecoccus brevipes*:** Destroy grasses and other monocot weeds which serve as alternate hosts for the pest.

**Base Rot, Fruit Rot and Leaf Spot, *Ceratocystis paradoxa*:** Destruction of affected plants is foremost. For fresh planting, suckers should be selected from the disease-free fields. Dipping of suckers in 1% Bordeaux mixture before planting has been advocated. The stem end rot is checked by exposure of the harvested fruits to the sun for 2 hours.

**Heart or Stem Rot, *Phytophthora nicotianae* var. *parasitica*:** Dipping of suckers in 1% Bordeaux mixture and planting in well drained soil can minimize the disease incidence.

**Root-knot Nematode, *Meloidogyne incognita*:** Yield increases have been observed when planting was done in a field, which was previously had pigeonpea, owing to decrease in infestation by *M. incognita*. Crop rotation with pangola grass resulted in elimination of *M. incognita* after 1 year.

### 7.1.7. Litchi (*Litchi chinensis*)

**Weed Management:** Litchi orchards need at least 3 to 4 cultivations in a year to keep them weed-free. As litchi trees have shallow roots, deep tillage must be avoided. Growing of intercrops like legumes during pre-bearing stage would bring more income to the grower besides improving the health of trees. In Bihar, intercrops like



turmeric, ginger, pointed gourd, sweet potato, tomato, radish, cabbage, turnip and brinjal have been suggested. In young litchi orchards, papaya and banana are suggested as fillers; cucurbits like pumpkin, cucumber, ridge gourd, bitter gourd and leguminous crops like green gram, black gram and cowpea during summer; and radish, beet root, turnip, cauliflower and carrot for rabi season are recommended.

## Pest Management

**Mealybugs:** Fasten 25 cm wide alkathene sheet (400 gauge) around the tree trunk about 30 cm above the ground level to prevent crawlers of freshly hatched 1<sup>st</sup> instar nymphs climbing during Nov-Dec.

**Bark Eating Caterpillar, *Inderbela teraonis*, *I. quadrinotata*:** Same as in citrus bark eating caterpillar.

### 7.1.8. Strawberry

**Weed Management:** Weeds like *Cyperus compressus*, *Digitaria* and *Eleusine indica* are common in strawberry. Mulching with black polythene or hay is an important cultural operation not only to check weed growth but also to regulate soil temperature and improve soil structure.

The weeds are controlled by light hoeing as and when the runners form. When plants blossom in spring, straw is used in the beds of the plantation to keep the fruits off the soil. After fruiting, straw and weeds are removed, and all runners are cut off. Hoeing is continued. Strawberry is rotated with vegetables every 3 years. An opaque plastic mulch suppressed weeds, conserved moisture, increased soil temperature in cool weather and reduced them in warm weather and increased the yield in strawberry. Black polythene mulch controlled annual weeds well.

## Pest Management

**Leaf Spot, *Mycosphaerella fragariae*:** Plant in well drained soil, keeping down weeds. Wider spacing can reduce the leaf spot incidence. The older leaves of the runner plants should be removed before fruit setting.

### 7.1.9. Mulberry

**Weed Management:** During the initial stages of plant establishment in field, weed growth should be kept to the minimum so that the growing young plants are not smothered by weeds. At least 2 hand weedings should be carried out during the first six months after

planting the cuttings. Periodical intercultivation should be restored to loosen the soil for better aeration, retention of soil moisture and stimulation of plant growth. In row system of mulberry planting, power tiller or bullock power with mould board plough may be used for removing weeds.

## Pest Management

**Stem Borer:** Same as in Fig.

### 7.1.10. Raspberry

**Weed Management:** The traditional intensive cultivation gave control of weeds and produced tallest canes. Reduced system like rotary cultivation + hoeing outyielded non-cultivation system which depended on herbicide alone.

### 7.1.11. Karonda

**Nutrient Management:** Karonda plants respond well to organic manuring when applied at 15-20 kg/plant/year preferably in the beginning of monsoon period (Table 7.8).

**Table 7.8. Yearwise requirement of FYM.**

Age of tree (year)	Requirement of FYM (kg)
1	10
2	15
3	20
4	25
5 and above	30

### 7.1.12. Date Palm

**Weed Management:** For controlling weeds and to conserve soil moisture, the land should be stirred throughout the year by manually or mechanically. Weed control is also done by spraying oils in winter and cover crops in summer. Mulching with black polythene and local weeds is also a common practice. Fodder crops and vegetables are taken as intercrops in date plantation. Mixed cropping with *Citrus medica*, guava, sapota and mango is also common.

## 7.2. Sub-Tropical Fruits

### 7.2.1. Grapevine

**Nutrient Management:** Application of FYM/ compost at 20 kg/ vine before planting (5 t/ha) and every year at 25 kg/vine along with 1 kg each of neem and honge cakes is recommended. The planting pits should be filled up with alternate layers of FYM/ compost, pongamia/ glyricidia leaves, bone meal (400 g) and neem cake (1 kg) per pit.

Application of FYM at 30 t/ha at summer pruning and 20 t/ha at winter pruning is recommended.

**Weed Management:** The common weeds present are *Polygonum plebium*, *Euphorbia geniculata*, *Amaranthus viridis*, *Portulaca oleracea*, *Oxalis* sp. and *Mollugo pentaphylla* among dicots, and *Cynodon dactylon*, *Cyperus rotundus*, *Digitaria marginata*, *Eleusine indica* and *Setaria glauca* among monocots.

The usual method of weed control is manual by employing women labour. They use khurupi and spade to remove the weeds. Mechanical method of weed control by using bullock drawn implement is very common. Motor run tractors and power tillers are used to cultivate the inter rows of grape. Mulching with sarkanda, wheat and rice straw, wheat bhusa, sugarcane trash, dried leaves, saw dust and black polythene film have been advocated for conserving soil moisture and for fostering rapid growth of plants. Cover cropping is another way of reducing weed growth in vineyards. The cover crops grown in grape orchards are cowpea, French beans, cucurbits, sunnhemp and green gram. Intercropping with some vegetables has been suggested during the first 2 years after planting.

### Pest Management

**Pink Mealybug (PMB), *Maconellicoccus hirsutus*:** Release of 100 day-old adult beetles of *C. motrouzieri* at 3000/ha (10/vine) resulted in significant reduction of mealybug population 30 days after release. A peak of 12.7 grubs/vine was recorded on 60<sup>th</sup> day after release. The predator has given good control of mealybugs in Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu. Tree like mango and hibiscus hedges were found ideal for multiplication and relaying predatory ladybirds (*C. motrouzieri* and *Scymnus coccivora*) to the new areas. The PMB indicator plant like okra may be planted and explored as trapping source for conservation of predatory ladybirds. Predators (*C. motrouzieri* and *Scymnus coccivora*) and parasitic wasp, *Anagyrus kamali* are effective against PMB. Growing

short duration crops like onion, okra, corn, cucumber, capsicum, chilli, brinjal, yam, sweet potato, pumpkin and long duration crops like sugarcane and banana are possible in the PMB - hot spot area provided ladybirds have established and the farm area is surrounded by forage plants like glyricidia and ornamentals like oleander alongside a few coconut trees. Since PMB attacks graminaceous weeds including congress grass (*Parthenium hysterophorus*), the residue of PMB remains either on glyricidia or congress grass which sustain *C. motrouzieri* population. The okra (the most susceptible plant) grown in vicinity gets infestation so late, by the time its harvesting is over and the plant residue are able to create balance between PMB and predator population. Okra acts as a trap crop which may be used even for the field multiplication of ladybirds if grown at different intervals.

*Anagrus dactylopii* was the principal parasitoid causing a mean parasitization of 62.5% in nature. Higher percentage of parasitization and more female progeny production were observed when 3<sup>rd</sup> instar and adult female mealybugs were exposed to the parasitoid.

Release of predatory beetle, *Cryptolaimus motrouzieri*, keeping the surroundings of the trees neat and clean and turning the soil around the trees up to September helps in reducing the pest incidence.

**Thrips, *Rhipiphorothrips cruentalis*, *Scirtothrips dorsalis*:** Spinosad 45% EC (chitin inhibitor) at 0.25 ml/l was most effective for the management of thrips especially in exportable grapes because of shorter pre-harvest interval and safety to natural enemies especially to *Cryptolaemus montrouzieri*.

**Lantana Scale, *Hemiberlesia lataniae*:** Release of *Chilocorus nigrita* helps in bringing down the scale population in grapevine.

***Spodoptera litura* and *Helicoverpa armigera*:** Application of *Sl* NPV, *Ha* NPV or *Bacillus thuringiensis* gave effective control of the above pests.

**Flea Beetle, *Scelodonta strigicollis*:** Remove the hollow bark from the plants. Mulching frequently in July-September reduces the population of grubs and pupae in soil. Neem and castor cakes both at 5 to 7.5 t/ha and tobacco waste at 2.5 t/ha were effective against flea beetle and all were at par.

**Leaf Roller, *Sylepta lunalis*:** Minor infestation can be controlled by picking and destroying the attacked leaves along with caterpillars inside.

**Bat, *Cynopterus sphinx*:** Netting all round the orchard and covering canopy gaps with twigs, beginning at fruit maturity, effectively prevents birds damage.

**Downy Mildew, *Plasmopara viticola*:** Fallen leaves, twigs, flowers and berries should be collected and burnt. Canes should be kept above the ground level and free circulation of air should be allowed by providing proper spacing and pruning. Spraying 1% Bordeaux mixture mixed with groundnut oil, coconut oil and neem oil reduces infection. The biocontrol agent, *Fusarium proliferatum* is effective against downy mildew under field conditions. Cvs. Amber Queen, Cardinal Champa, Champion, Excelsior, Red Sultana are reported resistant.

**Powdery Mildew, *Uncinula necator*:** The diseased plant parts should be removed and destroyed. Overcrowding of vine should be avoided by thinning of leaves to improve ventilation. Avoid pruning during sensitive periods of first and second fortnights of November. Spraying of 0.2% wettable sulphur gives effective control. *Ampelomyces quisqualis* grown on nutrient-treated cotton twine suspended over grapevines suppressed powdery mildew throughout the rainy season (pycnidiospores of mycoparasite suppressed powdery mildew). Grapevine cvs. Red Sultana, St. George and 1613 are highly resistant.

**Anthracnose, *Elsinoe ampelina*:** Removal and destruction of all the diseased twigs after pruning is the foremost requirement. Spraying 1% Bordeaux mixture at bud swell, fruitlet stages and 21 days after the second spray helps to reduce the disease incidence. Cvs. Angur Kalan, Bharat Early, Delight, Camphor Ash, Naibel, Concord, White Beauty Seedless, Muscat Hamburg (Gulabi), Himrod, Hussaini, Karachi Niagra, Khalili, Schuyler White, St. Valior, White Muscat, Large White, Golden Queen, Bangalore Blue, Isabella and Golden Muscat are resistant.

**Black Rot, *Gugnardia bidwelli*:** Collection and destruction of diseased leaves and berries, spraying with 1% Bordeaux mixture when the new shoots are 15 to 25 cm long and repeating the sprays before and after bloom helps in reducing the disease incidence.

**Grey Mold Rot, *Botrytis cineraria*:** Green pruning for the removal of leaves around the clusters and thinning of berries reduced the severity of grey rot. *Trichoderma harzianum* was found very effective against grey rot.

**Dead Arm, *Phomopsis viticola*:** The pruned canes should be collected and destroyed. The dead canes or arms should be pruned well beyond the region of healthy tissue. Cut ends should be applied with Bordeaux paste. Spraying of 1% Bordeaux mixture at fortnightly intervals reduces the disease incidence.

**Fruit Rot and Leaf Spot, *Greenaria vivicola*:** The pruned canes should be collected and destroyed as the fungus survives on pruned canes which serve as primary source of inoculum.

**Canker, *Xanthomonas campestris* pv. *viticola*:** Use of disease-free cuttings for planting, destruction of infected plant parts, avoiding excess use of irrigation water and late October pruning helps to reduce the incidence of canker.

**Root-knot Nematode, *Meloidogyne incognita*:** Hot water treatment of lightly root-knot infected rooted cuttings at 50°C for 10 min before planting. Intercropping with marigold, asparagus or sunnhemp gave effective control and resulted in increased fruit yield. The rootstocks 1613, Dogridge, Saltcreek, Harmony and Freedom are resistant. Grape cvs. Black Champa, Cardinal and Banquabad are also resistant to root-knot nematodes. Application of neem cake at 200 g and *Paecilomyces lilacinus* at 50 g/vine helps in improving vine growth and yield.

***Meloidogyne incognita* and *Fusarium moniliformae* disease complex:** Soil application of *Pseudomonas fluorescens* at 100 g/vine gave effective management of disease complex and improved the plant stand by reducing the nematode population, root gall index and % disease incidence (15.67%). This treatment also increased the number and weight of fruit bunches (17.83 and 90.50%, respectively) and fruit quality (more TSS – 13.53 Brix, TSS : Acid ratio – 14.87, lower acidity – 0.91%).

### 7.2.2. Guava

**Nutrient Management:** Application of FYM/ compost at 25 kg/plant before planting (7 t/ha) and every year at 25 kg/plant (7 t/ha) is recommended.

Application of the bio-fertilizer, *Azotobacter* on 3-year-old guava cv. Allahabad Safeda, gave maximum fruit yield (92 fruits/plant and 13.69 kg/plant) (Table 7.9).

**Table 7.9. Effect of different organic/biodynamic treatments on yield of guava.**

Treatment (Dose/tree)	No. of fruits/tree	Fruit yield (kg/tree)
Vermicompost – 5 kg	72	11.45
Vermiwash + 10 kg FYM	44	5.90
BD 500 + 10 kg FYM	58	8.70

CPP – 500 g	50	8.61
20 kg FYM + 250 g <i>Azospirillum</i>	63	7.88
20 kg FYM + 250 g <i>Azotobacter</i>	92	13.69
10 kg FYM + 5 kg Celrich	61	9.66
350 g N + 200 g P <sub>2</sub> O <sub>5</sub> + 350 g K <sub>2</sub> O	48	8.09
CD at 5%	24.81	5.18

Mulching of soil with banana leaf mulch gave highest fruit yield (11.8 kg/plant) followed by black polythene film mulch (10.0 kg/plant). The total fungal count in soil was found highest in banana leaf mulch ( $9.1 \times 10^4$  cfu/g soil) followed by dry grass mulch ( $8.7 \times 10^4$  cfu/g soil). The bacterial counts were highest in banana leaf mulch ( $1.4 \times 10^8$  cells/g soil) followed by black polythene film mulch ( $1.2 \times 10^8$  cells/g soil). The moisture per cent was highest in black polythene film mulch (74.3%) followed by paddy straw mulch (71.0%) and banana leaf mulch (70.0%). Banana leaf mulch was proved to be better mulch as higher yield, higher fungal and bacterial counts along with higher moisture improved the biological properties of the soil.

**Weed Management:** The problematic weeds of guava fields are *Cynodon dactylon* and *Cyperus rotundus* among monocots, and *Bidens pilosa*, *Tridax procumbens*, *Acanthospermum hispidum* and *Lagasca mollis* among dicots.

The young guava orchads are weeded manually using hand operated implements. In established orchards, mulching with inorganic and organic materials have been tried. The dried leaves are usually mulched into the soil in the basins soon after one or two rains. The growing of green manure crops like cowpea, cluster bean, sunnhemp and dhaincha during rainy season and clean cultivation during the rest of the year are recommended.

Intercropping with cauliflower, pea, French bean and senji in rabi season; cowpea, cluster bean, black gram and green gram during kharif season and cucurbits during summer have been recommended. Okra, onion, garlic, turmeric, cabbage, cauliflower, chilli and leafy vegetables can also be grown as intercrops in guava orchards. Under dryland conditions, *Stylosanthes* cover crop gave additional fodder yield of 21.2 t/ha.

Mulching with black polythene and sugarcane trash reduced weed intensity of guava + amla cropping system. Maximum reduction in weed population (14.5 /m<sup>2</sup>) and their dry weight (33.8 g/ m<sup>2</sup>) was noticed in black polythene mulching (Table 7.10). Among the organic

mulches, the minimum weed population was recorded in sugarcane trash (29.4 /m<sup>2</sup>) followed by paddy straw (30.8 /m<sup>2</sup>). The reduction in weed population was due to elimination of light intensity and regulation of soil temperature.

**Table 7.10. Effect of various mulches on weed population under guava + amla cropping system.**

Mulching material	No. of weeds/ m <sup>2</sup>	Dry wt. of weeds (g/ m <sup>2</sup> )
Black polythene	14.5	33.8
Paddy straw	30.8	64.8
Sugarcane trash	29.4	59.3
Dried lemon grass	116.8	89.3
Unmulched	101.7	310.2

## Pest Management

**Aphid, *Aphis gossypii*:** Five coccinellid predators, *Chilomenes sexmaculata*, *Scymnus* sp., *Pseudospidimerus circumflexus*, *Chilocorus nigrita* and *Paragus serratus* were quite effective in controlling aphids within 45 days of their appearance.

**Green Shield Scale, *Chloropulvinaria psidii*:** Pruning and burning of affected parts during non-fruiting season reduces infestation. Application of non-drying adhesive on tree trunk prevents ascent of ants.

A release of 20-30 adult beetles of *C. montrouzieri* / tree was found effective for the management of scales.

**Mealybugs, *Ferrisia virgata*, *Planococcus citri*, *P. lilacinus*, *Maconellicoccus hirsutus*:** Same as in mango mealy bug. The encyrtid, *Aenasius advena* is a very important parasitoid of *F. virgata* causing up to 50% parasitism in the field. Release of 380 adult beetles of *C. montrouzieri*/ha (10/tree) resulted in reduction of mealybug population to 2.8/plant as against 145/plant in control on 40<sup>th</sup> day and complete control on 50<sup>th</sup> day of release. Release of *C. montrouzieri* also helps in clearing *P. lilacinus* and *M. hirsutus*

The parasitoid, *Leptomastix dactylopii* gives effective and permanent control of *P. citri* in guava orchards. *P. citri* disappear subsequently due to the activity of *L. dactylopii*.



**Fruitfly, *Dacus dorsalis*:** Avoid taking rainy season crop, as the incidence is very high. Collect fruitfly infested fruits and destroy them. Plough during summer to expose and kill pupae.

**Bark Eating Caterpillar, *Inderbela tetronis*, *I. quadrinotata*:** Same as in citrus bark eating caterpillar.

**Waxy Scale, *Drepanococcus chiton*:** The parasitoids, *Anicetus ceylonensis* and *Cephaleta brunniventris* are highly effective in suppressing scale population. The predator, *Chilocorus nigrita* helps in bringing down the scale population.

**Spiralling Whitefly, *Aleurodicus dispersus*:** The build up and dispersal of parasitoids, *Encarsia guadeloupae* and *E. haitiensis* would bring down the population of spiralling whitefly.

**Guava Wilt, *Gliocladium roseum*, *Fusarium oxysporum* f. sp. *psidii*, *F. solani*:** Avoid water stagnation. Remove affected plants and burn them. Treat the soil with permalgon beg. Use Lucknow-49, Banarsi (Andhra strain), Dholak Sind, Nasik, White Guava No. 6299, Supreme, Clone 32-12 cvs. which are resistant to wilt. Biological control with *Aspergillus niger* AN 17 (Pusa Mrida), *Pencillium citrinum*, *Trichoderma harzianum*, *T. virens* and intercropping with marigold and turmeric gave good control of wilt. *A. niger* was found most effective which can be mass multiplied on FYM and applied every year as it controls wilt and also provide nutrition to guava plants (Tables 7.11 and 7.12).

**Table 7.11. Evaluation of bioagents against guava wilt.**

Bio-agent	Average wilting (%)	% Control
<i>Pencillium citrinum</i>	47.33	52.67
<i>Aspergillus niger</i> AN 17 (Pusa Mrida)	21.66	78.34
<i>Trichoderma harzianum</i>	24.66	75.34
Control	100.00	0.00

**Table 7.12. Effect of intercropping on the incidence of guava wilt.**

Intercrop	Total plants	Healthy	Wilted	Partially wilted	% Wilting
Control	20	16	3	1	17.5
Turmeric	20	19	0	1	2.5
Marigold	20	20	0	0	0.0
Garlic	20	18	1	1	7.5

**Anthracnose, *Gloeosporium psidii*:** Removal and burning of the infected twigs, branches and fruits immediately after rainy season. Spraying of 3-3-50 Bordeaux mixture has been recommended as soon as the disease appears in the orchard. Harvested fruits can be fumigated with bleaching powder to avoid post-harvest anthracnose/fruit rot.

**Stem Canker:** Spray 1% Bordeaux mixture at 2-3 litres/tree.

### 7.2.3. Fig

**Nutrient Management:** Application of FYM/ compost at 25 kg/plant (10 t/ha) every year is recommended.

**Weed Management:** Tillage to keep down weeds is necessary. Manual method of weed control using hand tools or small bullock drawn or machine drawn implements, if spacing is proper, is followed in figs.

### Pest Management

**Stem Borer:** Cut the dry twigs and burn them. Put kerosene or petrol in the holes and seal them with mud.

### 7.2.4. Passion Fruit

**Nutrient Management:** Application of 20 kg FYM and 5 kg *Azospirillum*/vine to passion fruit cv. Purple gave the maximum number of fruits/vine and the maximum yield (4 t/ha). A significant improvement in fruit quality in terms of fruit weight, fruit volume, TSS, reducing sugars and total sugars was recorded. The organic C and N levels in the soil were also higher.

## 7.3. Temperate Fruits

### 7.3.1. Apple

**Weed Management:** *Rosa moschata*, *R. eglantaria*, *Rubus* spp. and *Barberis* spp. are some of the predominant weeds of apple orchards.

The use of oak leaves and black polythene mulch proved as effective as chemical treatments for the management of weeds. Increase in yield up to 40% was also realized in apple. Mulching with peat and hoeing controlled weeds effectively. Apple trees growing in straw mulched strips of 1.5 m width made more growth and yielded

twice the weight of fruit from the control plots. Growing intercrops in rows between the trees and in the basins of apple trees suppressed weeds and supplemented the income. The suitable intercrops like tomato, cabbage, beans, strawberry, early potato, mustard, wheat, oat and to some extent barley can be taken during summer and rainy season. Cover cropping can be done during rainy season with sod or leguminous crops. Mulching with black polythene and oak leaves in apple basins indicated that oak leaves were the best for suppressing weeds.

## Pest Management

**San Jose Scale, *Quadraspidiotus perniciosus*:** Orchard sanitation viz. removal of alternate hosts, weed hosts, volunteer plants and crop residues greatly reduce the infestation potential. Heavily infested branches should be pruned and burnt. Release of parasitoid, *Encarsia perniciosi* at 2000 adults/infested tree once in spring. In endemic areas, repeat release, if necessary. Dormant spray (after leaf fall during winter) with 3% tree spray oil or diesel oil emulsion prepared locally with fish oil soap (potash base) at 6.33% (stock solution and water in 1:5 to 1:7 ratio). This will also give adequate control of aphids during the years of light infestations.

**Woolly Aphid, *Eriosoma lanigerum*:** Same as in San Jose scale. Cracks, crevices and wounds caused by pruning should be covered with Bordeaux paste. Remove suckers/water shoots. Keep the tree basin free from weeds. Use resistant rootstocks of M-21, M-25 and MM series. Golden Delicious suffer less from woolly aphid infestation.

The introduced parasitoid, *Aphelinus mali* has already been successfully colonized in all the apple growing areas of India. In Himachal Pradesh, it is more effective in suppressing woolly aphid in valleys rather than on hills slopes. The parasitoid is released at 1000 adults or mummies/infested tree once, as soon as infestation is noticed. The parasitoid is effective against aerial population of woolly aphid. Among the mummies collected, 63.3% were found parasitized by *A. mali*. Prepupae and pupal parasitization ranged from 58.4 to 78.5%.

*Coccinella septumpunctata* is the most important predator of woolly aphid. Each grub consumed 426 to 450 aphids. In areas where natural population of *C. septumpunctata* is high during summer months (April-June), application of toxic chemicals should as far as possible be avoided.

*Hippodamia variegata* is the most important predator of *E. lanigerum*. The beetles are capable of clearing the aphid colonies within 10-15 days. At Mashobra (HP) during spring and summer, entire woolly aphid population was wiped out within 24 days due to heavy predation by *C. septumpunctata* and *H. variegata*.

**Stem Borer:** Same as in citrus bark borer.

**Shot Hole Borer:** Clip off the terminal shoots with unshed cluster of dry leaves in winter. Shot hole borers are the pests of diseased and weak trees. The best way to prevent the attack is to follow good horticultural practices and grow healthy trees. All badly infested trees or dead and dying wood should be cut and burnt before leaf drop. Collect and kill grubs of root borer while preparing basins. Install light traps near the orchard to collect and kill the beetles in kerosinised water.

**Mealybugs, *Ferrisia virgata*, *Planococcus citri*, *P. lilacinus*, *Maconellicoccus hirsutus*, *Nipaecoccus viridis*:** The release of predators, *S. epigeus* and *C. motrouzieri* helps in clearing the mealybugs quickly on the fruits.

**Scale Insects, *Aonidiella orientalis*, *Parasaissetia nigra*:** *Aphytis* sp. attack scales causing up to 30% parasitism on *A. orientalis*. A pteromalid, *Scutellista cyanea* causes up to 42% parasitism on *P. nigra*. Release of *Chilocorus nigrita* also helps in bringing down the scale population.

**Chaffer Beetle:** Shaking of young non-bearing trees at dusk , collecting and destroyning the beetles is useful.

**Codling Moth, *Cydia pomonella*:** Scrape loose bark from trunks to eliminate shelter for over-wintering caterpillars of codling moth. Promptly remove and destroy all fallen fruits which could contain caterpillars will help in suppression of pest population. Release of *Trichogramma embryophagum* at 2000 adults/tree at weekly intervals is effective. First release should be initiated when the first moth is caught in pheromone traps or when eggs are noticed.

**Collar Zone Weevil, *Dyscerus fletcheri*:** Keep the tree basin clean. Collect and destroy the grubs and adults at the time of digging. Interculturing under the trees helps in killing the grubs and weevils.

**Root Borer, *Dorystenes hugelii*:** Avoid dry sandy soils for establishing new apple orchards as they provide congenial conditions for survival and multiplication of the pest. Interculturing under the trees helps in killing the grubs. Marking infested trees in July and digging their root system in winter for collection and mechanical destruction of grubs.

**Scab, *Venturia inequalis*:** Clean cultivation, ploughing to remove plant debris harbouring the fungus, raking and destruction of fallen leaves and pruned material can reduce the primary infection. Cvs. Emira, Red Free, Prima, Priscilla, Macfree, Liberty, and hybrids Ambstarking, Ambroyal, Ambrich and Ambred are resistant. The biocontrol agent, *Athalia bombacina* was found effective.

**Powdery Mildew, *Podosphaera leucotricha*:** Pruning after shedding of leaves, thinning out and cutting back of laterals, removal and destruction of all diseased parts reduces the disease incidence. Spraying of wettable sulphur at 0.3% is recommended during pre-bloom and bloom period. Apple cvs. Maharaja Chunth and Golden Chinese have been found resistant to powdery mildew disease.

**Seedling blight, *Sclerotium rolfsii*:** Rootstocks M 2, M 4 and MM 106 are found to be resistant.

**Black Rot and Canker, *Physalopora obtusa*:** Avoid mechanical injury. Apply wound dressers on cut areas. Remove girdled limbs. Cankers must be scraped with clean knife and covered with Bordeaux (Cu So<sub>4</sub> – 1 part, lime and linseed oil – 2 parts each) or Chaubatia paste (Lead oxide – 1 part, Copper carbonate – 1 part, Linseed oil – 11 parts). Remove all the mummified fruits, dead and pruned twigs from the orchard and burn.

**Collar Rot, *Phytophthora cactorum*:** Clean the infected collar area with a sharp knife and apply Bordeaux or Chaubatia paste. Grafting of rootstocks 30 cm above the ground level helps in reducing the disease incidence. Use of antagonists like *T. viride*, *T. harzianum*, *Enterobacter aerogenes* and *Bacillus subtilis* along with soil solarization have also been found to protect the plants from root rot infection. Rootstocks M2, M4, MM104, MM113 and MM114 have been reported to be resistant.

**White Root Rot, *Dematophora necatrix*:** Hot water treatment of infected seedlings at 45°C for 1 hr, digging up of isolation trenches, amending the structure of clayey soils by adding more organic matter, following central drainage system have proven quite effective in preventing the spread of disease and increasing tree life. Rotten roots must be cut and the cut ends painted with Bordeaux or Chaubatia paste. Soil solarization by polyethylene tarping further improved the control. Soil treatment with neem cake + *T. harzianum* was effective. The affected trees should be approach grafted with seedlings. Use of antagonists like *T. viride*, *T. harzianum* and *Enterobacter aerogenes* along with soil solarization have also been found to protect the plants from root rot infection.

**Crown Gall, *Agrobacterium radiobacter* and Hairy Root, *A. rhizogenes*:** Destruction of infested material by uprooting and burning, adoption of rigorous sanitation in the nursery and rotation of nursery sites are recommended. The disease incidence can be reduced by practicing budding instead of grafting (most infections appear at grafting point). Maize and other grain crops should be planted for several years prior to replanting of the nursery block.

**Mosaic:** The bud wood can be rendered virus-free by keeping the bud wood at 36°C for 4 weeks or by hot water treatment at 50°C for 8 min. Virus-free mother plants should be indexed for graft and bud wood.

## IPM

- Spraying 5% NSKE/Neemarin at blossom stage to control blossom thrips.
- Spraying of horticultural mineral oil at 2 litres / 200 litres of water in June-July i.e. just before breaking of dormancy to control San Jose scale, European red spider mite and overwintering eggs of red spider mite during pink stage.
- Pruning of canker affected branches in November and application of cow dung paste to reduce the incidence of canker.
- Releasing of chrysopids like *Chrysoperla carnea* and *C. scelestes* for aphid control.
- Spraying Dormant oil at 4 litres / 200 litres of water to manage San Jose scale and aphids and to prevent hatching of European red spider mite.
- Release of predatory mites like *Amblyseius falcis* and *Zitzellia mali* against European red spider mite.
- Using antagonists like *Enterobacter aerogenes* and *Bacillus subtilis* for the management of white root rot.
- Soil application of neem and mustard cake at 250 kg/ha for controlling the soil insect pests, collar rot and root rot pathogens.
- Spraying of kerosene oil in water during 15<sup>th</sup> Nov – 15<sup>th</sup> Mar to reduce root borer population.
- Application of *Trichoderma viride* for the control of root rot disease complex.
- Spraying of *B. thuringiensis* (Bilep) at 1 kg/ha against mites and fruit scrapper pests.

- Collection and destruction of fallen leaves and pruning of diseased shoots and twigs to control diseases.

### 7.3.2. Peach and Plum

**Weed Management:** Orchards should be regularly cultivated. Ploughing, which should not be deeper than 10 cm, is generally done in winter to suppress the weeds. Ploughing of whole orchard with bullock drawn implements or motor run implements was the best for controlling weeds in peach orchards. Intercropping orchards with green gram, chickpea, pea and onion reduced the density of weeds both in basins and inter rows. To keep the peach trees healthy and productive, it is essential that the weeds be kept under check and the soil stirred to a depth of about 10 cm by giving a cultivation starting in December and continuing till April-May. A suitable cover or green manure crop may be sown in rainy season after the fruits are picked and ploughed under during winter. Peach trees growing in straw mulched strips, 3 m wide, grew at a faster rate than the controls under permanent pasture and produced twice as many fruits of larger size in their fourth and fifth seasons. Peach under cover cropping had better physiological condition of the soil, increase in the organic matter content of the soil and improved water uptake by peach trees.

After intercropping for 2 years with soybean and pineapple, the N content in peach leaves was higher. Intercropping of peach orchards with short duration crops like cowpea and sesame up to 4 years, and the long duration crops like turmeric could be grown even beyond 6 years without any adverse effects on the productivity of peach trees and an income of Rs. 10,000 could be obtained.

### Pest Management

**Peach Fruitfly, *Dacus dorsalis*:** Use early maturing varieties like 'World's Earliest', 'Early White Giant', 'Pratap', 'Shan-e-Punjab' and 'Florida Sun' in infested localities. Do not delay harvesting of matured fruits. Collect and destroy the fallen fruits. Deep ploughing near the plants during May-June and December-January to expose the pupae to the biotic and abiotic factors.

**Leaf Curl Aphid, *Brachycaudus helichrysi*:** Removal of weed hosts which acts as secondary hosts is essential. During the months of March-April, avoid chemical sprays to encourage biotic agents like Coccinellids, Syrphids and Anthocorid bugs which are very active. Cvs. Stark Ealy Giant, Early White Giant and Flavour Crest are

found moderately susceptible (10-30% leaf whorl infestation) to leaf curl aphid.

**Crown Gall, *Agrobacterium radiobacter*:** A non-pathogenic strain of *A. radiobacter* (strain 84) is employed to control crown gall and 99% success has been achieved in case of peach crown gall.

**Leaf Curl:** Removal and burning of infected shoots reduce the spread of the disease. Removal of weed hosts which acts as secondary host is essential. A dormant spray of 6:10:100 Bordeaux mixture with an adhesive and a winter spray with 1.2% Bordeaux mixture before bud burst stage gives effective control of the disease.

## IPM

- Keep the trees free from mechanical wounds, winter injury, crotch separation and cankers.
- Destroy dead and dying trees and branches to avoid borer infestation.
- Prune and destroy the scale and borer infested branches.
- Maintain the vigour of the trees to keep away shot hole/pin hole borer and bark beetles.
- Spray 6.33% diesel oil emulsion or 3% tree spray oil during dormancy (when temp. is more than 4°C) to control scales, aphids and mites.
- Clean the stem borer holes and plug them with cotton soaked in petrol after inserting naphthalene balls in the holes.
- Fallen fruits which may contain grubs should be collected and destroyed.

### 7.3.3. Apricot

**Weed Management:** Cultivation by bullock drawn implements or motor run implements and cover cropping the inter rows with mustard and wheat reduces the density of weeds in apricot.

### 7.3.4. Walnut

## Pest Management

**Borer:** Pruning and destruction of borer infested branches.

**Hairy Caterpillar:** Collection and destruction of egg masses.



**Weevil:** Collect and destroy weevil infested fallen fruits every 10 days to kill the grubs.

**Leaf Blotch, *Massonia juglanis*:** Collection and burning of fallen leaves in autumn. Spray 1% Bordeaux mixture in the late spring and repeat at fortnightly interval (1-2 times).

## 7.4. Arid – Zone Fruits

### 7.4.1. Pomegranate

**Nutrient Management:** Application of FYM/ compost at 25 t/ha and every year at 12.5 t/ha is recommended. Green manure crop like sunnhemp can be grown during rainy season and incorporated in the soil at the time of flowering.

For young plants of 2-3 months, application of 200 g neem cake along with 3-4 kg FYM/plant is recommended. After 3 months, each plant may be given 250 g neem cake and 5 kg FYM. Again after 9 months, 1 kg neem cake and 10 kg FYM/plant is recommended.

Application of organic N through FYM (50% N) + castor cake (50% N) gave maximum fruit retention (47.75 fruits/plant) and fruit yield (8.84 kg/plant) compared to 100% N applied through urea (fruit retention of 32.75 fruits/plant and fruit yield of 5.80 kg/plant) (Table 7.13).

**Table 7.13. Effect of organic and inorganic N application on yield of pomegranate.**

Treatment	No. of fruits retained/plant	Fruit yield (kg/plant)
FYM (100%)	46.00	8.23
Castor cake (100%)	46.00	8.20
FYM (50%) + Castor cake (50%)	47.75	8.84
Urea (100%)	32.75	5.80
CD at 5%	12.05	2.19

**Weed Management:** Manual methods of weed control by using small hand operated tools is quite enough to produce superior quality fruits. Mechanical ploughing by power tillers are also done depending upon row spacing given to the crop. Mulching with paddy husk was found to be effective in controlling weeds in pomegranate. Intercropping can be done with fodders like berseem and lucerne, pulse crops like cowpea and green gram, and vegetables like cucurbits,

cabbage, cauliflower, beans, pea, tomato, carrot, onion, radish, potato and brinjal for first 5-6 years.

## Pest Management

**Aphid, *Aphis punicae*:** NSKE 5% is found to be effective in reducing the aphid population without affecting the population of natural enemies. The coccinellids, *Scymnus castaneus*, *S. sexmaculata*, *S. latemaculatus* and syrphid, *P. serratus* keeps the aphid population under check.

**Ash Whitefly, *Siphoninus phillyreae*:** The aphelenid, *Encarsia azimi* cause a high level of parasitism up to 90% in nature.

**Mealybug, *Ferrisia virgata*, *Planococcus citri*, *P. lilacinus*, *Maconellicoccus hirsutus*, *Nipaecoccus viridis*:** Same as in mango mealy bug. Prune the affected plant parts and destroy. The parasitoid, *Leptomastix dactylopii* is recommended for suppression of *P. citri* and *C. motrouzieri* for all other mealybugs.

**Shot Hole Borer, *Xyleborus similis*:** If the infestation is low, drench the soil around main trunk with Azadirachtin at 3 ml/litre (0.15%) at 2-3 litres/tree. Avoid waterlogging and keep the soil raked and aerated. Uproot and burn the infested trees.

**Bark Eating Caterpillar:** Same as in citrus bark eating caterpillar.

**Fruit Borer (Anar Butterfly), *Deudorix epijarbas*, *D. isocrates*:** Pluck and destroy the infested fruits. After fruit setting, cover the fruits with paper or cloth bags. The release of egg parasitoid, *T. chilonis* at 2.5 lakhs/ha 4 times at 10 days interval reduces the fruit borer infestation up to 50%. Collection and destruction of fallen fruits with exit holes, bagging of fruits with muslin cloth, removing flowering weeds especially of Compositae family and weekly spraying of *B. thuringiensis* at 1 g/litre are effective. Spray application of 5% NSKE gave satisfactory control of fruit borer.

## Bacterial Blight, *Xanthomonas compestris* pv. *punicae*

### Before Planting

- Use disease-free seedlings for planting.
- Application of FYM/compost/vermicompost helps in building up resistance in plants to bacterial blight.

## After Planting

- Practice field sanitation (collection and burning of diseased leaves, stem and fruits) to prevent the spread of the disease.
- Before pruning, spray 1% Bordeaux mixture on diseased leaves. Then spray with etherel solution (2.0-2.5 ml/litre) to defoliate the diseased leaves. Collect and destroy the fallen leaves.
- Disinfect the pruning knife in Sodium hypochlorite solution (25 ml/litre) while pruning to prevent the spread of the disease.
- Dust the tree basins with bleaching powder at 20-25 kg/ha to kill the bacteria on left over leaves.
- After pruning, paste the diseased stems with Bromopal (Bacterinashak or Bitrenetol) at 0.5 g/litre or copper oxychloride (3 g/litre) mixed with red sandy loam soil.
- Take hasta bahar crop (pruning during Sept-Oct) if the disease severity is high.
- Give rest to trees during December to May and prune during June-July to reduce the disease severity.
- At the beginning of disease incidence stage, give 5 to 6 sprays with Bromopal (0.5 g/litre) or copper oxychloride (2 g/litre) at 10 days interval.
- After each spraying of bactericides, give mineral spray (1 g each of  $\text{Cu SO}_4$ ,  $\text{Mg SO}_4$ ,  $\text{Ca SO}_4$  and Boron in 1 litre of water) to reduce the disease severity in plants.

### 7.4.2. Ber

**Nutrient Management:** Application of 1 kg FYM to planting pit is recommended. Application of FYM/ compost at 25-40 kg/plant (10 t/ha) every year is recommended (Table 7.14).

**Table 7.14. Yearwise requirement of FYM.**

Age of tree (year)	Requirement of FYM (kg)
1	2
2	3
3	4
4	5
5 and more	6

**Weed Management:** The commonest method of weed control during seedling stage is by manual means using small hand operated implements. Black polythene film and rice straw mulches have been found effective during the first year of planting to conserve soil moisture and to suppress weeds. Straw mulch was found superior to black polythene in keeping the soil temperature low. In well established commercial ber orchards, where enough space is given, mechanical weeding by bullock drawn implements or motor run implements (tractor or power tiller) are effective to suppress the weeds. At least 3-4 cultivations in a year are needed to keep the orchards free of weeds and to get increased yields. Intercrops like green gram, black gram, cluster bean and cowpea were proved to be best in western Rajasthan. Under irrigated conditions, grain cumin and chillies are recommended as intercrops. Cover cropping with short duration vegetable crops or forage crops is done in between trees to keep down the weed population and to conserve soil moisture.

## Pest Management

**Fruitfly, *Carpomyia vesuviana*:** Summer ploughing to expose pupae to the sun's heat and birds, collection and destruction of fallen infested fruits, preventing the fruits to ripe on the trees to escape egg laying on fruits and harvesting of green and firm fruit helps in reducing the pest incidence.

**Bark Eating Caterpillar:** Same as in citrus bark eating caterpillar.

**Mealybugs, *Ferrisia virgata*, *Planococcus citri*, *P. lilacinus*, *Maconellicoccus hirsutus*, *Nipaecoccus viridis*:** Frequent raking of soil under the tree during winter helps in destroying the eggs. Tying of alkathene sheet (400 gauge) around the tree trunk to prevent the nymphs from climbing the trees. Release of *C. motrouzieri* is found effective against *N. viridis*, while *L. dactylopii* is used against *P. citri*.

**Waxy Scale, *Drepanococcus chiton*:** Besides the two predators, *C. motrouzieri* and *Scymnus* sp. feeding on the crawlers of scale insects, two key parasitoids, *Cephaleta brunniventris* and *Anicetus ceylonensis* cause heavy parasitism. The scales disappear subsequently indicating check by the natural enemies.

**Beetles, *Adorestus pallens*, *A. nitidus*:** Using light traps to attract adults, raking/ploughing around the trees to expose hibernating larvae and crop sanitation i.e. keeping the orchard free of weeds helps in reducing the pest incidence.

**Canker, *Xanthomonas compestris* pv. *viticola*:** Use of disease-free cuttings, pruning after post-monsoon, destruction of infected plant parts, curb on excess use of irrigation water and late October pruning reduce the disease incidence. Spraying 3:3:50 Bordeaux mixture gave substantial reduction in disease.

**Powdery Mildew, *Oidium erysiphoides*, *Oidiopsis* sp.:** Pruning during second fortnight of April or first fortnight of May reduces the disease incidence. Spray 0.25% wettable sulphur when fruits are at peanut stage or at the appearance of the disease whichever is earlier and there after 3 more sprays at 10-15 days interval. Cvs. Safeda –Rohtak, Sua, Chonchal, Noki, Sanar No. 5, Katha Phal, Illaichi Jhajjar, Kakrol Gola, Kala-Gora, Mirchia and Pathani are reported to be resistant; while Umran is moderately resistant.

**Sooty Mold:** Spraying 1% Bordeaux mixture starting at the appearance of the disease and thereafter 3 more sprays at 10-15 days interval.

**Leaf Spot, *Alternaria* spp.:** Cvs. Bahadurgarhia, Govindgarh Special, Gola- Gurgaon, Popular-Gola, Seo Bahadurgarhia, Safeda-Rohtak, Jhajjar Special and Mirchia are reported to be resistant.

**Leaf Spot, *Isariopsis indica* var. *zizyphi*:** A mycoparasite, *Hansfordia pulvinata* has been found naturally controlling the disease. Cvs. Safeda-Rohtak, Mudia-Murhera, Sua, Sanar No. 1, Pathani, Jhajjar Selection, Seo Bahadurgarhia and Jhajjar Special are reported to be resistant.

**Leaf Spot, *Cladosporium zizyphi*, *C. herbarum*:** Cvs. Banarasi, Villaity, Govindgarh Selection No. 3, Jhajjar Selection and Jogia are reported to be resistant.

**Rust, *Phakospora zizyphivulgaris*:** Cvs. Banarasi, Seo, Katha-Gurgaon, Laddu, Dandan, Sanar-1, Gola-Gurgaon-2, Safeda Selection, Sanar-3, Kishmish, Narma and Safeda are reported to be resistant.

#### 7.4.3. Custard Apple

**Nutrient Management:** Application of FYM/ compost at 25 kg/plant (10 t/ha) every year is recommended (Table 7.15). In bearing orchards, growing green manure crops and ploughing in during August is beneficial for improving vigour and production of the tree.

**Table 7.15. Yearwise requirement of FYM.**

Age of tree (year)	Requirement of FYM (kg)
1	10
2	20
3	30
4	40
5 and above	50

**Weed Management:** Manual method is the only method for controlling weeds in the initial stages of growth to get vigorously growing healthy seedlings of custard apple for transplanting in permanent sites at a later stage. In young orchards, vegetables and legumes can be grown as intercrops for the first 5 years. Besides economic benefit, intercrops also check soil erosion and weed growth. Mulching the tree basins with dry grasses helps to avoid soil erosion due to wind and suppress weed growth.

### **Pest Management**

**Fruit Rot, *Glomerella cingulata*:** Spray 1% Bordeaux mixture at 2-3 litres/tree when infection starts at blossom end.

**Mealybug:** The mealybugs can be easily controlled by releasing the coccinellid predator, *C. montrouzieri*.

#### **7.4.4. Phalsa**

**Nutrient Management:** Application of 15 kg FYM after pruning is optimum for high production.

**Weed Management:** The common method of weed control practiced in phalsa is manual method by employing labour force to remove weeds by using small hand tools like khurupi and cutlasses. Small power tillers are also used inside the orchards for cultivating the inter rows and between the bushes. At least 3-4 cultivations in a year are necessary to keep the weeds under check. Cover cropping with short duration crops like beans and cowpea could also be done not only to control weeds but also to conserve the soil moisture.

### **Pest Management**

**Bark Eating Caterpillar, *Inderbela tetonis*:** Injecting petrol or kerosene in the holes and plugging the mouth with mud controls the pest.

#### 7.4.5. *Amla, Emblica officinalis*

**Nutrient Management:** Planting pits (1.5' x 1.5') are filled with 5 kg FYM during April-May and left undisturbed for 15-20 days. The young plants should be applied with 15-20 kg of well rotten FYM and the mature tree with 30-40 kg each year during Sept-Oct in addition to 5 kg as basal dose. For mature trees, application of FYM/ compost at 25 kg/plant (10 t/ha) every year is recommended.

**Weed Management:** Clean cultivation throughout the year becomes a necessity. This is done manually or mechanically. At least 2-3 cultivations in a year are necessary to keep the orchards free from weeds. During summer, the crop should be mulched with paddy or wheat straw at the tree base up to 15-20 cm, which not only conserves moisture, but also helps in keeping the weeds under check.

Cowpea and cluster bean can be used as cover crops to reduce the weed population. Mulching with mustard straw (8 cm layer below tree canopy) also helps in reducing the weed population.

#### Pest Management

**Bark Eating Caterpillar:** Same as in citrus bark eating caterpillar.

**Shoot Gall Insect:** Cut and destroy the twigs having galls.

**Rust:** Spray 0.2% wettable sulphur at 2-3 litres/tree.

#### 7.4.6. *Tamarind*

**Nutrient Management:** Application of FYM/compost at 50 kg/planting pit before planting is recommended. Application of FYM/compost at 50 kg and neem cake at 2 kg/plant during rainy season every year is beneficial for getting higher yields. In young plantation, intercropping with leguminous crops during rainy season is advocated.

**Weed Management:** Removing weeds by manual and mechanical means in commercial orchards could fetch more income to the grower. At least 2 ploughings in a year may be necessary to keep tamarind orchards free from weeds. Cover crops can be grown in older plantations to avoid soil erosion, to conserve soil moisture and to suppress weeds.

#### **7.4.7. Jamun**

**Nutrient Management:** Application of annual dose of 20 kg FYM during the pre-bearing period and 50-80 kg/tree to bearing trees is considered beneficial.

#### **Pest Management**

**Fruitfly:** Collection and destruction of infested fruits. Digging the soil around the tree trunk so that the maggots and pupae hibernating in the soil are destroyed.

**Stem Borer:** Same as in Fig.

**Leaf Spot & Fruit Rot:** Same as in custard apple.

#### **7.4.8. Wood Apple**

**Nutrient Management:** Application of 25 kg FYM/compost per tree in the beginning of monsoon helps in increasing fruit size and quality.

#### **7.4.9. Bael**

**Weed Management:** Any legume and forage crop can easily be taken during rainy season as intercrop to suppress weeds.



## Chapter 8

# VEGETABLE CROPS

### 8.1. Solanaceous vegetables

#### 8.1.1. *Tomato*

**Nutrient Management:** Raised nursery beds of 2 m x 1.5 m were prepared and 10 kg FYM was mixed in the soil. Seeds were sown in lines 5 cm apart and covered with 1 kg of vermicompost (Gomini). Leaf curl resistant/tolerant varieties such as Avinash-2 (T), Hisar Anmol (H-24), JK Asha, Nandi, Abhinav, Vaibhav, Sankranti, Mruthyunjaya-3 should be used.

The main field was prepared with application of FYM at 8 t/ha. Vermicompost at 2.6 t/ha was applied in 2 splits at planting and 30 DAP. Three foliar sprays of groundnut cake and vermicompost extract mixed with Panchagavya were given 27, 35 and 42 DAP. For this purpose, 1 kg of groundnut cake was soaked in water and to this 0.5 kg vermicompost (Gomini) was added next day and fermented for 1 more day. This was filtered and made to 10 litres. The requirement of groundnut cake and vermicompost was 100 and 50 kg/ha/spray, respectively. Panchagavya was prepared afresh each time by mixing 200 ml of cow urine, 200 ml milk, 20 g ghee, pulp of 1 robusta banana along with 500 g of cow dung. The mixture was squeezed by hand, filtered through muslin cloth and made into 10 litres. The extract of groundnut cake + vermicompost and Panchagavya were mixed in equal proportion and sprayed at 1000 litres/ha. The requirement of milk and ghee was 20 litres and 2 kg/ha/spray, respectively. Phytozeal, an organic tonic, was sprayed 2 times (at 2.5 ml/litre) at 43 and 52 DAP in tomato.

The availability of nutrients and their uptake were higher with the application of vermicompost. The vermins, enzymes and antibiotics can be effectively utilized for increasing the yield and quality of fruits in tomato. An integration of inorganics with vermicompost also gave higher yields (Table 8.1).

**Table 8.1. Influence of vermicompost on yield and quality of tomato.**

Treatments	Fruit yield (t/ha)	Protein (%)	Carbo-hydrates (%)	Crude fibre (%)
FYM 25 t/ha	4.4	8	19	2.9
Vermicompost 25 t/ha	5.4	10	20	2.6
Vermicompost 37.5 t/ha	6.9	12	24	2.5
Vermicompost 50 t/ha	7.1	16	33	2.0
Vermicompost 100 t/ha	8.5	20	34	1.1
Vermiculture <i>in situ</i>	6.0	17	33	2.2
FYM + Full NPK inorganics	8.5	15	31	1.4
Vermicompost 25 t/ha + Full NPK inorganics	10.8	15	38	1.6
C.D. at 5%	1.7	3	3	0.6

Application of neem and groundnut cakes each at 100 kg/ha (mixed intimately) 10 cm away from the plants at 15 DAP gave better growth and micronutrient uptake by tomato crop (Table 8.2). The better uptake of micronutrients (Zn, Mn, Fe and Cu) may be due to rhizosphere acidification because of neem and groundnut cake combination which releases micronutrients from soil reserves.

**Table 8.2. Effect of oil cakes on micronutrient uptake.**

Treatment	Dry matter at 60 days	Rhizosphere soil pH	Micronutrients in leaf (ppm)			
			Zn	Mn	Fe	Cu
Control (no oil cake)	120.1	7.1	16	25	18	4
Neem cake at 500 kg/ha	125.2	6.6	22	30	53	6
Groundnut cake at 500 kg/ha	135.0	6.9	20	28	38	6
Neem cake at 250 kg/ha + Groundnut cake at 250 kg/ha	160.5	6.2	34	62	74	6

In tomato, application of vermicompost, poultry manure, neem cake and FYM resulted in highest Vitamin C content (17.22-17.95 mg/100 g). The crude protein was highest in vermicompost and poultry manure (1.31-1.35g). TSS was highest in vermicompost, poultry manure, neem cake and FYM (5.64-6.05%). Acidity was highest in vermicompost (0.41%).

**Weed Management:** The normal weed control method followed by farmers is to give 2 hand hoeings in the first and third fortnight after transplanting and an earthing up operation during the second fortnight. The treatment combining drip irrigation at 0.4 PE with black plastic mulch reduced weed infestation by 95%, increased yield by 53% and resulted in a 44% saving in irrigation water. Highest tomato crop yield (51 t/ha) and 44% saving in irrigation water was obtained using the combination of drip irrigation at 0.4 PE and a mulch of sugarcane trash.

Plant basins covered with red coloured plastic mulch of 25  $\mu$  thickness along with drip irrigation helped in obtaining superior tomato fruit yield. The yield of tomato in red, white and black plastic mulch plots were 45.875, 36.562 and 31.218 t/ha, respectively, while it was 23.072 t/ha in unmulched control plot. The increased yields were 98, 58 and 35%, respectively over control. Mulching reduces the weed population and improves the microbial activity of the soil by improving the environment around the root zone.

## Pest Management

**Fruit Borer, *Helicoverpa armigera*:** Use of African marigold (*Tagetes erecta*) as a trap crop for the management of fruit borer on tomato involves planting one row of 45 day-old marigold seedlings after every 16 rows of 25 day-old tomato seedlings and sprays of *Ha* NPV at 250 LE/ha or 4% NSKE or 4% pulverized NSPE, 28 and 45 DAP coinciding with peak flowering. Soil application of neem cake at 250 kg/ha at flowering reduced the borer incidence to 13.2% as compared to 33.2% in control. Hence, soil application of neem cake at flowering may be used as a component of IPM against tomato fruit borer.

A field experiment was conducted to evaluate the effect of soaps on tomato fruit borer. The treatments evaluated were soil application of neem cake at 20 DAP, foliar sprays of NSKE 4%, neem oil, pongamia oil, neem soap and pongamia soap (all at 1%). Treatment of foliar applications were given on tomato starting from 25 DAP and

repeated four more times at 10 days interval. It was found that the soap sprays reduced the borer incidence to less than 7% as compared to 33% in unsprayed control plots. Hence, both neem and pongamia soaps can be used in the IPM of tomato. The soap sprays were also effective in reducing whitefly, red spider mite and leaf miner incidence (Table 8.3).

**Table 8.3. Efficacy of neem and pongamia soaps on tomato fruit borer**

Treatments	Dose	Mean fruits bored (%)
Neem cake	250 kg/ha	13.21
NSKE	4 %	11.12
Neem oil	1 %	13.24
Pongamia oil	1 %	13.76
Soluneem	600 ppm	7.97
Neem soap	1 %	6.64
Pongamia soap	1 %	6.96
Control	—	33.23

The egg parasitoid, *Trichogramma brasiliensis* gave as high as 90% parasitism when 2.5 lakh/ha were released, while *T. pretiosum* also proved effective at 2.5 lakh/ha and resulted in less than 2% fruit damage with 60-80% parasitism. In Solan, Himachal Pradesh region, *T. chilonis* gave 90-100% parasitism following releases. In Gujarat, fruit borer was checked by releasing *T. chilonis* at 2.5 lakh/ha at weekly interval during Dec-Feb.

Five releases of *T. brasiliensis* at 50,000/ha commencing the first release at the time of flower initiation and repeated at weekly intervals resulted in egg parasitism up to 78.4% as compared to 12.3% in control. Percentage bored fruits in parasitoid released plots was 19% in comparison with 42% in control plots. Releases of *T. brasiliensis* and *T. pretiosum* each at 2.5 lakhs/ha resulted in significant reduction in borer damage to 8.92 and 7.20%, respectively as compared to 23.06 and 13.72% in control.

**Table 8.4. Efficacy of *Trichogramma* spp. against *Helicoverpa armigera* on tomato**

<i>Trichogramma</i> spp.	Dosage/ha (in lakhs)	Parasitism (%)
<i>T. brasiliensis</i>	5.0	100
	2.5	20-71
	3.0	78.4
<i>T. chilonis</i>	2.5	20-96
	0.63-10.88	76.3
<i>T. exiguum</i>	5.0	100
<i>T. pretiosum</i>	5.0	100
	0.55-10.58	92.4
	2.5	31.3

Application of 5 rounds of *Ha* NPV at 250 LE/ha at weekly intervals commencing first spray on flower initiation is needed to check the borer very effectively.

For effective control of *H. armigera*, the egg parasitoid, *T. pretiosum* and *Ha* NPV could be integrated to tackle different stages of the pest. *T. pretiosum* was released at 2.5 lakh/ha and *Ha* NPV was sprayed 2 times at 250 LE/ha for effective control of the pest (4.18% fruit borer damage as compared to 21.79% fruit borer damage in control). The increase in yield was 65.5% over control and the reduction in fruit borer damage was 80.8% over control.

Larval parasitoids like *Campoletis chloridae*, *Eriborus argentiopilosus* and *Senometopia illota* and the nematode, *Hexamermis* sp. cause 10 to 40% mortality of fruit borer in tomato fields.

The tomato fruit borer can be effectively controlled by sprays of *B. thuringiensis* (Dipel) at 0.5 kg/ha at 10 days interval. The borer infestation was found to be significantly low (7.41%) in 'Dipel' sprayed plots as against 20 to 30% in control.

Five rounds of sprays of *Ha* NPV at 250 LE/ha in combination with adjuvants and feeding stimulants at weekly intervals commencing the first spray on flower initiation were effective in increasing the mortality of tomato fruit borer, *H. armigera* to 75 – 85% in the treated plots as against 0 to 5.7% in control plots. The fruit damage was 4% in NPV treated plots as against 15% in control plots .

Application of 3 rounds of NPV at 250 LE/ha along with adjuvants viz., 1% soya flour and 0.01% soya oil applied during evening hours at weekly intervals, right from the initial observation of few eggs per plant, recorded significant reduction in tomato fruit borer damage (2.2%) and increase in yield (11.34 kg) as compared to control (21.7% fruit damage and 7.64 kg yield).

Four applications of *Nomurea rileyi* at  $3.2 \times 10^8$  spores/ml along with Triton X -100 (0.01%) at weekly intervals controlled the fruit borer.

Three releases of *T. pretiosum* + 3 sprays of *B. thuringiensis* at 1 kg/ha was found highly effective against fruit borer in Himachal Pradesh. The release of *T. pretiosum* (2.5 lakh/ha) + 2 sprays of Ha NPV (250 LE/ha) was found effective for the management of fruit borer.

Use nylon nets (40 gauge) to avoid insect vectors. Ha NPV was sprayed twice at 28 and 35 DAP. Spray of pongamia soap at 1% was given at 40 DAP for the management of fruit borer and leaf miner. The bored fruits were removed mechanically once 40 DAP. The fruit borer and leaf miner incidence were 2% and 0.7-2.7 mines/leaf, respectively.

**Serpentine Leaf Miner, *Liriomyza trifolii*:** Integrated management of this pest can be achieved by sprays of 4% NSKE, avoiding indiscriminate use of insecticides so as to facilitate build up of the natural enemies and avoiding excess application of N-fertilizers (Krishna Kumar and Krishna Murthy, 2001). Use of yellow sticky traps help in trapping adult flies. Tomato variety Sheetal was less attacked followed by Rupali, Rashmi and Naveen.

**Damping-off, *Pythium aphanidermatum*:** Cultural practices like rabbing, thin sowing, use of light soil, light but frequent irrigation and use of well decomposed FYM should be adopted. *Streptomyces distaticus* was effective in suppressing damping off of tomato. Success in suppression of damping off in tomato was achieved through soil and seed application of *Trichoderma virens* and *T. longibrachiatum*.

Seed treatment with *Trichoderma viride* and *Pseudomonas fluorescens* and addition of neem cake to the nursery beds enhanced seed germination and seedling stand. Soil drenching with 1% Bordeaux mixture at 1 litre/m<sup>2</sup> help in reducing the disease incidence.

Soil solarization using polythene sheet for 30 days during peak summer was most effective and resulted in least occurrence of damping off (3.9%) when compared to control (30.64%). Seed treatment with *Trichoderma viride* resulted in lowest incidence of damping off (5.7%).

Delivery of *T. harzianum* through solid matrix priming (SMP is a process in which moistened seeds are mixed with an organic carrier and the moisture content is brought to a level just below that required for seed sprouting. SMP can further enhance the efficacy of the antagonist in treated seeds. *Trichoderma* spp. grow on seed surface during priming process and increase in numbers and other microbes may not easily dislodge it) reduced the incidence of damping off in nursery.

**Early Blight, *Alternaria solani*:** Give wider spacing of 90 x 60 cm. Remove the lower diseased leaves periodically.

**Buckeye Rot, *Phytophthora nicotianae* var. *parasitica*:** Ridge and furrow system of planting, staking plants at flowering stage and removal of basal leaves up to 15-20 cm height reduce the disease incidence. The rotten fruits should be collected and destroyed. Spray 1% Bordeaux mixture to reduce the disease incidence.

**Collar Rot, *Sclerotium rolfsii*:** The disease was effectively managed under greenhouse and field conditions by soil + root-dip treatment and seed + soil treatment with *T. harzianum*; and seed + soil treatment with *B. subtilis*.

**Bacterial Wilt, *Ralstonia solanacearum*:** Soil amendment with green manuring crop, transplanting disease-free seedlings and following 3 years rotation with cereals/crucifers are effective for the management of wilt. Crop rotation with cowpea – maize - cabbage, okra – cowpea - maize, maize – cowpea - maize and finger millet - brinjal (Pusa Purple Cluster) - French bean are reported effective in reducing bacterial wilt. Intercropping of tomato with sorghum, maize, onion, garlic and marigold resulted in better crop stand. Grafting tomato on brinjal rootstocks such as Pusa Purple Cluster and Dingra Multiple Purple helps in reducing the disease incidence.

Application of bleaching powder at 15 kg/ha and groundnut cake before planting was found effective.

Bacterial wilt of tomato was successfully controlled by incorporation of *Pseudomonas fluorescens*. Prior inoculation of tomato roots with *T. viride* and *P. fluorescens* protected the plants. Application of paste formulation of *P. fluorescens* in vermicompost exhibited lower wilt incidence with maximum reduction of wilt pathogen in the rhizosphere and significant yield enhancement.

Dipping of seedling roots in avirulent strain of *Ralstonia solanacearum* (Av 10) before transplanting gave least wilt incidence (6.66%) as compared to control (75%). Seed treatment with *P. fluorescens*, *P. aeruginosa* and *B. subtilis* resulted in least seedling

mortality (< 1%, 2.66 and 4%, respectively) as compared to control (27.58%). Seedling root dip in *P. fluorescens*/ *B. subtilis* followed by application of antagonists cell suspension to soil in root zone was found effective in reducing the disease incidence (16.66 and 25%, respectively) as compared to control (74.5%). Soil application of *Glomus mosseae* reduced the incidence of wilt.

Tomato cvs. Arka Abha, Arka Alok, Arka Shreshta, Arka Abhijit, Megha, Shakthi, Sonali, Sun 7610, Sun 7611, BT-1, BT-10, LE 79-5 are resistant to bacterial wilt.

Integration of growing and incorporation of sunnhemp (green manure crop) into the soil and seed treatment with *Pseudomonas fluorescens* ( $10^{10}$  cfu/ml) was highly effective in reducing the bacterial wilt incidence to 6.75% and significantly increasing the fruit yield to 25.5 t/ha as compared to high wilt incidence (55.6%) and low yield (7.8 t/ha) in control. Thus, the efficacy of *Pseudomonas fluorescens* is increased under green manure incorporated soil against bacterial wilt of tomato.

**Bacterial Spot, *Xanthomonas compestris* pv. *vesicatoria*:**

Use of disease-free seeds, clean cultivation and 3 sprays of 1% Bordeaux mixture reduced the disease incidence.

**Leaf Curl:** The nursery should be raised under nylon net to prevent entry of whiteflies which transmits leaf curl. Field sanitation should be given top priority as many weeds are alternate hosts for the whitefly vector. Crop should be frequently irrigated which invites less oviposition by whiteflies. Leaf curl affected plants should be uprooted and destroyed.

When tomato is grown along with French bean and brinjal, the incidence of TLCV is low as they act as trap crops for whiteflies. Grow leaf curl resistant/tolerant varieties such as Avinash-2 (T), Hisar Anmol (H-24), Hisar Gourav, JK Asha, Nandi, Abhinav, Vaibhav, Sankranti, Mruthyunjaya-3. The disease spread can be minimized by growing border or barrier crops like maize, sorghum and bajra (5 to 6 rows of these crops should be sown alround the tomato plot 50 to 60 days before transplanting tomato which prevents incoming viruliferous whiteflies from entering into the tomato crop). Mulching tomato fields with straw or yellow polythene sheets during early crop stages shall attract whiteflies which stay there long enough to be killed by reflected heat. Yellow sticky traps can also be used for controlling whitefly population. Use of biocontrol agent like *Encarsia* has shown great promise in reducing whitefly population.



Sowing of 5 rows of maize (border crop) about 5 weeks before transplanting tomato resulted in low incidence of leaf curl disease (14.42%) followed by sunnhemp (18.27%) and jowar (23.94%) as compared to 48.09% in control. Hence growing maize as barrier crop around tomato crop is effective in preventing further spread of the leaf curl disease.

**Tomato Spotted Wilt Virus (TSWV):** Spraying of Adathoda leaf extract (10%) was found to be equally effective as that of the existing practice of spraying Monocrotophos (0.15%) for the management of TSWV. Both these treatments recorded the least incidence of 10% and maximum yield of 3.2 and 3.9 kg/plot, respectively.

**Root-knot Nematodes, *Meloidogyne* spp.:** Several physical and cultural methods like selection of nematode-free nursery sites, destruction of infested roots after crop harvest, burning of paddy husk or saw dust on infested nursery, crop rotation with non-host or antagonistic crops (marigold, mustard, sesame, maize, wheat, sorghum), flooding, fallowing, deep summer ploughing, harrowing and soil solarization either alone or in combination proved to be reasonably effective and economical to check multiplication of root-knot, reniform and lesion nematodes on the transplanted vegetable crops like tomato, brinjal and capsicum. Ploughing not only leads to disturbance and instability in nematode community but also causes their mortality by exposing them to solar heat and desiccation. Generally, 2 to 3 summer ploughings each at 10 days interval during April – May (40-46°C) have been recorded to reduce 96% *M. javanica* population while fallowing itself during the same period registered 45.5% reduction. Additional use of plastic sheets for covering soil either in nursery beds or in field further enhance nematode reduction. Such an approach also helps in reducing the intensity of weeds, fungi and bacteria in the soil.

Application of 'Royal 350' (*Arthrobotrys irregularis* cultured on oat seed medium) at 140 g/m<sup>2</sup> a month before transplantation of tomato resulted in good protection against root-knot nematodes. Among the egg parasites, efficacy of *Paecilomyces lilacinus* (commercially formulated as 'Biocon' in Philippines) has been found to be comparatively higher in suppressing the population of *Meloidogyne* spp. and *R. reniformis* on crops like tomato, brinjal and capsicum.

Application of *Bacillus thuringiensis* causes 95% mortality of *M. javanica* juveniles due to b-exotoxin production and suppresses gall formation, egg mass production and nematode population in soil. Root material containing *Pasteuria penetrans* spores at 212-600 mg powder/kg soil, when broadcast in soil, showed reduction in galling on tomato roots and final nematode population. *P. penetrans* is highly

resistant to heat, desiccation and has ability to survive for more than 2 years in soil, qualifies as the most potential biocontrol agent against root-knot nematodes infesting vegetable crops.

Arbuscular mycorrhizal fungus (AMF), *Glomus fasciculatum* was effective against root-knot nematodes and *G. mosseae* against reniform nematodes on tomato. Organic amendments (oil cakes, calotropis leaves) in combination with AMF enhance the colonization of AMF on tomato roots which further increased plant growth and reduced gall index.

Integration of *P. lilacinus* with neem cake gave effective control of *M. incognita* on tomato. The neem cake increased egg and egg mass parasitization and colony forming units of *P. lilacinus* in the soil.

*T. harzianum* in combination with neem cake was effective in increasing plant growth parameters in tomato and in reducing the population of *M. incognita*. Neem cake was also effective in increasing root colonization, egg parasitization and spore density of *T. harzianum* in soil.

Application of neem products to the soil increased root colonization, egg parasitization of *V. lecanii* and the fruit yield of tomato. Application of neem cake at 15 g/spot or 100 g/m furrow, 3 weeks prior to transplanting tomato and brinjal have been reported to give 36 to 450% enhanced yield with corresponding reduction in gall index to 2.3 as against 4.3 in control.

Incorporation of neem cake/castor cake at 400 g/m<sup>2</sup> and application of spore suspension of *P. lilacinus* or *P. chlamydosporia* in the tomato nursery beds amended with the above plant products facilitated the effective management of root-knot, *M. incognita* and reniform, *R. reniformis* nematodes. Further, root-dip treatment of seedlings in 5% aqueous suspension of cake mixed with the spores of *P. lilacinus* or *P. chlamydosporia* for 20-30 minutes before transplanting was effective for the management of root-knot and reniform nematodes in the main field.

Application of *Pseudomonas fluorescens* at 10 g/m<sup>2</sup> in nursery beds gave good control of root-knot nematodes.

Inoculation of *G. mosseae* or *G. fasciculatum* in the nursery beds amended with neem cake/castor cake reduced the infestation of root-knot and reniform nematodes to the maximum extent on tomato. Amendment of botanicals in the nursery beds increased the multiplication of endomycorrhizae and colonization of tomato roots which in turn could protect the crop from these nematodes in the main field resulting in increased yields.

Interestingly, integration of bio-agent (*P. lilacinus*) and endomycorrhizae (*G. mosseae*/*G. fasciculatum*) have culminated into the successful management of *M. incognita* infecting tomato. This phenomenon facilitated standardisation of a strategy wherein inoculation of mycorrhizae and bio-agent in the nursery beds protected the seedlings of tomato from the attack of *M. incognita*. Further, these mycorrhizal seedlings (colonised either with *G. mosseae* or *G. fasciculatum*) can be given a root-dip treatment with spore suspension of *P. lilacinus* for 5-10 minutes for the effective management of these nematodes in the main field after transplanting.

Inoculation of *G. mosseae* in neem cake amended nursery beds followed by the root-dip treatment of mycorrhizal seedlings of tomato in spore suspension of *P. lilacinus* was effective for the management of *M. incognita* under field conditions.

Combination of *G. deserticola* and *P. chlamydosporia* has increased the plant growth parameters of tomato and reduced root galling due to *M. incognita*. The above treatment was also responsible for maximum colony forming units of both the bioagents in the soil.

Integration of two bio-agents, *P. lilacinus* and *P. chlamydosporia* resulted in combined and complimentary effects for the successful management of *M. incognita* infecting tomato.

The population of *M. incognita* and *M. javanica* were suppressed effectively and yields of tomato were greater when *P. penetrans* and *P. lilacinus* were applied together.

Combined soil application of *P. lilacinus* and *Aspergillus niger* at the time of transplanting tomato is very effective in reducing root-knot nematodes.

Intercropping with marigold or mustard with tomato reduced the damage of root-knot and reniform nematodes.

**Root-knot and Wilt Complex, *Meloidogyne* spp. and *Fusarium oxysporum* f. sp. *lycopersici*:** Deep ploughing and exposing soil to hot sun in summer, removal and burning of crop debris, soil application of *Trichoderma viride* and *Paecilomyces lilacinus*, use of wilt resistant varieties like Utkal Pallavi, Utkal Deepti, Utkal Kumari, Utkal Urbasi, etc. help in controlling the disease complex.

## IDM

- Crop rotation with French beans reduces bacterial wilt.

- Crop rotation with cereals, sesame and mustard, so also intercropping with marigold, onion, garlic reduce nematode infestation.
- Soil solarization of nursery beds for 2-3 weeks using transparent polythene sheets (100-160 gauge) kills soil borne pathogens.
- Raising nursery in raised seed beds (10-15 cm) provides good drainage and thereby avoid damping off.
- Use of bacterial wilt resistant varieties (Arka Abha, Arka Alok, Arka Shreshta, Arka Abhijit, Megha, Shakthi, Sonali).
- Seed treatment with *Trichoderma viride*/*T. harzianum*/*Pseudomonas fluorescens* at 20 g/kg of seeds to prevent damping off and nematodes.
- Deep summer ploughing helps in exposing pathogens and their resting stages to sun's heat.
- Use of barrier crops like pearl millet, maize and sorghum to reduce the incidence of tomato leaf curl.
- Collection and destruction of diseased plants/ plant parts from the field from time to time.
- Soil application of neem cake at 250 kg/ha as basal dose to control nematodes.
- Soil application of FYM enriched with *Trichoderma viride* at 1 tonne/ha.
- Installation of yellow water-pan/sticky trap to monitor whitefly population which transmits leaf curl virus.

## IPM

### Nuesery

- Deep off-season / summer ploughing helps in exposing resting stages of the pests and nematodes.
- Green manuring with sunnhemp in July – August.
- Raising nursery on raised beds (10 cm above ground level).
- Soil solarization using transparent polythene sheets on nursery beds for 2-3 weeks which helps in killing nematodes, soil-borne pathogens, weed seeds and resting stages of insect pests.
- Seed treatment with *T. viride* at 4 g/kg of seed to prevent soil-borne infection of fungi and nematodes.

- Soil application of *T. harzianum* at 50 g/m<sup>2</sup>.
- Use leaf curl tolerant hybrids.
- Use nylon net (40 gauge) to avoid insect vectors (whitefly).
- Raising marigold nursery 20 days before tomato nursery.

### **Main Field**

- Transplanting 1 row of 45 day-old marigold seedlings for every 16 rows of tomato.
- Giving wider spacing of 90 x 60 cm to reduce the incidence of early blight and powdery mildew.
- Soil application of fresh neem cake at 250 kg/ha at 20 DAP to reduce fruit borer and leaf miner incidence.
- Spraying 4% NSKE at 15 DAP to reduce the leaf miner incidence.
- Setting up of yellow sticky traps for whitefly at 10/ha.
- Installing pheromone traps at 13/ha to trap fruit borer adults.
- Release of *Trichogramma pretiosum* at 1 lakh/ha 6 times from flower initiation stage at weekly intervals brings about significant reduction in fruit borer damage.
- Spraying good quality *Ha* NPV at 250 LE/ha at 28 DAP and repeat 2 more times at weekly interval. Mix 2% jaggery and spray in the evening to prevent fast degradation of *Ha* NPV due to UV light.
- Collection and destruction of borer infested fruits and leaf curl disease affected plants from time to time.
- Crop rotation with cereals such as wheat, sorghum and/or sesame, mustard or marigold to reduce nematode problem.

### **8.1.2. Brinjal**

**Nutrient Management:** Application of FYM/ compost at 25t/ha is recommended.

**Weed Management:** Generally, manual weeding by khurupi and other small hand operated implements are used for removing weeds in this crop.

### **Pest Management**

**Shoot and Fruit Borer, *Leucinodes orbonalis*:** Shoot and fruit borer is the major pest in brinjal which is very difficult to control

using synthetic insecticides. Spraying of 5% NSKE and 3% neem oil effectively checked the fruit borer infestation in brinjal (Table 8.5).

**Table 8.5. Effect of neem products in the control of fruit borer in brinjal.**

Treatment	Mean % of infestation (Number basis)	Mean % of infestation (Weight basis)
Neem cake extract 10%	55.74	54.57
Neem seed kernel extract 5%	50.89	49.01
Neem oil 3%	50.85	52.48
Carbosulfan 0.04%	39.77	41.77
Untreated check	61.56	59.35

Removal and destruction of borer damaged shoots during pre-flowering period has potential for reducing the pest population early in the season. Further, growing a barrier crop such as maize, destruction of borer affected fruits, marginally help in reducing the borer damage. Combination of clipping of shoots affected by the borer at weekly interval followed by soil application of neem cake at 250 kg/ha at 30 DAP and 4% pulverized NSPE/ 1% neem soap/ 1% pongamia soap sprays at 60, 75, 90 and 105 DAP was found most effective in reducing the borer incidence. Soil application of neem cake/pongamia cake at 250 kg/ha also reduces ash weevil, gall midge and thrips damage.

Application of neem cake four times during the crop growth decreases the incidence of borer to 8% from 40% in control. Farmers could realize an additional return of Rs. 35,498/ha.

Dusting of ash reduces the incidence of shoot and fruit borer. Inundative release of *Trichogramma chilonis* at 50,000/ha, 5 times at weekly intervals starting from flower initiation stage is also effective.

Application of *B. thuringiensis* at weekly intervals controlled the fruit borer. In plots treated with *B. thuringiensis* (Delfin), there was 30% reduction in larval population and 48.3% yield increase in brinjal. Application of 5 rounds of *B. thuringiensis* var. *kurstaki* (Biobit) at 1 kg/ha at weekly intervals, right from flower initiation was effective in checking the pest. The % fruit damage was low in Biobit (13.44%) as compared to control (19.25%). The yield was also significantly high in Biobit (28.5 kg/plot) as compared to control (14.74 kg/plot).

It is suggested to integrate the release of *Trichogramma* spp. with *B. thuringiensis* to bring down borer damage.

Pheromone lure (Lucinlure™) in combination with Portable Water Traps (both of PCI) was effective in mass trapping of *Leucinodes orbonalis* to the tune of 1927/acre in Bangalore, 1022/acre in Belgaum and 590/acre in Jogipet in A.P.

**Mealybug, *Coccidohystrix insolita*:** It was effectively controlled by release of the predator, *C. motrouzieri*.

**Epilachna Beetle, *Henosepilachna vigntioctopunctata*:** It was effectively kept under check by *Pediobus foveolatus* producing 60-77% parasitism. 'Thuricide' dust ( $3 \times 10^6$  spores/mg) recorded total elimination of the grubs of epilachna beetle on brinjal plants within 10 days.

**White Grub, *Holotrichia consanguinea*:** Collection of beetles from plants during night hours and killing them in kerosene water reduced the infestation. Fungal pathogens, *Metarrhizium anisopliae* and *Bacillus popillae* var. *holotrichiae* are also effective in reducing the infestation.

**Aphid:** The seedling bare root dip in 3% neem oil followed by 5% NSKE spray significantly reduced the aphid infestation in brinjal (Table 8.6).

**Table 8.6. Effect of seedling bare root dip in neem products on brinjal aphid.**

Treatment	Mean population of aphids/3 leaves	% Reduction over untreated check
Neem cake extract 10%	1.36	24.86
Neem seed kernel extract 5%	1.25	30.93
Neem oil 3%	1.18	34.81
Monocrotophos 0.1%	0.67	62.98
Untreated check	1.81	---

Release of *Chrysoperla carnea* at 2 grubs/plant was also found effective.

**Damping-off, *Pythium aphanidermatum*:** Soil solarization using polythene sheet for 30 days during peak summer was most effective and resulted in least occurrence of damping off (1.5%) when compared to control (30.64%). Seed treatment with *Trichoderma viride* resulted in lowest incidence of damping off (4.7%).

**Collar Rot, *Sclerotinia sclerotiorum*:** *B. subtilis*, *T. viride* and *T. virens* were effective.

**Bacterial Wilt, *Ralstonia solanacearum*:** Crop rotation with cowpea – maize - cabbage, okra – cowpea - maize, maize – cowpea - maize and finger millet - brinjal (Pusa Purple Cluster) - French bean are reported effective in reducing bacterial wilt. Grafting brinjal on *Solanum torvum* rootstock was found effective against wilt.

Bacterial wilt of brinjal was successfully controlled by incorporation of *Pseudomonas fluorescens*.

Brinjal cvs. Pusa Purple Cluster, Digra multiple purple, Arka Keshav, Arka Nidhi, Arka Neelkanth, Gulla, Vijay hybrid and Banaras Giant Green are found resistant.

**Little Leaf (*Mycoplasma*):** Removal of weed hosts like *Datura fistulosa* and *Catharanthus roseus* and diseased plants from the field and nearby areas and use of disease resistant/tolerant varieties like Pusa Purple Cluster and Arka Sheel shall keep the disease under check.

**Root-knot Nematodes, *Meloidogyne* spp.:** Integration of *Paecilomyces lilacinus* with neem cake gave effective control of *M. incognita* on brinjal.

Integration of *P. chlamydosporia* with castor cake increased plant growth parameters of brinjal and reduced root galling due to *M. incognita*. Root colonization and egg mass parasitization of *P. chlamydosporia* was also maximum in castor cake amended soil.

Incorporation of neem cake/castor cake in nursery beds at 400 g/m<sup>2</sup> and application of spore suspension of *P. lilacinus* or *P. chlamydosporia* in brinjal nursery beds amended with the above plant products facilitated the effective management of root-knot, *M. incognita* and reniform, *R. reniformis* nematodes. Further, root-dip treatment of seedlings in 5% aqueous suspension of neem cake mixed with the spores of *P. lilacinus* or *P. chlamydosporia* for 20-30 minutes before transplanting was effective for the management of root-knot and reniform nematodes in the main field.

Inoculation of *G. mosseae*/*G. fasciculatum* in the brinjal nursery beds and subsequent application of 5% aqueous extracts of neem cake/castor cake in the nursery beds resulted in the effective management of root-knot and reniform nematodes and yielded healthy brinjal seedlings which would withstand the attack of these nematodes after transplanting in the main field.



Combined soil application of *P. lilacinus* and *Aspergillus niger* at the time of transplanting brinjal is very effective in reducing root-knot nematodes.

Rotation of brinjal with sweet potato (cv. Sree Bhadra) reduced the root-knot nematode population by 47% and increased the fruit yield by 22%. Crop rotation with sorghum, wheat and chilli reduced the root-knot nematode population. Intercropping with marigold, onion and garlic is also recommended.

## IPM

### Nuesery

- Deep off-season / summer ploughing to expose resting stages of pests to sunlight.
- Soil solarization for 2-3 weeks during summer using 400 gauge thick polythene sheet.
- Soil application of *Trichoderma harzianum* mixed with FYM.
- Raising nursery on raised beds (10 cm above ground level).
- Use of bacterial wilt resistant varieties (Arka Nidhi, Arka Keshav, Arka Neelkant, Swarna Shree, Swarna Mani, Swarna Shyamali, Surya, Pant Rituraj, Pusa Purple Cluster).
- Seed treatment with *Trichoderma viride* at 4 g/kg of seeds to prevent seed and soil borne infection of fungi and nematodes..

### Main field

- Soil application of fresh neem cake at 250 kg/ha 30 DAT and repeat after 35-40 days to reduce shoot and fruit borer incidence.
- Errection of bird perches at 25/ha.
- Release of egg parasitoid, *T. chilonis* at 1 lakh/ha 6 times starting from shoot formation stage at weekly intervals to bring down shoot and fruit borer damage.
- Setting up of yellow sticky traps.
- Spraying of 5% NSKE to control sucking pests in early stages.
- Installing pheromone traps at 13/ha to trap fruit and shoot borer adults.
- Collection and destruction of borer infested fruits from time to time.

- Destruction of little leaf and bacterial wilt affected plants from time to time.
- Crop rotation with non-host crops like sorghum, wheat, marigold or onion to reduce nematode population in soil.

### 8.1.3. Chilli

**Nutrient Management:** Application of FYM/ compost at 25 t/ha is recommended. The application of vermicompost/vermiculture was found to have considerable effect on physico-chemical properties of soil (Table 8.7). The water stable aggregates more than 0.25 mm were found to be more in vermicompost treated plots. The presence of earthworm could retain more soil moisture in the field. Water holding capacity was higher in surface soil in plots with vermiculture *in situ*. There was increased infiltration rate with *in situ* application of worms to soil which indicated the improvement in water permeability of soil as compared to plots without worms. Organic carbon content was found highest in treatment receiving vermicompost + NPK. Vermicompost application could record highest values for available nutrients, yield and yield attributes.

Application of vermicompost at 3 t/ha + FYM at 10 t/ha + neem cake at 0.6 t/ha increased number of pickings, very low pest and disease incidence and enhanced maturity of the chilli crop. The above treatment also increased the fruit yield and cost:benefit ratio (260 q/ha and 1:2.38) compared to control (150 q/ha and 1:1.93). The gross and net income derived was more in treated plots (Rs. 1,56,000 and Rs. 90,625) compared to control (Rs. 90,000 and Rs. 28,975).

**Table 8.7. Comparison of FYM and vermicompost in combination with inorganics in chilli.**

Parameters	FYM at 25 t/ha + Full NPK	Vermicompost at 25 t/ha + Full NPK
Water stable aggregates (%)	43.76	46.47
Moisture content (%)	15.53	19.64
Infiltration rate (cm ha <sup>-1</sup> )	9.30	12.30
Organic C content (%)	1.38	1.48
Available N kg ha <sup>-1</sup>	275.16	284.74
Available P kg ha <sup>-1</sup>	45.19	48.38
Available K kg ha <sup>-1</sup>	183.66	196.04

Available Ca kg ha <sup>-1</sup>	1.56	1.61
Available Mg kg ha <sup>-1</sup>	2.63	2.85
Yield (t ha <sup>-1</sup> )	7.41	8.36
DMP	38.57	41.91
Shoot:root ratio	3.34	4.23
Leaf area	18.19	23.84

Incorporation of crop residues and FYM/compost in the soil through rotavator improves the physical and biological properties of the soil and increase crop yield by 25%.

**Weed Management:** The major weeds of chilli fields are *Cynodon dactylon*, *Digitaria marginata*, *Cyperus* spp., *Euphorbia hirta*, *Oldenlandia umbellata*, *Aegyratum conyzoides*, *Phyllanthus niruri* and *Amaranthus* spp.

The irrigated crop is weeded and hand hoed 3 or 4 times, while the rainfed crop is given 2 to 3 hoeings with bullock drawn implements and sometimes earthed up to help the surplus rain water to flow freely. Mulching with maize and sorghum residues (10 t/ha) increased chilli yields. This is attributed to reduced weed growth due to mechanical hindrance to emerging weed seedlings and availability of more nutrients to crop plants.

Among different mulch materials tested, black plastic film and straw mulch produced greater green fruit yields (10.7 t/ha). An increase of 66.40 to 67.19% in yield of chillies was recorded over unmulched control. The above mulches showed better weed control which eventually led to smother the weeds and encouraged the crop growth.

## Pest Management

**Gall Midge, *Asphondylia capparidis*:** NSKE 4% sprayed at the time of the first flush was found most effective in controlling gall midge infestation.

**Aphid, *Myzus persicae*:** Parasitoids, *Aphidius platensis* and *Aphelinus* sp. produced 80-98.8% parasitism in an insecticide-free field. The predators, *Chrysoperla carnea* and *Mallada boninensis*, very effectively controlled aphids on chilli when releases were made at 1:5 ratio of predator: prey.

**Thrips, *Scirtothrips dorsalis* and White Mites, *Hemitarsonemus latus*:** Spraying of Vertimec at 0.3 to 0.4 ml/l was found

effective against thrips and mites for 45 days. Cvs. NS 1101, NS 1701 (Namdhari seeds), NP 46A, Pusa Jwala, Arka Lohit and K 2 (Kovilpatti) are tolerant to thrips. *Chrysoperla carnea* can be released at 2 grubs/plant.

**Fruit Borer, *Helicoverpa armigera*:** Two round of sprays of *Ha* NPV at 250 LE/ha ( $6 \times 10^{12}$  PIB/ha) at 10 days interval were found effective in reducing the loss caused by fruit borer. *H. armigera* can also be controlled by using marigold as trap crop (planting 1 row of marigold after every 16 rows of chilli), installation of pheromone traps at 5/ha, 6 releases of *Trichogramma brasiliensis*, *T. pretiosum* or *T. chilonis* at 50,000/ha at weekly intervals, hand collection of larvae on main and trap crops and spraying with 5% NSKE or *Bt* at 500 g/ha.

**Tobacco worm, *Spodoptera litura*:** Two round of sprays of *Sl* NPV at 250 LE/ha ( $6 \times 10^9$  PIB/ha) at 10 days interval were found effective in reducing the loss caused by *S. litura*. It can also be controlled by installation of pheromone traps at 5/ha (Lures should be replaced once in 15 days), hand collection of egg masses and early instar larvae, release of *Telenomus remus* at 50,000/ha, installation of bird perches at 50/ha and spraying with 4% NSKE.

**Yellow Mite, *Polyphagotarsonemus latus*:** Sprays of 4% NSKE or 4% pulverized NSPE were found highly effective.

**White Grub, *Holotrichia consanguinea*:** Collection of beetles from plants during night hours and killing them in kerosene water reduced the infestation. Fungal and bacterial pathogens, *Metarrhizium anisopiale* and *Bacillus popilliae* var. *holotrichiae* are also effective in reducing the infestation.

**Damping-off, *Pythium aphanidermatum*:** Soil solarization using polythene sheet for 30 days during peak summer was most effective and resulted in least occurrence of damping off (1.28%) when compared to control (30.64%). Seed treatment with *Trichoderma viride* resulted in lowest incidence of damping off (4.7%).

Delivery of *T. harzianum* through solid matrix priming (SMP is a process in which moistened seeds are mixed with an organic carrier and the moisture content is brought to a level just below that required for seed sprouting. SMP can further enhance the efficacy of the antagonist in treated seeds. *Trichoderma* spp. grow on seed surface during priming process and increase in numbers and other microbes may not easily dislodge it) reduced the incidence of damping off in nursery.

Integration of soil solarization, application of neem cake and *T. viride* gives effective control of the disease.

**Phomopsis Blight and Foot Rot, *Phomopsis vexans*:** Deep summer ploughing, seed treatment in hot water at 50°C for 30 minutes, crop rotation with non-solanaceous crops and collecting and destruction of crop debris shall keep the disease under check.

**Wilt/Collar Rot, *Sclerotium rolfsii*:** Soil application of Bioderma (*Trichoderma viride*), avoiding excess irrigation and maintaining wider spacing shall reduce the disease incidence.

**Wilt, *Fusarium oxysporum*:** Seedling root-dip treatment and soil application of non-pathogenic *Fusarium* (Fo 52) significantly suppressed the wilt incidence. The combination of Fo 52 with *P. fluorescens* gave maximum inhibition of wilt.

**Fruit Rot and Leaf Blight, *Phytophthora* spp.:** Use of disease-free seeds for raising seedlings, collection and destruction of rotten fruits and soil application of neem cake + *Trichoderma viride* reduce the disease incidence.

**Crown and Fruit Rot, *Phytophthora capsici* in capsicum:** Minimum plant mortality (16.7%) was recorded when the plants were subjected to *T. viride* (PDBC TV 31) and *T. harzianum* (PDBC TH 10) followed by *T. harzianum* (PDBC TH 18) and *T. viride* (PDBC TV 23) where the mortality was 30%. In fungicidal treatment, 33.3% plant mortality was recorded while in pathogen check, it was highest (46.7%).

**Anthracnose, *Colletotrichum capsici*:** Cv. Arka Lohit is tolerant to anthracnose disease.

**Bacterial Wilt, *Ralstonia solanacearum*:** Cvs. Kandhari, Pungent Pride, Cherry Red, Vattal, Dark Purple, Long Red and Pant C-1 were reported resistant. Manjari and Ujwala developed by Kerala Agricultural University, Vellanikkara, are also highly resistant to bacterial wilt.

**Bacterial Leaf Spot, *Xanthomonas campestris* pv. *vesicatoria*:** Chilli cv. Jwala is reported to be field resistant.

**Viral Diseases (CMV, PVY):** Raise nursery under nylon net. Use tolerant cvs. NS 1101 and 1701.

**Murda Disease:** Chilli cvs. KDC-1, GPC-82 and Hybrid-9646 were found resistant to Murda disease.

**Root-knot Nematode and Bacterial Wilt Complex in Capsicum:** Combined application of neem based formulations of *Pseudomonas fluorescens* and *Pochonia chlamydosporia* at 25 g/m<sup>2</sup> in nursery beds and root dip treatment with either of these bioagents

before transplanting resulted in significant reduction in disease complex to the tune of 70% and increased the crop yield by 37%.

## IDM

- Crop rotation with French beans reduces bacterial wilt.
- Crop rotation with cereals, sesame and mustard, so also intercropping with marigold, onion, garlic reduce nematode infestation.
- Soil solarization of nursery beds for 2-3 weeks using transparent polythene sheets (100-160 gauge) kills soil borne pathogens.
- Raising nursery in raised seed beds (10-15 cm) provides good drainage and thereby avoid damping off.
- Seed treatment with *Trichoderma viride*/*T. harzianum*/*Pseudomonas fluorescens* at 20 g/kg of seeds to prevent damping off and nematodes.
- Deep summer ploughing helps in exposing pathogens and their resting stages to sun's heat.
- Collection and destruction of diseased plants/ plant parts from the field from time to time.
- Soil application of neem cake at 250 kg/ha as basal dose to control nematodes.
- Soil application of FYM enriched with *Trichoderma viride* at 1 tonne/ha.

### 8.1.4. Potato

**Nutrient Management:** Application of FYM/compost at 25 t/ha is recommended.

Soaking of potato tubers in plant growth promoting rhizobacteria (*Bacillus cereus* and *B. subtilis*) resulted in highest tuber yield (29.973 t/ha) and increase in uptake of N (147.87 kg/ha) and P (22.88 kg/ha) and net return of Rs. 37,769/ha (Table 8.8).

Significantly higher yield (31.1 t/ha) was obtained with application of water hyacinth at 15 t/ha compared to application of 60 kg K<sub>2</sub>O/ha through Murate of Potash (28.8 t/ha).

**Weed Management:** Manual weeding is the common method practiced. Straw mulching resulted in maximum mortality of weeds and highest yield.

**Table 8.8. Effect of soaking of potato tubers in plant growth promoting rhizobacteria (*Bacillus cereus* and *B. subtilis*) on tuber yield, increase in uptake of N and P and net return**

Treatment	Yield (t/ha)	Net return (Rs./ha)	N uptake (kg/ha)	P uptake (kg/ha)
Control	24.782	23711	119.47	16.91
<i>Bacillus cereus</i>	29.973	37769	147.87	22.88
<i>B. subtilis</i>	27.248	30099	124.26	25.81
CD at 5%	0.612	5322	3.16	1.03

Soil solarization helps in reducing the weed density. In solarized soil, number of weeds and fresh weight of weeds per plot of 1.5 m<sup>2</sup> were, 5 and 4.29 g, respectively. Whereas, corresponding figures for control were 265 and 416 g, respectively (Table 8.9). Reduction in weed population in solarized plots could be due to direct thermal killing of weed seeds which might have occurred because of increase in temperature below the tarp.

**Table 8.9. Effect of soil solarization and organic mulch on seed potato tuber yield and Weeds**

Treatment	Tuber		Weed (45 DAP)	
	Number/ 1.5 m <sup>2</sup>	Yield (t/ha)	Number/ 1.5 m <sup>2</sup>	Weight (t/ha)
Soil solarization	370	33.83	5	0.43
Organic mulch	304	22.20	259	41.07
Control	263	20.33	265	41.61
CD at 5%	44.6	3.37	31.6	5.08

## Pest Management

**Early Blight, *Alternaria solani*:** Use disease-free seed tubers for planting. Avoid cultivation of solanaceous crops nearby potato fields. Spray 1% Bordeaux mixture to control the disease. Use disease resistant cvs. like Kufri Sindhuri, Kufri Jyoti, Kufri Lalima for planting.

**Late Blight, *Phytophthora infestans*:** In North Indian Plains, use disease resistant cvs. like Kufri Sindhuri, Kufri Jyoti, Kufri Badshah, Kufri Chipsona 1 and 2, Kufri Jawahar, Kufri Sutlej. Use

disease-free seed tubers for planting. Ridges should be made up high enough to cover all daughter tubers and reduce chances of their infection upon exposure. In hills, use disease resistant cvs. like Kufri Jyoti, Kufri Girija in Himachal Pradesh hills, Kufri Kanchan and Kufri Jyoti in Darjeeling hills, Kufri Swarna and Kufri Thenamalai in Nilgiri hills. Spray 1% Bordeaux mixture to control the disease.

Biocontrol agents like *Pencillium* sp. and *Trichoderma* sp. have been found effective.

**Dry Rot or Black Scurf, *Rhizoctonia solani*:** Use disease-free seed tubers for planting. Seed treatment with acetic acid + Zn, boric acid or *T. viride* at 3.5 g/kg was very effective. Combination of soil solarization of black scurf infested fields and seed treatment with *T. viride* further improved the disease control.

Soil application of mustard/groundnut cake at 2.5 t/ha significantly reduced the number of black scurf diseased tubers and intensity of the disease.

Tuber damage and injury must be avoided during harvest and storage. Tubers should be washed to remove contaminated soil adhering to the tubers, followed by drying under shade reduces the infection substantially. In plains, tubers should be stored in cold stores. In country stores, tubers must be examined periodically and rotting tubers sorted out.

**Common Scab:** Use disease-free seed tubers for planting. Irrigate the crop repeatedly to keep the moisture to the field capacity right from tuber initiation until the tubers measure 1 cm diameter. Follow crop rotation with wheat, peas, oat, barley, lupin, soybean, sorghum, bajra and adopt green manuring to keep the disease in check. Plough the potato fields in April and leave the soil exposed to high temperature during May-June. Grow disease resistant cvs. like Patna Red, Kufri Alankar, Kufri Sindhuri, Kufri Dewa and Kufri Lalima.

**Brown Rot or Bacterial Wilt, *Ralstonia solanacearum*:** Seed production may be undertaken only in disease-free areas (higher hills of Himachal Pradesh and Plains of Punjab). Selection of disease-free tubers for planting, soil application of bleaching powder, hot/cold weather cultivation, disinfection of cutting knives with mercurials, adopting crop rotation for 2-3 years with non-host crops (maize, sorghum, ragi, cereals, garlic, onion, lupin, cabbage, green manuring crops like sunnhemp, etc.) and use of resistant cultivars have been recommended. Restrict post-emergence tillage to minimum. Practice full earthing up immediately after planting. Collect and burn all



diseased plant material including tubers after harvest. The pathogen is susceptible to high temperature. Raising the soil temperature by covering the soil with polythene film has been found effective in reducing the wilt. Opening the deep furrows in infested fields at 50-60 cm intervals, spreading the straw and burning (Jhumming cultivation) reduced the wilt incidence by 100%. Avirulent and bacteriophage producing strains of *R. solanacearum* induce resistance to bacterial wilt. Tuber bacterization followed by one soil application of avirulent strain of *Ralstonia solanacearum* significantly reduced the disease incidence to an extent of 80 to 82.5% and increased the tuber yield (15.08 to 15.83 t/ha) compared to 6.04 to 6.94 t/ha in control.

In North Easrern and North Western hills, early planting of the summer crop in February and harvesting in June can avoid the wilt. In Shillong and Ooty, planting in last week of July reduced the bacterial wilt and the wilt was negligible to nil in crop planted in first week of September. These practices reduce the cropping period to only 90 days. Therefore short duration varieties can be used to minimize the losses.

Crop rotation with maize, wheat, barley, oat, sunnhemp, finger millet and vegetables like cabbage, onion, garlic reduced the wilt incidence to the extent of 94%. Studies undertaken in North Western hills using 6 cropping sequences revealed that the reduction in wilt incidence ranged between 25 to 81% by following 2 years rotations. Potato-finger millet-finger millet-potato gave maximum reduction in wilt incidence (81%) (Table 8.10). Roots of finger millet were free from *R. solanacearum* infection, whereas paddy, maize, wheat and beans carried the infection. However, rhizosphere population of the pathogen was found to be reduced.

Intercropping of potato with maize and cowpea were most effective in reducing the wilt incidence.

Promising biocontrol agents include *Bacillus* spp., *B. polymyxa* and *Pseudomonas fluorescens* which have been found to reduce the wilt development and incidence. Root colonization by *P. fluorescens* have been reported. *Bacillus* spp. reduced bacterial wilt incidence up to 79%, while *P. fluorescens* by 43 to 75%. Summer (during May-June in Plateau and Plains where very hot and dry climate prevails) and winter ploughing (during December-January in hills where cold temperature prevails) alone reduced wilt incidence by 66% and 50%, respectively. Dipping of seed tubers in 0.25% solution of the formulation of *Bacillus cereus* (strain B4) and *B. subtilis* (strain B5) for 20 min. was effective in reducing the wilt by 59-72% and

enhancement of tuber yield by 16.7-25.6%. Tuber treatment with *P. fluorescens*/ *B. subtilis* reduced wilt incidence by 76.31 and 53.15% and increased tuber yield by 220 and 129%, respectively.

**Table 8.10. Effect of crop rotation on bacterial wilt incidence and yield of potato in North Western Hills (Bhowali)**

Crop rotation	Wilt incidence (%)	Yield loss	Popn. of <i>R. solanacearum</i> in cfu/ root system of different crops
Potato- Potato- Potato- Potato	51.7 (+ 92)	56.9	9.0 x 10 <sup>6</sup> (Potato)
Potato-Bean-Bean- Potato	19.7 (- 25)	18.3	9.2 x 10 <sup>4</sup> (Bean)
Potato-Paddy-Paddy- Potato	12.0 (- 53)	29.7	1.0 x 10 <sup>5</sup> (Paddy)
Potato-Wheat-Wheat- Potato	9.2 (- 63)	18.8	4.2 x 10 <sup>4</sup> (Wheat)
Potato-Maize-Maize- Potato	8.7 (- 66)	13.1	1.0 x 10 <sup>6</sup> (Maize)
Potato-Finger millet-Finger millet- Potato	4.7 (- 81)	7.1	0.0 (Finger millet)

In non-endemic areas (Gujarat, Maharashtra, North Western and North Central Plains and North Western high hills), use of disease-free seeds alone is adequate to control the disease completely. In mid hills (North Western mid hills up to 2200 MSL, North Eastern hills and Nilgiris hills), use of disease-free seeds, cold weather cultivation and application of bleaching powder at 12 kg/ha will be adequate for the disease control. Application of bleaching powder can be substituted with 2 years crop rotation with wheat, barley, finger millet, cabbage, cauliflower, knol-khol, carrot, onion, garlic. In Eastern Plains and Deccan Plateau, the disease can be reduced to considerable extent by following cultural practices like use of disease-free seeds, adjusting the date of planting, application of bleaching powder, straw burning in infested soil, blind earthing, hot weather cultivation and crop rotation (Table 8.11).

**Wilt, *Sclerotium rolfsii*:** Wet tuber treatment with *P. fluorescens* combined with *T. harzianum* at 10 g/kg was most effective.

**Charcoal Rot, *Macrophomina phaseolina*, *Rhizoctonia solani*:** Grow early maturing varieties. Harvest the crop early before it gets too warm by the middle of April. Keep the harvested tubers in cold stores. If the harvesting is delayed, keep the soil cool by frequent irrigations.

**Table 8.11. Control of bacterial wilt and brown rot**

Treatment	% reduction		% yield increase
	Wilt	Brown rot	
Healthy seed	50 – 76	40 – 46	18 - 27
Bleaching powder at 12 kg/ha + Blind earthing	70 – 94	50 – 85	22 – 28
Summer ploughing in Plains	50 – 83	50 – 70	5 – 25
Winter ploughing in Hills	60 – 75	62 – 78	35 – 40
Early planting in Hills	77 - 80	75 - 85	44 - 68

**Soft Rot, *Erwinia carotovora*:** Avoid excess irrigation. Provide proper drainage. Adjust planting time to avoid hot weather during plant emergence. Harvest the crop before the temperature raises to 28°C. Harvest the crop only when the tuber skin is fully cured. Avoid injury to tubers and sort out injured tubers. Treat tubers before storage with 3% boric acid for 30 min. and dry under shade. Store the produce in well ventilated cool stores or cold stores.

**Wart:** Cultivate immune cvs. like Kufri Jyoti, Kufri Sherpa, Kufri Kanchan and Pimpernel. Practice long crop rotation (5 years or more). Rogue out infected plants along with tubers.

**Mosaic Virus:** Strict sanitation should be practiced in the field and also in stores. Disinfect all field equipments with 3% Trisodium phosphate or 1% Calcium hypochlorite solution. Use disease-free seed tubers for planting. Rouging of diseased plants along with their tubers at least twice in growing season helps in reducing the incidence of the disease. Dehaulming the crop before the aphids cross the critical level. Follow thermotherapy by meristem culture for eliminating the virus from seed tubers. Potato cvs. having resistance are Kufri Ashoka, Kufri Badshah, Kufri Jawahar, Kufri Jyoti, Kufri Lalima, Kufri Pukhraj and Kufri Sindhuri.

**Virus Diseases (Potato Virus X, Potato Virus Y, Potato Leaf Roll Virus):** Potato cvs. Kufri Jyoti, Kufri Kuber, Kufri Lalima, Kufri Sindhuri and Kufri Ashoka have in built resistance/tolerance to PVX, PVY and PLRV.

**Aphid, *Myzus persicae*:** Cropping in aphid-free periods or when their population is low by adjusting the planting dates in the Indo-Gangetic Plains, where about 90% of seed crop is grown i.e. up to 15<sup>th</sup>

October in North Western Plains, up to 5<sup>th</sup> November in North Eastern Plains. Remove all weed hosts susceptible to viruses and for aphids (especially those having yellow flowers) from within and around the vicinity of seed potato plots. The haulm cutting of seed crop should be done as soon as the aphid number crosses the critical level i.e. 20 aphids/100 leaves. Care must be taken to prevent any regrowth of stumps before harvest.

**Cut worm, *Agrotis ipsilon*, *A. flammatra*:** Hot weather ploughing in plains and autumn ploughing in hills reduce the population of immature stages. A number of birds such as crow, mynah, starling, etc. feed on insects that gets exposed upon ploughing. Planting of potato on 25<sup>th</sup> November recorded least foliage damage (1.25%).

Some of the natural enemies which play important role in the management of cut worms are *Broscus punctatus*, *Liogryllus bimaculatus*, *Anopopus hypsipylae*, *Ichneumon* sp., *Turanogonia chinensis*.

The percentage foliage damage in *Bacillus thuringiensis* treated plots ranged between 0.0 to 2.0% compared to 1.6 to 6.4% in control. Similarly, tuber damage recorded at harvest was also less in *B. thuringiensis* treated plots. Further, significantly higher yield of potatoes was recorded from *B. thuringiensis* treated plots.

**White Grub, *Holotrichia consanguinea*:** Mechanical control by collection of beetles should be organized on community basis and started in late May or early June after the first shower by vigorous shaking of host trees/shrubs and then killed. Repeated ploughing before monsoon (April – May) exposes the grubs and pupae for predation by natural enemies (birds) or may be hand collected and destroyed. Flooding of the fields for 7-10 days, wherever possible may be undertaken. Adopt suitable crop rotations. Apply only well rotten FYM/compost in the fields.

A majority of beetles are attracted to the light source. Hence, light traps may be operated for mass collection.

**Tuber Moth, *Phthorimaea operculella*:** The pest is controlled through deep planting, high ridging and cold storage of seed. In country stores, use of sex pheromones on water traps at 4 traps/100 m<sup>3</sup> store space are effective for mass trapping of males. Use of biocontrol agents like *Bacillus thuringiensis* and Granulosis Virus are also advocated.

Keep the tubers in storage before sun set covered with 5 cm sand layer to prevent the adult moths from laying eggs on the eyes of the tubers. Use 2.5 cm thick layers of dried lantana or eucalyptus leaves

below and on top of the potato heaps which checks tuber moth infestation.

**Root-knot Nematode, *Meloidogyne* spp.:** Root-knot nematode-free seed tubers should be used for planting. Incubation of potato tubers at 45°C for 48 hr is recommended for getting satisfactory control. Deep ploughing and drying of soil in summer months facilitate drying and death of infective larvae. In small holdings, burning of trash in the field not only helps in reducing the nematode population but also enriches the soil. Following 2 years crop rotational sequence of maize-wheat-potato-wheat reduces root-knot damage significantly. Crop rotation with non-host crops like maize, wheat, barley, etc. reduces nematode population. Late planting of autumn crop and early planting of spring crop in North Western Plains, while in hills, early planting of summer crop in fourth week of March is ideal. In Jalandhar, planting in second week of October in autumn crop and early January in spring crop can limit the tuber infestation. In Shimla, early planting in third or fourth week of March reduces both root and tuber infestation without affecting the yield. Growing of trap crops like *Tagetes patula* and *T. erecta* (African marigold) in between 2 to 3 rows of potato reduces the root-knot nematode population. Clean cultivation (free from weeds which act as hosts) reduces nematode population to a great extent.

Application of neem cake/FYM/compost enriched with *Trichoderma harzianum*/*Paecilomyces lilacinus* will give effective control of root-knot nematodes.

**Cyst Nematode, *Globodera rostochiensis*:** Growing non-host crops like radish, garlic, beet root, French bean, cruciferous vegetables, turnip or green manuring crops bring down the cyst nematode population by more than 50%. A crop rotation pattern (using potato-French bean-peas), wherein potato is grown once after 3-4 other crops, decreased the nematode population by 98 to 99% and increased yields of potato. In Nilgiris, crop rotation with cabbage and carrot gave effective control of cyst nematodes. Application of neem cake at 1 t/ha/FYM at 20 t/ha/compost at 10 t/ha enriched with *Trichoderma harzianum*/*Paecilomyces lilacinus* will give effective control of cyst nematodes. Application of eucalyptus distillation waste at 2.5 t/ha or eucalyptus litter at 10 t/ha helps to reduce the cyst nematode population in soil. Application of *Pseudomonas fluorescens* at 10 g/m<sup>2</sup> also gives good control. Grow cyst nematode resistant varieties like Kufri Swarna and Kufri Thenamalai.

## IPM

- Deep summer ploughing to expose resting stages of pests to sunlight.
- Use disease-free seed material for planting.
- Grow resistant varieties (Table 6.25).
- Adjustment of planting and harvesting time for avoidance of pests and diseases. Optimum time for planting is 15<sup>th</sup> to 30<sup>th</sup> October in Western and Central Plains and 1<sup>st</sup> to 15<sup>th</sup> November in Eastern Plains.
- Covering the exposed tubers by high ridging.
- Use yellow sticky traps at 10/ha for attracting aphids.
- Use sex pheromone traps at 20/ha for mass trapping of tuber moth.
- Rouging of diseased plants.

## 8.2. Bulb Crops

### 8.2.1. Onion and Garlic

**Nutrient Management:** Application of FYM/compost at 25 t/ha is recommended. Dipping of onion seedling roots in *Azospirillum brasiliense* slurry (500 g/ha) for 15 minutes and application of 100% NPK (125:50:125 kg/ha) gave maximum yield, TSS and cost:benefit ratio followed by soil application of VAM (*Glomus mosseae*) at 1 kg/m<sup>2</sup> of nursery bed and application of 100% NPK.

Vermicompost application in onion and garlic yielded similar to that obtained with recommended doses of chemical fertilizers (Table 8.12).

**Table 8.12. Effect of manures on the yield of onion and garlic**

Treatment	Yield (t/ha)	
	Onion	Garlic
Recommended dose of Chemical fertilizers (RDF)	37.67	5.63
FYM - 8 t/ha	37.90	6.80
Vermicompost – 8 t/ha	41.40	10.60
50% RDF + Vermicompost – 8 t/ha	48.70	11.60

In onion, TSS was highest with vermicompost, poultry manure and FYM (11.41 – 12.09%). Specific gravity was highest in neem cake, vermicompost, poultry manure and FYM (1.71 – 1.95 g cm<sup>-3</sup>).

In garlic, application of sunnhemp at 20 t/ha produced the highest bulb yield (70.82 q/ha) which was on par with poultry manure at 2.5 t/ha (68.30 q/ha) compared to 26.55 q/ha in control.

## Pest Management

**Thrips, *Thrips tabaci*:** Thrips are weak fliers and carried to long distances by wind. Blocking adult thrips can reduce the initial and subsequent pest load on onion. Barrier crops (2 rows of maize around onion crop) can be employed for this purpose. Coccinellid predators were higher in plots where maize was used as a barrier crop. *Scymnus nubilis*, *Chrysoperla* spp. and *Latus* spp. are predaceous on thrips. Cvs. Arka Lalima, White Persian, Grano, Sweet Spanish, Crystal Wax, Spanish White, Bombay White, Pusa Red, Udaipur 103, N 780, N 53, and White Poona Red are reported to be resistant/tolerant. Sprinkling of water through jet nozzles prevents thrips multiplication. Spraying with 5% NSKE during vegetative stage is also effective against thrips.

**Tobacco Caterpillar, *Spodoptera litura*, *S. exigua*:** Fields should be properly ploughed to expose and kill the pupae in the soil. Flood irrigation may be done to drown the hibernating caterpillars. Digging trenches around the infested field prevents migration of larvae. Release of *Trichogramma brasiliensis* at 50,000/ha at weekly interval should be done 4-5 times.

**Greasy Cut Worm, *Agrotis ipsilon*:** Clean cultivation and regular stirring of soil reduces the infestation of cut worm.

**Damping-off, *Pythium* sp., *Rhizoctonia solani*, *Fusarium oxysporum* f.sp. *cepae*, *Sclerotium rolfsii*, *S. cepivorum*:** Use disease-free seeds for sowing. Seed treatment with *T. harzianum* at 5 g/kg and sowing in solarized soil helps in reducing the disease incidence. Overcrowding of seedlings and water stagnation in the nursery beds should be avoided. Drenching the soil with 1% Bordeaux mixture reduces the disease incidence.

**Basal Rot, *Fusarium oxysporum* f.sp. *cepae*:** Mixed cropping and crop rotation reduces the incidence of the disease. Seedling dip in antagonists like *Pseudomonas cepacis* and *T. viride* gives protection to seedlings. Soil solarization using polythene sheet of 750 gauge in summer season for 20-30 days reduces the infectious propagules, which in turn reduces the disease incidence. *T. viride* at 1250 g + 50

kg FYM if applied in soil before planting gives good control of basal rot in seed crop. Cvs. Arka Laima, Arka Niketan, Arka Pragati are reported to be resistant/tolerant.

**Purple Blotch, *Alternaria porri*:** Heat treatment of onion bulbs at 35°C for 8 hr before planting gives effective control of the disease. Summer sown crop should be encouraged to escape the disease infection. Cvs. Arka Kalyan, Arka Kirtiman, Arka Lalima and Agrofound Dark Red are reported to be tolerant to purple blotch. Crop rotation with coarse cereals also reduces blotch incidence.

**Blight, *Stemphyllium* sp.:** Summer ploughing of infested field reduces inoculum potential of blight. Field sanitation, collection and burning of crop residues minimizes infection rate.

**Anthracnose, *Colletotrichum gloeosporoides*:** The red onion is resistant. Field sanitation and destruction of infected crop debris helps in reducing the disease incidence.

**White Rot, *Sclerotium cepivorum*:** Removal and destruction of infected plants reduces the inoculum potential in the soil. Early planting of garlic is an important management strategy to avoid white rot in areas with infected soil. Soil solarization for 8-11 weeks during summer using transparent sheet resulted in reduction of *S. cepivorum* in garlic to undetectable levels in upper 20 cm of soil. Application of *T. harzianum*, *T. viride*, *T. virens* and *Bacillus subtilis* to the solarized soil effectively controlled the disease.

**Leaf Spot, *Cercospora* sp.:** Timely sprays of 1% Bordeaux mixture at fortnightly intervals minimized the disease incidence.

**Storage Rot, *Erwinia* sp.:** Storage of bulbs in well aerated and ventilated storage structures and eliminating the rotted bulbs by periodical turning of the storage heaps are recommended for minimizing the losses during storage.

**Root-knot Nematode, *Meloidogyne* sp.:** Root dip treatment of onion seedlings in *P. lilacinus* + neem cake suspension for 1 hr before transplanting proved effective.

## IPM

- Sprinkling of water through jet nozzles to prevent thrips multiplication.
- Use yellow sticky traps at 10/ha to prevent thrips damage.
- Spraying 5% NSKE 2 to 3 times during vegetative growth to prevent thrips damage.



### 8.3. Malvaceous Vegetables

#### 8.3.1. Okra

**Nutrient Management:** Application of FYM/ compost at 25 t/ha is recommended. The substitution of chemical fertilizers with organic manures such as neem cake, poultry manure, green leaf and enriched compost produced better yield and quality as compared to package of practice recommendation (Table 8.13).

**Table 8.13. Effect of organic manures on yield and quality of okra.**

Treatment	Fruit yield (t/ha)	Crude protein (%)	Ascorbic acid (mg /100g fresh fruit)	Shelf life (days)
FYM	10.590	17.04	21.49	5.17
FYM + Poultry manure	13.538	17.92	21.78	5.37
FYM + Neem cake	15.848	17.88	21.82	5.68
FYM + Green leaf	15.278	17.86	21.80	5.54
FYM + Enriched compost	12.671	17.78	21.85	5.65
CD at 5%	1.802	0.014	0.025	0.05

Okra raised with basal application of poultry manure at 2 t/ha with 3% Panchagavya foliar spray 4 times at 30, 45, 60 and 75 DAS recorded fruit yield of 10.27 t/ha and net returns of Rs. 46,440/ha which was on par with yield of 10.39 t/ha and net returns of Rs. 47,250/ha in okra raised through application of recommended NPK through inorganic source with monocrotophos spray.

Application of 120 kg N/ha gave maximum fruit yield. Processed city waste at 120 kg N/ha emerged as potential alternative to locally available FYM in terms of yield and pest infestation. The uptake of N, P and K and micronutrients in FYM treatment was significantly superior. Increase in fruit yield with FYM application was attributed to higher retentive capacity of soils for water and nutrients, increased biological activity and higher uptake of major nutrients.

Application of 52 t/ha fly ash or sewage sludge individually or co-application in 50:50 proportion increased the pod yield of okra by 18.5, 61.9 and 64.0%, respectively over control. The increase in yield was attributed to elevated concentrations of both macro and microelements

in different parts. There was efficient use of nutrients during the early stages of the crop up to 45 DAS, which contributed to higher pod yield and biomass.

**Weed Management:** Give 3 to 4 hoeings to keep the crop free from weeds. The first hoeing may be given when the seedlings are 2 weeks old and subsequent hoeings at fortnightly intervals.

## Pest Management

**Fruit Borer, *Erias vitella*; Petiole Maggot, *Melanagromyza hibisci*; Hopper, *Amrasca bigutulla bigutulla*:** Field experiment was conducted during *Kharif* 2000 at IIHR to study the efficacy of neem cake, pongamia cake, neem seed powder and pongamia seed powder on the pests of okra. Cakes and seed powders were applied to the soil immediately after germination and repeated at 30 days interval twice at 250 kg per ha. The results indicated that the borer incidence got reduced to less than 7% by both neem and pongamia cake soil application. Similarly significant reduction in hopper (*Amrasca biguttula biguttula*) (<3/plant) and petiole maggot (*Melanagromyza hibisci*) (<5%) were also noticed. Cakes were better than seed powders in reducing pest incidence and neem cake was the best treatment. This treatment was also found to reduce yellow vein mosaic virus and powdery mildew diseases (Table 8.14).

**Table 8.14. Efficacy of neem and pongamia cakes on major pests and YVMV disease in okra**

Treatment	Incidence of petiole maggot (%)	Mean no. of hoppers / 3 leaves	Incidence of fruit borer (%)	Incidence of YVMV
Neem seed powder	13.79	3.63	11.21	0.66
Pongamia seed powder	15.73	3.97	16.54	1.33
Neem cake	4.76	2.77	5.22	0.00
Pongamia cake	2.44	3.04	6.22	5.00
Untreated control	16.67	7.24	24.24	80.64

Spraying of 5% NSKE also gives effective control of shoot and fruit borer. Spraying of 5% NSKE and 3% neem oil effectively checked the fruit borer damage in okra (Table 8.15).

**Table 8.15. Effect of neem products in the control of fruit borer in okra**

Treatment	Fruit borer damage (%)	
	Weight basis	Number basis
Neem cake extract 10%	7.72	3.26
NSKE 5%	1.87	0.36
Neem oil 3%	1.44	0.23
Carbosulfan 0.044%	2.77	0.53
Untreated check	37.71	33.77

Releases of *T. chilonis* brought about 49.22% reduction in fruit borer (*E. vitella*) in Tamil Nadu. Three applications of *B. thuringiensis* (Dipel) at 0.5 kg/ha at weekly intervals reduced damage by *E. vitella*.

Okra variety Selection-2 (Gujarat Agricultural University, Anand) and Parbhani Kranti have lower borer infestation on shoots and fruits.

**Leaf Hopper, *Amrasca bigutulla bigutulla*; Whitefly, *Bemisia tabaci* and Aphid:** Sprays of 1% neem/pongamia soap were highly effective. Spraying 5% NSKE acts as oviposition deterrent, repellent and growth inhibitory effect on leaf hoppers and resulted in lower percentage of normal adult emergence. Lower population of above pests was noticed with sprays of poultry manure + herbal leaf extract and neem cake + herbal leaf extract.

Spraying of 5% NSKE effectively controlled the whitefly in okra resulting in over 80% reduction followed by 3% neem oil spray with 78% reduction over untreated control (Table 8.16).

**Table 8.16. Effect of foliar application of neem products in the control of whiteflies in okra**

Treatment	Mean popn. of whiteflies/3 leaves	% Reduction over untreated check
Neem cake extract 10%	9.2	67.9
NSKE 5%	5.7	80.1
Neem oil 3%	6.3	78.0
Carbosulfan 0.044%	23.9	16.5
Untreated check	28.6	---

**White Grub, *Holotrichia consanguinea*:** Collection of beetles from plants during night hours and killing them in kerosene water

reduced the infestation. Fungal and bacterial pathogens, *Metarrhizium anisopliae* and *Bacillus popilliae* var. *holotrichiae* are also effective in reducing the infestation.

***Helicoverpa armigera*:** Application of 5 rounds of *Ha* NPV at 500 LE/ha at weekly intervals right from flowering gave effective control of the pest.

**Powdery Mildew:** Spraying of NSKE and neem oil effectively controlled the disease.

**Yellow Vein Mosaic Virus (YVMV):** Kharif okra should be sown between last week of May and second week of June under Konkan conditions for obtaining higher yield with less YVMV incidence. Rouge out diseased plants. Do not use infested crop for seed production. Use resistant cultivars like Pusa Sawani, Harbajan, Parbhani Kranti.

**Leaf Spot, *Cercospora* sp.:** Spraying 0.8% Bordeaux mixture at 500 liters/ha starting from the appearance of symptoms at 14 days interval. Three sprays are enough.

**Root-knot Nematodes, *Meloidogyne* spp.:** Application of pressmud at 15 t/ha, a week prior to sowing is recommended for effective management of root-knot nematodes in kharif season. Crop rotation with cereals and marigold helps in reducing the nematode population in soil. Application of fresh neem or karanj cake at 1 t/ha at the time of final land preparation is recommended.

Integration of *Paecilomyces lilacinus* with neem cake gave effective control of *M. incognita* on okra.

Application of 5 per cent inoculum of *Arthrobotrys conoides* to the soil amended with FYM, effectively reduced the larval penetration of *M. incognita* and root galling was reduced by 30-40 per cent in okra.

Neem cake suspension (5%) mixed with the spores of *P. lilacinus* is also effective for the treatment of okra seeds for the management of *M. incognita* under field conditions.

Rotation of okra with sweet potato (cv. Sree Bhadra) reduced the root-knot nematode population by 21% and increased the fruit yield by 21%. Crop rotation with cabbage, marigold and wheat significantly reduced the root-knot nematode population.

## IPM

- Deep off-season/summer ploughing is useful to expose nematodes and resting stages of insects.

- Using YVMV resistant varieties (Arka Abhay, Arka Anamika, Parbhani Kranti, Varsha Uphar) for planting.
- Seed treatment with *Trichoderma viride* at 4 g/kg of seeds.
- Errection of bird perches at 25/ha.
- Intercropping with onion or cowpea is useful.
- Crop rotation with non-host crops such as sesame, marigold, onion or mustard reduces nematode infestation.
- Sowing of sorghum/maize all around okra field to prevent the entry of fruit borer.
- Soil application of fresh neem cake at 250 kg/ha to reduce fruit borer incidence.
- Setting up of yellow sticky traps for monitoring whitefly at 10 traps/ha.
- Installation of pheromone traps for *H. armigera* and *Earias vitella* at 5 traps/ha.
- Release of egg parasitoid, *T. chilonis* at 1 lakh/ha.
- Collection and destruction of borer infested fruits from time to time.
- Destruction of YVMV affected plants from time to time.

## 8.4. Cruciferous Vegetables

### 8.4.1. Cabbage/Cauliflower

**Nutrient Management:** Raised nursery beds of 2 m x 1.5 m were prepared and 10 kg FYM was mixed in the soil. Seeds were sown in lines 5 cm apart and covered with 1 kg of vermicompost (Gomini).

The main field was prepared with application of FYM at 8 t/ha. Vermicompost at 2.6 t/ha was applied in 2 splits at planting and 30 DAP. Three foliar sprays of groundnut cake and vermicompost extract mixed with Panchagavya were given 27, 35 and 42 DAP. For this purpose, 1 kg of groundnut cake was soaked in water and to this 0.5 kg vermicompost (Gomini) was added next day and fermented for 1 more day. This was filtered and made to 10 litres. The requirement of groundnut cake and vermicompost was 100 and 50 kg/ha/spray, respectively. Panchagavya was prepared afresh each time by mixing 200 ml of cow urine, 200 ml milk, 20 g ghee, pulp of 1 robusta banana along with 500 g of cow dung. The mixture was squeezed by hand, filtered through muslin cloth and made into 10 litres. The extract of groundnut cake + vermicompost and Panchagavya were mixed in

equal proportion and sprayed at 1000 litres/ha. The requirement of milk and ghee was 20 litres and 2 kg/ha/spray, respectively. Phytozeal, an organic tonic, was sprayed 2 times (at 2.5 ml/litre) at 20 and 45 DAP in cabbage.

The application of FYM at 20 t/ha was effective in increasing the head size (391.27 sq. cm.) and head yield (76.116 t/ha) as compared to 339.40 sq. cm (head size) and 68.045 t/ha (head yield) in recommended dose of NPK (120:60:60) (Table 8.17).

**Table 8.17. Effect of different sources of nutrients on growth and yield of cabbage.**

Source of nutrients	Head size (sq. cm.)	Yield (t/ha)
FYM at 5 t/ha	359.61	69.264
FYM at 10 t/ha	344.17	69.155
FYM at 15 t/ha	345.06	71.745
FYM at 20 t/ha	391.27	76.116
Pressmusd at 5 t/ha	358.54	57.451
Pressmusd at 10 t/ha	335.69	61.635
Pressmusd at 15 t/ha	350.76	66.519
Pressmusd at 20 t/ha	350.32	70.931
NPK (120:60:60 kg/ha)	339.40	68.045
CD at 5%	22.5	4.555

**Weed Management:** Weed control is done manually by using small hand operated tools. The crop should be hand weeded twice at 20 and 40 days after transplanting.

Weed control in cauliflower is done manually by using khurupi. Increase in yield of cauliflower by 40% using black polythene film has been reported. This inorganic mulch also helped in retaining moisture, prevented deterioration of soil structure and reduced the difference between maximum and minimum temperature. Best growth and increased yield were obtained with mango leaf mulch followed by pine needles and hay mulch.

## Pest Management

**Diamondback Moth (DBM), *Plutella xylostella*:** Sprays of NSKE 4% / 4% pulverized NSPE were found to be highly effective against DBM. Field sprayed with NSKP/NSP extract had obtained

higher yield, incurred 15% less cost and realized 43% higher net returns. The performance of powder formulation of 'Soluneem' was on par with 4% NSKE in controlling DBM. Sprays of neem soap or pongamia soap both at 1% were highly effective in reducing DBM (Table 8.18), aphids (*Brevicoryne brassicae*) and leaf webber (*Crocidolomia binotalis*). Further, the soap sprays significantly increased the yield of cabbage and cauliflower and were relatively safe to the parasitoid, *Cotesia plutellae*.

**Table 8.18. Efficacy of neem and pongamia soaps on DBM and yield in cabbage**

Treatment	DBM incidence/plant	Yield (t/ha)
NSKE	3.00	109.60
Bt	3.00	92.67
Soluneem	3.33	99.60
Neem oil	9.00	66.53
Pongamia oil	7.67	73.33
Neem soap	2.33	111.33
Pongamia soap	4.67	116.67
Control	36.33	43.87

Under natural conditions in an undisturbed ecosystem (insecticide-free environment), the parasitoid, *Cotesia plutellae* is capable of excersizing about 70-80% control of DBM in India.

The parasitoid, *Didegma semiclausum* producing excellent parasitism up to 68% in Nilgiris, showed its full potential in places of cooler temperatures ranging from 15-20° C and high hills.

'Biotrol' WP ( $25 \times 10^6$  spores/mg) was effective in controlling the diamondback moth, *Plutella xylostella* on cabbage. 'Thuricide' HPSC and 'Dipel' WP ( $16 \times 10^6$  IU/mg) at 1 and 1.5 g/l could effectively check *P. xylostella* on cabbage. Weekly sprays of 'Dipel' at 0.5 kg/ha were recommended for the control of *P. xylostella* and *Crocidolomia binotalis*. Application of 5 rounds of *B. thuringiensis* var. *kurstaki* (Halt) at 1 kg/ha at weekly interval gave effective control of larval population (0.61-0.81 larva/plant) (79.9% reduction in larval population over check) as compared to control (3.02 larvae/plant). The yield was also high in Halt (70.2 kg/plot) as compared to control (53.8 kg/plot).

The highest mortality of DBM (52.5% in WP and 70.0% in Emulsified suspension formulation) was recorded in case of *Beauveria bassiana* isolated from DBM. Emulsified suspension formulation of *B. bassiana* will be an ideal organic input as foliar mycoinsecticide in cabbage ecosystem. Application of 5 rounds of *Paecilomyces farinosus* at weekly intervals significantly brought down the larval population of DBM and increased the marketable yield.

**Cabbage Butterfly, *Pieris brassicae*:** Mechanical removal of egg masses and gregarious larvae is effective. Spraying of *Bacillus thuringiensis* also gives good control of this pest. 'Thuricide' (30x10<sup>6</sup> spores/mg) at 0.4% was found effective for the control of *Pieris brassicae* and *P. xylostella* on cauliflower.

**Tobacco Caterpillar, *Spodoptera litura*:** Destruction of egg masses and skeletonized leaves where young larvae are feeding gregariously is very effective. NSKE 4% spray controls early stage larvae. Large larvae have to be controlled by piercing with a sharp thick iron needle in head and killing.

**Aphid, *Lipaphis erysimi*:** Cauliflower intercropped with non-crucifer host plants like sunflower, tomato and marigold were highly effective in reducing the aphid incidence and enhancing the number of natural enemies resulting in higher yields.

**IPM:** IPM using Indian mustard as a trap crop involves planting of paired rows of mustard after every 25 rows of cabbage/cauliflower and spraying of NSKE 4% at primordial formation. Two more sprays of NSKE 4% may be given at 10-15 day interval after the first spray. The IPM gave 152% more returns than pure cabbage crop. IPM controls diamondback moth, leaf webber (*Crocidolomia binotalis*); stem borer (*Hellula undalis*); aphids (*Brevicorne brassicae*, *Hyadaphis erysimi*) and bug (*Bagrada cruciferarum*).

**Use of Neem and Pongamia Soaps in Cabbage IPM:** The field experiments conducted at IIHR, indicated that neem and pongamia soap sprays were highly effective in reducing DBM, aphids (*Brevicoryne brassicae*) and leaf webber (*Crocidolomia binotalis*) and were at par with NSKE. They were superior to many commercial synthetic insecticides like dichlorvos, cypermethrin, combination formulation of cypermethrin and profenfos etc. and commercial bath soap of neem, liquid soap in controlling DBM. Further, the soap sprays significantly increased the yield of cabbage. Oil sprays though effective in reducing DBM, reduced the yield and were toxic to cabbage leaves. Both neem and pongamia soaps were at par in reducing DBM and aphids. On cauliflower too, the neem and pongamia soap sprays were effective. The soap sprays were also found to be relatively safe to



the DBM parasitoid, *C. plutellae* and were also found to increase yield significantly in cabbage and cauliflower.

The use of both neem and pongamia soaps in the cabbage IPM was successfully validated in more than 50 farmers field during 2001 and 2002. Among them, 15 farmers used only soap sprays while others used 1-2 insecticide applications (which was not really necessary) and managed the crop very well and reduced the cost towards pesticides. These farmers were previously spraying insecticides more than 12 times for controlling insect pests of cabbage.

The soaps lack systemic effect and the residual toxicity is limited. Therefore, the coverage on the crop surface is very important while spraying to get effective control. During summer months if adults of DBM are found in large numbers, then they have to be controlled first using light traps during night. Otherwise, larval population may not get reduced as the eggs laid by the high adult population hatch and develop without any problem due to low residual toxicity.

**Damping-off, *Pythium aphanidermatum*, *Rhizoctonia solani*:** Well drained nursery beds, use of well decomposed organic manure, wide spacing between the rows, lesser density of seedlings and light but frequent irrigations helps in reduction of damping off. Good control of damping off was obtained through soil incorporation of wheat bran preparation of *T. harzianum* in commercial nursery. Seed treatment with *Trichoderma* spp. was found to be as effective as soil treatment for managing the disease.

Soil drenching with 0.6% Bordeaux mixture commencing 15 DAS and subsequent 2 more drenchings at 10 to 15 days interval gives effective control of the disease.

**Black Rot, *Xanthomonas compestris* pv. *compestris*:** Hot water treatment of seeds at 50°C for 30 minutes, drenching of seed beds with 1% Bordeaux mixture, 3 years crop rotation with non-host crops and strict field sanitation will help in checking the disease. Rouging of diseased plants helps in reducing the disease incidence. Crop rotation with rice was found to be best in reducing the black rot disease. *B. subtilis* was found effective as seed treatment, seedling root-dip treatment and soil drenching. Cauliflower cvs. Pant Shubra and Pusa Ice are reported resistant.

**White Rot or Stalk Rot, *Sclerotinia sclerotiorum*:** Avoiding excess moisture with less frequent irrigation and reducing the plant populations by following wider spacing will create microclimate less congenial for disease development. Application of FYM or saw dust reduces the disease incidence. Follow cabbage/cauliflower – paddy

rotation. Remove diseased leaves and destroy them. Soil application of *T. harzianum* (TH 4) and *Aspergillus niger* (Sanjeevini and Kalisena) were highly effective.

**Alternaria Black Spot and Downy Mildew:** Seed treatment with hot water maintained at 50°C for 30 min is effective. Giving wider spacing of 60 x 50 cm and removal of basal leaves from time to time help to reduce the disease incidence. Seed treatment with *T. viride* and *P. fluorescens* and soil treatment of nursey beds with neem cake enhanced seed germination and seedling stand.

**Club Root:** Trap cropping with rayosak among susceptible brassicas in the first year and tori sarson and radish among resistant brassicas in the second year with 30 days optimum trapping period were found most effective in reducing the disease intensity and increasing the yield.

## IPM in Cabbage

### Nursery

- Deep off-season ploughing.
- Soil solarization for 2-3 weeks during summer using 400 gauge thick transparent polythene sheet.
- Green manuring with sunnhemp in July – August.
- Raising nursery on raised beds (10 cm above ground level) for good drainage, to avoid damping-off.
- Seed treatment with *T. harzianum*/*T. viride* at 4 g/kg to prevent infection of soil/ seed borne fungal diseases.
- Apply 1 kg FYM enriched with 50 g of *T. harzianum*/*T. viride* / m<sup>2</sup> nursery bed.
- Spraying *B. thuringiensis* at 5 g/l to control DBM.

### Main field

- Growing 2 rows of Indian mustard as a trap crop after every 25 rows of cabbage to trap DBM, leaf webber and aphids. One row of mustard is sown 15 days before cabbage planting and second after 25 days after cabbage planting.
- Giving wider spacing of 60 x 50 cm to reduce the incidence of *Alternaria* black spot, black rot and downy mildew.
- Installation of light traps at 8/ha to attract DBM adults.

- Three sprays of 5% NSKE/ 1% neem/pongamia soap at primordial stage and repeat at 10 days interval to control DBM. NSKE is safe to *Cotesia plutellae*, the dominant parasitoid of DBM.
- Removal of basal leaves to reduce the incidence of *Alternaria* black spot, black rot and downy mildew.

## 8.5. Leguminous Vegetables

### 8.5.1. Pea

**Nutrient Management:** Application of FYM/compost at 15-20 t/ha is recommended. The highest increase in yield (181.5%) (yield - 9.15 t/ha) over control (yield - 3.25 t/ha) was recorded with application of FYM at 20 t/ha which was on par with FYM at 15 t/ha (166.1%) (yield - 8.65 t/ha). FYM at 10 t/ha (yield - 7.54 t/ha) and poultry manure at 6 t/ha (yield - 7.55 t/ha) were the next best treatments.

**Weed Management:** The fields should be kept free from weeds by giving 2 weedings and hoeings after 4 and 8 weeks of germination, respectively.

### Pest Management

**Stemfly:** Sow the crop in second fortnight of October to escape the damage of stemfly in Punjab. Soil application of neem cake at 200 kg/ha is effective.

**Macrophomina phaseoli:** *Rhizobium* spp. were found effective in suppressing *M. phaseoli* in pea.

**White Rot, *Sclerotium rolfsii*:** Burn all plant debris after harvest. Follow crop rotation with wheat/barley. Follow proper spacing between rows and plants. Avoid excessive irrigation from pre-flowering stage onwards. Stake medium to tall cultivars. Avoid injury to stem during picking. The late sown crop in November escape the disease to a great extent.

**White Mold, *Sclerotinia sclerotiorum*:** Reduction in white mold of pea was reported under field conditions through the application of *Trichoderma harzianum*.

**Powdery Mildew:** In organically grown pea, biopriming of pea seeds with *Trichoderma harzianum* + *Pseudomonas fluorescens* was most effective in improving the seedling stand. Foliar application of bioagents significantly reduced the incidence of powdery mildew disease. Application of *Pseudomonas fluorescens* + *Trichoderma*

*harzianum* through seed and foliar spray was most effective in increasing the yield of organically grown pea (Table 8.19).

**Table 8.19. Effect of different biocontrol agents applied through seed, FYM and/or foliar application on powdery mildew disease and yield of pea**

Treatment	Seedling stand/ m <sup>2</sup>	Powdery mildew incidence (%)	Yield (kg/ha)
Seed biopriming with <i>Trichoderma harzianum</i> + sprays with <i>Pseudomonas fluorescens</i>	56	13	355
FYM colonized with <i>Trichoderma harzianum</i> + sprays with <i>Pseudomonas fluorescens</i>	63	16	352
Seed biopriming with <i>Trichoderma harzianum</i> + FYM colonized with <i>T. harzianum</i> + sprays with <i>T. harzianum</i>	69	12	388
Control	52	36	301
CD at 5%	6	10	53

**Root-knot Nematodes, *Meloidogyne* spp.:** Intercropping with marigold or mustard with pea reduced the damage of root-knot and reniform nematodes.

## IPM

- Late sowing of pea in November month escapes the attack from stem fly.
- Seed treatment with *T. viride*/ *T. harzianum* at 4g/kg of seed.

### 8.5.2. French Bean and Cowpea

**Nutrient Management:** Application of FYM/compost at 25 t/ha is recommended. The vermicompost coated cowpea seeds recorded the highest grain yield of 66.20 g/plant. Dry matter production both at flowering stage and at harvest showed significant response to the use of vermicompost coating of seeds. The use of vermicompost either as seed inoculant or as organic source gave better results in terms of yield as well as biometric characters. The use of vermicompost as bioinoculant resulted in increased availability of N and P due to biological fixation of N and biological solubilization of P (Table 8.20).

**Table 8.20. Effect of vermicompost coating on cowpea**

Treatment	No. of pods/plant	Wt. of pods (g/plant)	Grain yield (g/plant)
Uncoated seeds + Full NPK	21.33	126.60	38.19
Rhizobium coating+ Full NPK	32.33	203.21	65.31
Vermicompost coating+ Full NPK	33.33	210.32	66.22
CD at 5%	7.99	---	14.518

Maximum vegetable cowpea yield of 10.7 t/ha was obtained with basal application of poultry manure and neem cake at 50 kg N/ha. FYM application registered an yield of 8.0 to 8.6 t/ha.

Maximum grain yield, bhusa yield and quality of cowpea were obtained in treatments receiving enriched vermicompost (with low grade carriers like rock phosphate) as an organic source (Table 8.21).

Application of poultry manure or neem cake equivalent to 50 kg N/ha gave cowpea yield more than 10 t/ha.

**Table 8.21. Comparative efficacy of enriched vermicompost on cowpea**

Treatment	Grain yield (kg/ha)	Bhusa yield (kg/ha)	Protein content (%)
Rock phosphate (RP)	690.0	1324.5	20.13
FYM	817.5	1619.5	21.56
Vermicompost	877.5	1823.0	23.81
Enriched vermicompost	1072.5	2093.5	24.94
FYM + Full RP	837.5	1650.0	21.62
FYM + Half RP	831.5	1650.0	21.62
Vermicompost + Full RP	882.5	1839.5	23.87
Vermicompost + Half RP	879.0	1830.0	23.81
Vermicompost + Half RP (primed)	898.5	1810.5	24.19
FYM + Full RP (primed)	859.0	1678.0	22.18
FYM + Half RP (primed)	833.5	1623.5	22.06
CD at 5%	54.05	137.05	0.412

**Weed Management:** At least 2-3 weedings at an interval of 20 days are needed to keep the fields free of weeds. Manual weeding is

the common practice adopted to control weeds in French bean. This has to be repeated 3-4 times due to pre-emergence of weeds after every weeding and irrigation.

### Pest Management

**Beanfly, *Ophiomyia phaseoli*:** As soon as few puncture marks are noticed on unifoliate leaves caused by oviposition by the adults inside leaf lamina, spraying of 4% NSKE/ 4% pulverized NSPE/1% neem soap/1% pongamia soap is to be given. Second spray can be given after 15 to 20 DAS. Soil application of neem cake at 200 kg/ha is also effective.

**Spider Mite:** The predatory mite, *Phytoseilus persimilis* gave excellent control of spider mites when released at 10 adults/plant.

**Gujarat Hairy Caterpillar, *Amsacta moorei*:** Moths can be effectively managed by installing UV light traps (Pest-O-Flash) at 1 light trap/ha. Spraying of 4% NSKE on bunds and field boundaries gives effective and economical control.

**Aphid, *Aphis craccivora*:** Single spray of water suspension of *Fusarium pallidoroseum* (7 x 10<sup>6</sup> spores/ml) gave effective control of aphids under field conditions. Reinfestation of plant by aphids was not observed while the plants sprayed with quinalphos at 0.05% showed reinfestation necessitating repeated application of the insecticide (3 sprays).

**Leaf Spot and Bacterial Blight, *Xanthomonas compestris* pv. *phaseoli*/ *vignicola*:** Pre-soaking of seeds at 15°C for 20 hours and then immersing them in water maintained at 30-60°C for 25 minutes, clean cultivation, spraying of 1% Bordeaux mixture and use of resistant varieties (Pundulea 68-5939, Bistremiki, TVU 200, 347, 401, 456, 580, 726, 1460, 2460 and 4540) gave effective control of the disease. Use of healthy seed and clean cultivation helps to reduce the disease incidence.

**Collar Rot, *Rhizoctonia solani*:** Integration of *Glomus mosseae* with *T. viride* gave total protection.

**Rust:** *T. viride* and *T. koningii* as 2% foliar sprays were effective both in French bean and cowpea.

**Common Mosaic:** Grow resistant cultivars like Pusa Parvati, Contender, Kentucky Wonder.

### IPM

- Seed treatment with *P. fluorescens* at 5 g/kg of seeds.

- Soil application of enriched FYM with *T. harzianum* at 1 tonne/ha.
- Spraying of 4% pulverized NSPE or 1% neem soap immediately after germination and repeated after 1 week to control stem fly.
- Spraying of *P. fluorescens* 2 times (20 and 45 DAP) to induce disease resistance.
- Spraying of 4% pulverized NSPE or 1% neem soap at flowering.
- Spraying of 1% neem soap or 1% pongamia oil on the under surface of the leaves, if mite/hopper incidence is noticed.

### 8.5.3. Pigeonpea

#### Pest Management

**Pod Borer, *H. armigera*:** Integrated management of pigeonpea pod borer using *Ha* NPV at  $2 \times 10^6$  PIB's/ml + nematode DD-136 (*Steinernema feltiae*) at  $3 \times 10^3$  infective juveniles/ml was attempted. The least population of *H. armigera* was observed in virus + nematode treated plots (0.2) when compared to control (12.6). The percentage of pod damage was significantly lower in virus + nematode (1.07) when compared to control (40.31). Significant increase in pod yield was obtained in virus + nematode treated plots (10.7 kg) when compared to control (3.2 kg).

The main borers in pigeon pea are flower bud borer (*Lampides boeticus*) and pod borer (*H. armigera*). Neem cake @ 250 kg/ha was incorporated to soil at the time of flowering. There was significant reduction in borer incidence in pigeon pea to 6 % as compared to more than 20% in other non-IPM plots.

**Wilt, *Fusarium udum*:** *Bacillus subtilis* brought about a marked reduction in the incidence of pigeonpea wilt. Amendment of soil with roots of certain leguminous crops (sweet clover), molasses and oil cakes (groundnut cake) markedly increased the antibiotic (bulbiformin) production by *B. subtilis* and a reduction of 88% in the incidence of wilt. Seedlings gained resistance to *Fusarium* infection when the seeds were bacterized with *B. subtilis* before sowing. It was suggested that bulbiformin became systemic in the plant and provided a protective zone around the roots of pigeonpea seedlings.

*Trichoderma harzianum* effectively suppressed Fusarial wilt of pigeonpea.

#### 8.5.4. Cluster Bean

**Nutrient Management:** Application of FYM/compost at 10 t/ha is recommended.

#### Pest Management

**Root Rot, *Sclerotium rolfsii*:** Control of root rot of cluster bean was achieved with *Streptomyces nigrifaciens*.

**Leaf Spot and Bacterial Blight, *Xanthomonas compestris* pv. *cyamopsidis*:** Use of healthy seed from summer grown irrigated crop and hot water treatment of seeds at 56° C for 10 minutes will help in reducing the disease incidence.

#### 8.5.5. Field Bean

**Nutrient Management:** Application of FYM/compost at 15-20 t/ha is recommended.

#### Pest Management

**Pod Borer, *Adisura atkinsoni*:** The 'Biotrol' at 1 g/l reduced the pod borer infestation on field beans.

Neem cake @ 250 kg/ha was incorporated to soil at the time of flowering. In lab lab, the borer incidence was 14% due to neem cake application as compared to more than 36% in non-IPM plots.

Crop rotation with cereals (jowar, maize) reduced the incidence of pod borer.

### 8.6. Leafy Vegetables

#### 8.6.1. Amaranthus

**Nutrient Management:** Application of FYM/compost at 12.5 t/ha is recommended. High amaranthus yield was obtained from 100, 125 and 150% levels of FYM, vermicompost and poultry manure. Total dry matter production showed an increasing trend with increasing doses of manures. Quality of amaranthus improved with various organic manures. Maximum vitamin C content was recorded in highest level of vermicompost. Highest dose of poultry manure (25 t/ha) gave highest protein content (Table 8.22).



**Table 8.22. Effect of organic manures on organic nutrition of amaranthus**

Treatment	Yield (t/ha)	Vitamin C (mg/100g)	Protein (%)	B:C Ratio
FYM 100% POP	61.34	62.03	16.86	1.63
FYM 125% POP	66.41	63.67	18.78	1.76
FYM 150% POP	74.12	64.93	20.58	1.89
Poultry manure 100% POP	59.48	61.99	16.82	1.63
Poultry manure 125% POP	61.02	64.13	20.41	1.74
Poultry manure 150% POP	66.12	63.80	21.67	1.85
Vermicompost 100% POP	58.00	64.07	16.69	1.56
Vermicompost 125% POP	67.32	64.97	18.60	1.80
Vermicompost 150% POP	75.15	65.57	21.50	1.93
CD at 5%	1.31	1.30	1.67	0.04

## Pest Management

**Leaf Caterpillar, *Hymenia recurvalis*:** The population of leaf webber caterpillars and the extent of leaf damage in yellow oleander, *Thevetia nerriifolia* plant extract (2% seed and fresh leaf extract) treated plots was significantly low compared to control plots. Seed extract sprayed plots gave an yield of 4.10 kg/plot as compared to 2.75 kg/plot in control.

‘Thuricide’ dust ( $3 \times 10^6$  spores/g) at 20 to 25 kg/ha, ‘Thuricide’ WP at 0.1 and 0.2% and ‘Thuricide’ EC ( $15 \times 10^9$  spores/g) at 0.1 and 0.2% were found to be highly effective in controlling the leaf caterpillar.

## 8.7. Cucurbitaceous Vegetables

### 8.7.1. Pumpkin and Gourds

**Nutrient Management:** Application of FYM/compost at 25 t/ha is recommended. The yield and yield attributing characters of snake gourd were highest in plots applied with FYM and vermicompost to substitute NPK. The organic forms of manure showed a definite advantage over inorganic fertilizers in the quality of the fruit. Among quality attributes, significant higher values for TSS, Vitamin C, total sugars and increased shelf life were observed in fruits obtained from vermicompost applied plots.

## Pest Management

**Fruitfly, *Bactrocera cucurbitae*:** Soil application of neem cake at 250 kg/ha (50 g/plant) followed by foliar sprays of 4% NSKE/4% pulverized NSPE/1% neem soap/1% pongamia soap at flowering were found effective.

Field experiments were conducted to know the effect of cakes on the incidence of fruitfly in bitter gourd. Soil application of neem and pongamia cakes, recorded fruitfly incidence ranging from 8.33 and 18.66%. Sprays of 4% pulverised neem seed powder recorded the lowest (0 to 3.60%) fruitfly incidence. Application of pongamia cake was moderately effective in reducing the fruitfly incidence. All other insecticide treated plots recorded high fruitfly incidence. Hence, soil application of neem cake followed by foliar sprays of neem seed powder extract is effective for managing fruitfly in bitter gourd.

One field experiment was conducted to know the efficacy of sprays of neem and pongamia soaps on fruitfly incidence in gherkins as compared with synthetic insecticides. It was found that the incidence of fruitfly was reduced to less than 9% by sprays of both the soaps as compared to 32% incidence in unsprayed control. Spraying of monocrotophos and phosphamidon recorded more than 10% incidence. The soap sprays were also effective on leaf miner.

**Serpentine Leaf Miner, *Liriomyza trifolii*:** Left alone, the leaf miner gets suppressed by natural enemies. NSKE 4%/ 4% pulverized NSPE /neem soap 1% spray is very effective when sprayed 10-15 DAS and repeated after 15 days, if necessary.

**Pumpkin Leaf Beetles, *Aulacophora* sp. and *Marguronia indica* and the Leaf Feeding Caterpillars:** Dusting the plants with ash temporarily repels the beetles. Sow the crop in November to avoid the damage from the pest. Pumpkin leaf beetles and the leaf feeding caterpillars on gourds were found to be highly susceptible to *B. thurigiensis*. Spraying with *Beauveria bassiana* ( $2 \times 10^6$  cfu/g) is effective against red pumpkin beetles.

**Root-knot Nematode, *Meloidogyne* sp.:** Pulverize the planting pit soil and expose to sunlight by repeated raking. Heap 4" to 6" dry trash and burn it before application of compost. Add 250 g fresh neem cake or karanj cake enriched with *Trchoderma harzianum*/ *Paecilomyces lilacinus* per planting pit to effectively control the nematodes.

## IPM

- Deep summer ploughing to expose resting stages of insects and nematodes.

- Seed treatment with *T. harzianum*/*T. viride* at 4g/kg of seed.
- Give enough spacing to prevent overlapping of the crop.
- Collection and destruction of red pumpkin beetles.
- Stirring the soil causes mortality of pupal stages of fruitfly, *Dacus cucurbitae*.
- Removal and destruction of damaged fruits from time to time.
- Installation of methyl euginol sex traps to monitor fruitfly.

### 8.7.2. Cucumber

**Nutrient Management:** Application of FYM/compost at 25-30 t/ha is recommended. Application of Chetna at 1 ml/litre (containing 1.5% w/w potentised botanical extract of *Cynadon dactylon*, *Ficus* sp. and *Dendrocalamus* sp.) gave better seed germination (76.01% compared to 62.75% in control), flowering and yield (16.2 fruits/plant as compared to 7.0 fruits/plant in control) of cucumber.

### Pest Management

- Seed treatment with *P. fluorescens* at 5 g/kg of seeds.
- Soil application of enriched FYM with *T. harzianum* at 1 tonne/ha.
- Soil application of fresh neem cake at 250 kg/ha immediately after germination and repeated at the time of flowering.
- Spraying of *P. fluorescens* 2 times (20 and 45 DAP) to induce disease resistance.

**Fruit fly, *Dacus cucurbitae*:** Application of neem cake or sprays of 4% NSKE were very effective in controlling fruit fly in cucumber (Table 8.23). Soil application of neem cake reduced the incidence of fruit fly to 6%, whereas insecticide sprayed plots recorded 15% incidence.

**Powdery Mildew, *Sphaerotheca fuliginea*, *Erysiphe cichoracearum*:** Crop rotation with paddy in low lying areas is very effective against powdery mildew. Application of *Ampelomyces quisqualis* to the foliage, starting shortly after colonies of *S. fuliginea* began to appear, efficiently suppressed powdery mildew and increased yields of marketable cucumbers. Water spray of *A. quisqualis* gave acceptable control of powdery mildew on cucumber in the field if applied with 2% paraffin oil.

Both *A. quisqualis* and *Sporothrix flocculosa* are effective in controlling powdery mildew on cucumber under high humidity

conditions, especially in greenhouses. The pycnidial hyperparasite, *A. quisqualis* has sticky conidia that are splash dispersed, as are the spores of yeast like antagonist, *S. flocculosa*. Biocontrol of powdery mildew therefore, depends on maintaining high humidity and occasional water sprays to ensure splash dispersal of antagonist spores. *Tilletiopsis washingtonensis* and *T. pallescens* when applied at  $1 \times 10^8$  spores/ml, could significantly reduce powdery mildew on cucumber in greenhouse.

**Table 8.23. Efficacy of neem cake and NSKE on fruit fly in cucumber**

Treatment	Dose (%)	Incidence of fruit fly (%)
NSKE	4.00	11.08
Carbaryl	0.15	15.17
Metasystox	0.05	22.77
Monocrotophos	0.05	20.84
Phosphomidon	0.05	22.36
Neem cake	100 g/pit	6.26
Pongamia cake	100 g/pit	21.45
Control	-	48.96

### 8.7.3. Watermelon

**Nutrient Management:** Application of FYM/compost at 25 t/ha is recommended.

**Weed Management:** The yields due to black, red, green, blue, white and clear (transparent) polyethylene mulches were 61.1, 50.9, 44.9, 42.5, 34.7 and 31.1%, respectively higher than control. Minimum weed growth was observed under black polyethylene mulch. The economic return from black polyethylene mulch was highest.

### Pest management

**Thrips, *Thrips palmi*:** Sprays of 1% neem soap/1% pongamia soap were found to reduce thrips damage in watermelon. Sprays of 4% NSKE / 4% pulverized NSPE were found very effective.

### 8.7.4. Musk Melon

### Pest Management

**Wilt, *Fusarium solani*:** *T. harzianum* and *T. viride* when applied as seed treatment (5 g/kg) followed by soil application along

with FYM/neem cake at 1 kg/basin were effective. Soil application of neem cake/mustard cake at 2% reduced the wilt by 80% and 65%, respectively.

## 8.8. Root Crops

### 8.8.1. Radish

**Nutrient Management:** Application of FYM/compost at 20 t/ha is recommended.

#### Pest Management

**Diamondback Moth (DBM), *Plutella xylostella*:** Effective control of *P. xylostella* on radish was reported with ‘Thuricide’ 90 TS flowable at 2.25 l/acre.

**Mustard Sawfly, *Athalia lugens proxima*:** Spraying 5% NSKE showed higher antifeedant and larvicidal effect.

### 8.8.2. Beet Root

**Nutrient Management:** Application of FYM/compost at 20 t/ha is recommended.

#### Pest Management

**Seedling Blight, *Rhizoctonia solani*:** *Streptomyces distaticus* was effective in suppressing seedling blight of beet root.

**Leaf Spot, *Cercospora* sp.:** Spray 1% Bordeaux mixture as soon as the disease incidence is noticed.

**Storage Rot, *Sclerotium rolfsii*:** *T. harzianum* was highly effective in suppressing *S. rolfsii* in beet root under field conditions. The conidial mixture of 2 bioagents *T. pseudokoningii* (effective in reducing the mycelial growth) and *T. virens* (good colonizer of sclerotia) was effective in reducing the incidence of storage rot.

## 8.9. Miscellaneous Vegetables

### 8.9.1. Drumstick

**Nutrient Management:** Application of 60 kg FYM /pit/plant of drumstick gave highest net income (1.18 lakh/ha) with benefit : cost ratio of 6.81 in drumstick based cropping system (intercropped with pumpkin and bottle gourd). The same treatment recorded the higher

yield of pumpkin (13.26 t/ha), bottle gourd (10.10 t/ha) and drumstick (10.70 t/ha) under rainfed conditions (Table 8.24).

Ring trenches are dug around the trees at 60-90 cm away from the plant and green leaves, FYM and ash are applied in the trench and covered with soil. Organic manure at 75 kg/plant can be given to 1 year-old plants and above in trenches 1 m away from plants.

**Table 8.24. Effect of FYM and pit size on yield and economics of pumpkin, bottle gourd and drumstick**

Pit size (m)	FYM/Pit (kg)	Yield(t/ha)			B:C ratio
		Pumpkin	Bottlegourd	Drumstick	
0.5 x 0.5 x 0.5	40	2.080	2.147	1.020	4.112
0.5 x 0.5 x 0.5	50	2.373	2.353	2.200	4.628
0.5 x 0.5 x 0.5	60	2.720	2.493	2.213	4.898
0.5 x 0.5 x 0.5	70	3.027	2.387	2.293	4.986
1.0 x 1.0 x 1.0	40	5.233	4.973	4.200	4.218
1.0 x1.0 x 1.0	50	5.520	5.280	5.427	4.644
1.0 x 1.0 x 1.0	60	5.693	5.947	5.627	4.740
1.0 x 1.0 x 1.0	70	7.827	5.713	6.453	5.364
1.5 x 1.0 x 1.0	40	9.760	6.333	8.107	4.814
1.5 x 1.0 x 1.0	50	13.267	10.107	10.720	6.815
1.5 x 1.0 x 1.0	60	10.027	7.800	9.253	4.935
1.5 x 1.0 x 1.0	70	10.200	6.333	9.120	4.387
2.0 x 1.0 x 1.0	40	9.960	6.000	8.680	2.781
2.0 x 1.0 x 1.0	50	9.773	5.467	8.587	2.513
2.0 x 1.0 x 1.0	60	8.707	5.213	8.347	2.158
2.0 x 1.0 x 1.0	70	8.840	5.027	7.960	1.983

### 8.9.2. Curry Leaf

**Nutrient Management:** Application of 250 g N/plant through castor cake (in 4 equal splits) showed maximum green biomass production of curry leaf cv. Local.

### 8.9.3. Babycorn

**Weed Management:** Application of sugarcane trash (10 cm thickness) proved best in improving the yield of babycorn and

suppression of weed flora. Among the bio-mulches, coriander gave satisfactory results (Table 8.25).

**Table 8.25. Effect of organic and bio-mulches on weed count, biomass and control efficiency (Mean of 2001 and 2002).**

<b>Treatment</b>	<b>Weed count/ m<sup>2</sup></b>	<b>Weed biomass (kg/ha)</b>	<b>Weed control efficiency</b>
Control	32.95	47.23	---
Water hyacinth residue at 5 cm thickness	9.90	22.41	69.92
Sugarcane trash at 10 cm thickness	7.00	16.20	78.71
Coir pith at 2 cm thickness	8.67	19.47	73.80
Saw dust at 2 cm thickness	17.67	35.82	46.16
Mint (bio-mulch)	11.57	23.26	64.70
Coriander (bio-mulch)	11.37	22.73	66.80
Fenugreek (bio-mulch)	15.65	26.20	52.30
CD at 5%	1.09	2.93	3.29

## Chapter 9

# ORNAMENTAL CROPS

### 9.1. Rose

**Nutrient Management:** Application of FYM/compost at 8-10 kg/plant is recommended for growth and flowering.

**Weed Management:** Mulching with 5-8 cm layer preferably of organic material to the surface of a rose bed in late spring as soon as the soil begins to warm up keep the soil moist by preventing evaporation, smother the majority of annual weeds during summer, breakdown into humus and provide plant foods particularly if FYM is used. Saw dust controlled weeds better than bark, rock wool or pine straw mulch.

Hoeing is another important cultural operation practiced in rose. Not only does it remove weeds, but also helps in giving a fine texture to the soil.

### Pest Management

**Red Scale, *Aonidiella aurantii*:** Application of pongamia oil 10% to infested shoots, immediately after pruning provides complete control of red scale within 3 weeks.

**Leaf Caterpillars, *Euproctis frateranae*, *Spodoptera litura*, *Achaea janata*:** Deep ploughing in summer exposes pupae to predators. Collection and destruction of leaves with egg masses and early instars reduces further infestation. Setting up of light traps attract adult moths. Spraying of neem oil 1% or NSKE 4% checks damage by caterpillars. Complete control of leaf caterpillars, *E. frateranae* and *A. janata* was achieved with 'Thuricide' dust and spray



( $3 \times 10^6$  spores/g). Application of *Sl* NPV at 250 LE/ha gives effective control of *S. litura*.

**Thrips, *Rhipiphorothrips cruentus*, *Scirtothrips dorsalis*:** Spraying of pongamia oil 0.5% when early symptoms are observed control thrips in open cultivated roses. Spraying Vertimac (biopesticide of *Streptomyces avermitilis*), 4% NSKE, 2% neem oil, 1% jatropha or annona oil was found effective.

**Aphids, *Macrosiphum roseae*:** Neem or pongamia oil 1% sprays offers control of aphids in open cultivated roses.

**Two Spotted Spider Mite, *Tetranychus urticae*:** Proper ventilation, clean cultivation and frequent irrigation to bring down temperature keep mites under check. Cutting and burning of heavily infested shoots should be done. Neem or pongamia oil 0.5 to 1% sprays should be given in evening hours and before onset of summer to avoid mite build up and better control under polyhouse conditions. Release of predatory mite, *Phytoseilus persimilis* at 26/m<sup>2</sup> successfully contains mite population.

**Bud Borer, *Helicoverpa armigera*:** Collection and killing of grown up larvae reduces further damage and population. NSKE 4% or neem oil 1% sprays offer protection to plants from borer damage. Application of *Ha* NPV at 250 LE/ha causes considerable mortality of early instar larvae.

**Chafer Beetles, *Adoretus* spp., *Apogamia* spp.:** Deep ploughing after pruning exposes eggs, grubs and pupae to natural enemies. NSKE 2.5% spray inhibits feeding by the beetles.

**Weevils, *Myloccerus* spp.:** Deep digging after pruning exposes grubs and pupae to natural enemies.

**Blight, *Botrytis cinereria*:** Since *Botrytis* sporulates readily on wounded and senescent tissue, these should be thoroughly removed. Infected plant debris should be removed. Bioagents like *Gliocladium roseum*, *Myrothecium verucaria*, *T. harzianum* and *Pencillium* spp. were found to be effective against rose blight.

**Powdery Mildew, *Sphaerotheca pannosa*:** Two antagonistic fungi, *Ampelomyces quisqualis* and *Pseudozyma flocculosa* are reported to control powdery mildew when their spore suspensions were sprayed on the foliage.

**Black Spot, *Diplocarpon roseae*:** Cultural practices like wider spacing, pruning the dense central portion of the canopy to allow good air circulation contribute to disease control. The debris from infected plants should be removed and burnt.

**Die-back, *Diplodia rosarum*, *Colletotrichum* sp.:** Pruning of infected stems 5-10 cm below the margin of infection and painting the cut ends with Bordeaux paste is recommended. Cvs. White Sign, Red Gold, Bhim, Summer Queen, Quebec, Ressolute, Samba and Blue Moon are reported to be resistant.

**Crown Gall, *Agrobacterium tumefaciens*:** Clean nursery practices, production of disease-free planting material and removing and destroying all infected plants helps in checking the disease. Commercial formulation of non-tumorigenic strain of *Agrobacterium rhizogenes* (K-84 strain) is being used successfully to control crown gall.

**Lesion Nematode, *Pratylenchus* sp.:** Intercropping with marigold helps in reducing the nematode population. Cv. Major is resistant to lesion nematodes.

## 9.2. Carnation

**Nutrient Management:** Application of FYM/compost at 10 kg/sq. m./year is recommended.

### Pest Management

**Two Spotted Spider Mite, *Tetranychus urticae*:** Cutting and burning of severely infested and dried plant parts. Washing of plants with water dislodges the webs. Pongamia oil in combination with annona oil 2% effectively checks mite population. Cvs. Isaq, Alcardi and Sunrise were reported resistant to mite attack.

**Bud Borer, *Helicoverpa armigera*:** Proper closing of doors and vents prevent entry of moths. Collection and killing of grown up larvae reduces borer population. Other control measures are same as in rose bud borer.

**Wilt, *Fusarium oxysporum* f. sp. *dianthi*:** Bioagents like *T. harzianum*, *B. subtilis*, *Streptomyces* sp. and non-pathogenic isolates of *Fusarium oxysporum* are reported to give good control of Fusarial wilt.

**Root-knot Nematodes, *Meloidogyne* spp.:** Three antagonistic fungi viz., *T. harzianum*, *V. lecanii* and *P. lilacinus* at  $2 \times 10^4$  spores/ml in combination with neem cake reduced *M. incognita* population in both soil and roots of carnation.

## 9.3. Gerbera

**Nutrient Management:** Application of FYM/compost at 7.5 – 10 kg/m<sup>2</sup> or at 15-20 t/ha is recommended.

**Weed Management:** Weed removal by hand operated implements and surface mulching helps to keep the weeds under check.

## Pest Management

**Whitefly, *Bemisia tabaci*:** Excessive dampness and dark conditions should be avoided. Removal and burning of heavily infested leaves check pest build up. Clean cultivation and use of insect proof nets are essential. Oil sprays are to be given during evening inside polyhouse for better efficacy. Use of yellow sticky traps for trapping adults and release of parasitoid, *Encarsia formosa* at 6 adults/m<sup>2</sup> are recommended for control of whiteflies in polyhouse. Annona and pongamia oil at 2% were found very effective with more than 90% mortality of nymphs.

**Leaf Miner, *Liriomyza trifolii*:** Plucking and burning of severely mined leaves and spraying of pongamia oil at 1% is very effective. Use of yellow sticky traps gives considerable protection and encourages parasitization by *Diglyphus isaea*. Intercropping with field bean (*Vicia faba*) which acts as trap crop is effective. Release of eulophid parasitoid, *Diglyphus intermedius* at 1000 at weekly intervals gives considerable reduction in leaf miner population.

**Red Spider Mite, *Tetranychus ludeni*:** Thinning of old and heavily infested leaves prevents severe attack. Annona, pongamia or jatropa oil at 1% cause considerable mortality.

**Bud Caterpillar, *Spodoptera litura*:** Treatment with *Bacillus thuringiensis* offers effective control. Installing pheromone traps after first showers is quite helpful in bringing down the population of *S. litura*. Other control measures are same as in rose leaf eating caterpillar.

**Aphid, *Myzus persicae*:** Same as in chrysanthemum aphids.

**Powdery Mildew, *Erysiphe cichoracearum*:** Foliar sprays of K<sub>2</sub>HPO<sub>4</sub> at 4.3 g/l were found to be effective in reducing conidial production and thus controlled the disease (disease incidence of 5% as compared to 62% in control) which was on par with fungicidal spray (Hexaconazole at 0.1%).

**Root-knot Nematodes, *Meloidogyne* spp.:** Three antagonistic fungi viz., *T. harzianum*, *V. lecanii* and *P. lilacinus* at 2 x 10<sup>4</sup> spores/ml in combination with neem cake reduced *M. incognita* population in both soil and roots of gerbera.

## 9.4. Chrysanthemum

**Nutrient Management:** As the crop responds well to manuring, addition of well rotten FYM/compost at 10-20 t/ha is recommended.

**Weed Management:** Manual weeding using khurupi is the commonest method of weed control in chrysanthemum. Intercultural operations using hand hoes are also tried to keep the weeds in check. Covering of black plastic or green woven cloth prevented weed growth in soil under pot grown chrysanthemums. Mulching with bark of 5 cm thickness effectively controls weeds and conserve moisture.

### Pest Management

**Aphid, *Macrosiphoniella sanborni*:** Aphids can be controlled by spraying 4% pongamia kernel extract or 2 % neem or pongamia oil at 10-15 days interval. Use of commercial formulation of *Verticillium lecanii* (Microgermin) reduces aphid menace. Release of 1 day old *Chrysoperla carnea* larvae at 50:1 ratio (aphid:chrysopid) eliminated aphid population in polyhouse.

**Thrips, *Microcephalothrips abdominalis*:** Covering of young buds with polythene bags with holes prior to blooming protects flowers from attack by thrips.

**Bud Borer, *Helicoverpa armigera*:** 4% NSKE sprays offers protection to the crop from the borer damage. Other control measures are same as in rose bud borer.

**Leaf Miner, *Liriomyza trifolii*:** Removal and destruction of weeds which act as alternate hosts is very important to protect the crop from leaf miner damage. Cutting and burning of heavily mined leaves reduce further damage. Installing yellow sticky traps, trap adult population. The parasitoid, *Diglyphus* sp. at 1000/week effectively checks larval stages. Other control measures are as in gerbera leaf miner.

**Spider Mite, *Tetranychus urticae*:** Removing and burning of heavily infested shoots checks further build up of mites. Spraying of pongamia oil 1% controls mite damage. Other control measures as in rose spider mite.

**Root Rot, *Pythium* sp., *Phytophthora* sp.:** Provision of good drainage conditions to prevent water logging. Soil solarization by covering with black polythene mulch during summer.

**Stem Rot, *Fusarium solani*:** Soil solarization by covering with black polythene mulch during summer.

**Bacterial Blight, *Erwinia chrysanthemi*:** Growing of disease-free planting material in solarized soil.

**Lesion Nematode, *Pratylenchus coffeae*:** Application of neem cake enriched with *T. harzianum* at 1 t/ha is effective in reducing the nematode population.

**Bud and Leaf Nematode, *Aphelenchoides ritzemabosi*:** Hot water treatment of stools at 46°C for 5 min. eliminates nematode infestation.

## 9.5. Gladiolus

**Nutrient Management:** Application of FYM/compost at 25 t/ha is recommended.

**Weed Management:** The main method of weed control is manual method using hand hoe. Mulching is also another way to check weeds in this crop. Plastic mulching benefitted the gladiolus crop with black and photo selective plastic being preferable to the transparent type. It gave good weed control, conserved soil moisture well and kept the temperature around the roots comparably low.

## Pest Management

**Mite, *Tetranychus equatorius*:** Spraying of neem or pongamia oil 1% gave considerable control of mites.

**Wilt, *Fusarium oxysporum* f. sp. *gladioli*:** Planting healthy corms in clean soil, crop rotation, soil solarization and hot water treatment of corms at 50-55°C for 10 min were effective in controlling wilt disease. Solarization of field soil by mulching with transparent polythene sheets (100 gauze) raised the soil temperature which was lethal to wilt pathogen. *T. harzianum*/ *T. viride* either alone or in combination with compost (mushroom, vermin, paddy straw) reduced wilt effectively (58 to 92%). Soil application of *T. harzianum*, *T. viride*, *T. koningii*, *T. virens* increased germination (95.6 to 100.0% compared to 79.0% in control), decreased the plant mortality (2.33 to 8.70% compared to 28.67% in control), increased plant height (76 to 85 cm compared to 51 cm in control), increased spike length (65 to 72 cm compared to 46 cm in control) and increased the number of cormels/plant (15 to 22 compared to 13 cm in control). Cvs. IARI Selection-1, *Psittacinus* hybrid and Suchitra were found resistant to wilt under Pune conditions.

**Root-knot Nematodes, *Meloidogyne* spp.:** Use nematode-free planting material for planting. Hot water treatment of corms at 58°C

for 30 min. eliminates root-knot nematode infection. Crop rotation or intercropping with marigold helps in reducing the nematode population. Soil application of neem cake enriched with *T. harzianum* at 1 t/ha is also effective.

## 9.6. Tuberose

**Nutrient Management:** Application of a basal dose of FYM/compost at 20-25 t/ha, 10 to 15 days prior to planting of bulbs is recommended to ensure better growth and flowering. Chicken manure at 500 kg/ha is also used.

**Weed Management:** Manual method of weeding once a month is the most common method of weed control followed in this crop. Mulching is also done by the growers. Mulching the plots with fresh manure, strips of black polythene, dried grass clippings, chopped straw, saw dust, husk, peat, bark is effective in controlling weeds, besides helping in conserving soil moisture.

## Pest Management

**Weevil, *Myloccerus* spp.:** Neem oil 1% effectively checks feeding by the weevils.

**Aphid, *Aphis* spp.:** Spraying of neem or pongamia oil 1% at 10-15 days interval cause effective mortality of aphids. Use of commercial formulations of *Verticillium lecanii* at 15 days interval reduces aphid population.

**Bud Borer, *Helicoverpa armigera*:** Same as in rose bud borer.

**Leaf Eating Caterpillar, *Spodoptera litura*:** Same as in rose leaf eating caterpillar.

**Mealbug, *Ferrisia virgata*:** Application of 2% pongamia oil provides good control of mealybugs.

**Leaf Spot / Blight, *Alternaria polyantha*:** Spraying of 1% Bordeaux mixture is recommended to control the disease. Tuber treatment with *Trichoderma harzianum* and *Pseudomonas fluorescens* at 4 g/kg tuber and seedling dip in *T. harzianum* suspension before planting resulted in effective control of blight and increased the plant vigour.

**Root-knot Nematodes, *Meloidogyne* spp.:** Integration of *Paecilomyces lilacinus* with neem cake gave effective control of *M. incognita* on tuberose. Treatment of tuberose bulbs with neem cake extract mixed with *P. lilacinus* spores significantly reduced *M.*

*incognita* infection and multiplication besides stimulating the plant growth. Soil application of *T. harzianum* ( $10^9$  cfu/g) + *P. lilacinus* ( $10^6$  cfu/g) gave effective control of root-knot nematodes. Soil application of neem cake enriched with *T. harzianum* at 1 t/ha is also effective. Cv. Shringar (single type) is resistant, while Suvasini is tolerant to root-knot nematodes.

## 9.7. Crossandra

**Nutrient Management:** Application of FYM/compost at 15-25 t/ha at planting helped to increase flower yield.

### Pest Management

**Bug, *Cynencia affinis*:** Neem oil 1% spray protects foliage from bug damage.

**Nematodes, *Meloidogyne incognita*, *Pratylenchus delattrei*, *Longidorus africanus*:** Deep ploughing and fallowing in summer for about a month helps in reducing the nematode population. Planting crossandra after graminaceous crops should be avoided.

Incorporation *Verticillium lecanii* with neem cake facilitated the effective management of *M. incognita* on crossandra. Application of neem cake enriched with *Trichoderma harzianum* at 2 kg/m<sup>2</sup> (1 t/ha) in nursery beds gives effective control. Incorporation of FYM in soil and intercropping with marigold or pangola grass helps in reducing the nematode population in soil.

The root colonization of AM fungi increased significantly in the presence of neem cake which in turn improved their efficacy in reducing *M. incognita* population in crossandra roots.

Integration of a bioagent (*V. lecanii*), endomycorrhiza (*G. mosseae*) with botanicals improved the growth of crossandra and reduced the population of *M. incognita*. *G. mosseae* reduced the requirement of phosphatic fertilizer and favoured the antagonistic potential of *V. lecanii* against *M. incognita*.

Combined application of *P. lilacinus* and *Pasteuria penetrans* enhanced plant growth and flower yield of crossandra besides reducing root galling due to *M. incognita*.

## 9.8. China Aster

**Nutrient Management:** Application of FYM/compost at 20 t/ha is recommended. Application of arbuscular mycorrhizal fungus, *Glomus fasciculatum* saves up to 25% P.

**Weed Management:** Earthing up twice at 30 days interval is followed to keep the weeds under check till the completion of the life cycle of the crop.

### **Pest Management**

**Wilt, *Fusarium* sp.:** Soil solarization should be done during summer months. Planting may be done on ridges. Cvs. Heart of France, Crego, Ostrich, Feather, Stardust and Roment are reported to be resistant.

**Red Pumpkin Beetle, *Aulacophora foveicallis*:** Neem oil 1% or NSKE 4% reduces damage to foliage by beetles.

**Leaf miner, *Liriomyza trifolii*:** Same as in gerbera leaf miner.

## **9.9. Marigold**

**Nutrient Management:** Application of FYM/compost at 15-20 t/ha during land preparation is recommended.

**Weed Management:** Weeds may cause 30-40% loss in oil yield. Four to five weeding are required during the entire growth period. Weeding makes the soil loose and weed free. Light hoeing should be followed at short intervals to keep the soil porous and to remove weeds.

### **Pest Management**

**Aphid, *Aphis gossypii*:** Neem or pongamia oil 1% cause considerable reduction in aphid population. Other control measures are same as in chrysanthemum aphids.

## **9.10. Dahlia**

**Weed Management:** Weeds are removed by women labour by using hand hoe. Mulching is an important operation in dahlia cultivation. This can be done with grass clipping, old hay and saw dust showing several beneficial effects. It helps to maintain an even soil temperature and causes earlier and better bloom. Mulch slows down water evaporation and reduces the irrigation requirements. It also keeps weeds under control. Using black plastic mulch for growing dahlia is also beneficial as it improves growth, flowering, tuberous root formation and suppresses weed growth.



### 9.11. Orchid

**Weed Management:** In orchids grown under greenhouse conditions, mulching is done every month in pots and they are always weed-free.

#### Pest Management

**Armoured Scale, *Diaspis boisduvalli*:** Removal of heavily infested leaves avoids spread of scales. Spray of fish oil rosin soap 0.05 kg in 30 litres of water is recommended for controlling scale population.

**Mealybug, *Pseudococcus maritimus*:** Collection and destruction of heavily infested plant parts reduce further spread of the pest. Pongamia oil 2% sprays check mealybug infestation. Release of coccinellid predator, *Cryptolaemus montrouzieri* and a parasitoid, *Leptomastidea abnormis* reduces the mealybug population.

**Scale, *Diaspis boisduvalli*:** Spraying fish oil rosin soap at 0.5 kg/30 litres of water provides effective control.

**Snail, *Achatina fullica*:** Hand picking of grown up stages and killing them by dropping in 5% salt solution reduce the snail population. Neem oil 1% or 6% soapnut extract sprays protect foliage from damage.

### 9.12. Anthurium

**Nutrient Management:** Application of FYM/compost at 30 t/ha is recommended.

#### Pest Management

**Whitefly, *Aleurotulus anthuricola*:** Removal and burning of old and heavily infested leaves check pest build up. Spray of 1% pongamia oil effectively controls nymphs and pupae menace on anthurium. Other control measures as in gerbera whitefly.

## Chapter 10

# MEDICINAL CROPS

### 10.1. Betelvine

**Nutrient Management:** Application of FYM/compost at 25-50 kg/vine (25-30 t/ha) every year is recommended.

**Weed Management:** Conventional method of hand weeding, hoeing and mulching are adopted to control weeds and conserve soil moisture.

#### Pest Management

**Foot and Leaf Rot, *Phytophthora* spp.:** Soil application of *T. harzianum* reduced the vine mortality (11 to 21% compared to 15 to 55% in control) and increased the disease control (46 to 75% compared to 0% in control).

**Collar/ Basal Rot, *Sclerotium rolfsii*:** Soil application of *T. harzianum* (strains MTCC Nos. 3841 to 3843) and *T. virens* (strain MTCC No. 794) increased vine height (199 to 254 cm compared to 67 to 69 cm in control), decreased plant mortality (7 to 33% compared to 73 to 87% in control), increased the disease control (64 to 83% compared to 0% in control) and increased the yield significantly. Consortium of 2 strains of *Pseudomonas fluorescens* (NBRI-N6 and NBRI-N) showed significant increase in yield of betelvine leaves.

**Root-knot Nematode, *Meloidogyne incognita*:** Application of FYM at 25 t/ha or neem cake at 1 t/ha before planting or crop rotation with rice helps to reduce the nematode population in soil.

## IPM of Foot Rot and Root-knot Nematode

- Summer ploughing and exposing the field to sunlight during May prior to sowing of *Sesbania* sp. (live standard) minimizes the initial load of inoculum of both the nematode and fungus.
- Select healthy seed vines from nematode-free and disease-free mother plants for planting.
- Dip seed vines in 0.25% Bordeaux mixture solution for 5 min before planting.
- Apply FYM at 30 t/ha to promote multiplication of antagonistic microbes which in turn kills nematodes.
- Spot application of neem cake at 3 t/ha in 3 split doses – 1<sup>st</sup> dose at 45 DAP and remaining 2 splits at 45 days interval during North-East monsoon season (Oct-Dec).
- Rotate betelvine crop with rice.

### 10.2. Solanum, *Solanum viarum*

**Nutrient Management:** Application of FYM/compost at 5-10 t/ha into the soil before last ploughing as basal dose and another dose just before flowering is found to support good crop growth.

**Weed Management:** Weeding is essential in the initial phase of crop establishment and done at suitable intervals until 90 to 120 days. The first manual weeding is done after 3 weeks of transplanting and later after 2-3 months, if needed. After that, the crop spreads enough canopy to the surface and generally the growth of weeds is affected.

### Pest Management

**Fruitfly, *Dacus latiformis*:** Collection and destruction of fallen fruits reduce fruitfly population. Spraying 1% neem oil kills the eggs and controls fruitfly damage.

### 10.3. Periwinkle, *Catharanthus roseus*

**Nutrient Management:** Application of FYM/compost at 10-15 t/ha is recommended both as basal and during subsequent dressings.

**Weed Management:** The crop requires 2 weedings in the initial stage at 60 and 120 DAS.

## Pest Management

**Sphingid Larvae, *Dilephila nerii*:** Deep ploughing before planting expose pupae to predators. Collection and destruction of grown up larvae check further attack. Spraying 1% neem oil controls damage by larvae.

**Die-back, *Pythium aphanidermatum*:** Mulching between the rows at seedling stage with dry spent straw of citronella or palmarosa reduces the incidence of dieback to a considerable degree. Cultivation of a new strain WH-40 developed at CIMAP Centre, Bangalore, which has field resistance, minimizes the loss due to dieback.

### 10.4. Isabgol, *Plantago ovata*

**Nutrient Management:** Application of FYM/compost at 15-20 t/ha at the time of last ploughing is recommended.

**Weed Management:** The first weeding is generally done after 20-25 DAS. Ordinarily, only 2-3 weedings are required to be done within the first 2 months of the crop stage which will help to keep the weeds under control.

## Pest Management

**Downy Mildew:** Bordeaux mixture (6-3-50) at 600 to 800 l/ha should be sprayed 30 DAS followed by 2 or more sprays at an interval of 15-20 days.

**Aphid, *Aphis gossypii*:** Spraying 1% neem/pongamia oil effectively reduces aphid population.

**Seed Beetle, *Lasioderma serricorne*:** Seed treatment with 2% neem/pongamia oil protects them from beetle damage.

### 10.5. Aswagandha, *Withania somnifera*

**Nutrient Management:** Application of well rotted FYM/compost at 5-10 t/ha before last ploughing is recommended.

**Weed Management:** Hand weeding at 25-30 days interval helps to control unwanted weeds effectively.

## Pest Management

**Epilachna Beetle, *Henosepilachna vigntioctopunctata*:** Collection and destruction of eggs, grubs and adults bring down the

population. Spraying 2% neem oil effectively prevents feeding of the beetle.

**Mealybug, *Coccidohysterix insolitus*:** Removal and destruction of severely infested plant parts avoid further spread. Spraying 2% pongamia oil checks mealybug infestation.

### 10.6. Coleus, *Coleus forskoli*

**Nutrient Management:** Application of well decomposed FYM/compost at 10-25 t/ha is conducive for good tuber formation.

**Weed Management:** Frequent weeding in early stages of crop growth is essential to eliminate weed competition.

### Pest Management

**Grasshopper, *Chrotogonus* sp.:** Spraying 2% neem oil checks attack of the pest.

### 10.7. Aloe Vera, *Aloe indica*

**Nutrient Mngement:** FYM or compost at 10 t/ha is applied as a supply of nutrients for growth and development of the crop.

**Weed Management:** Three to four manual hand weedings are necessary during initial establishment of crop followed by 1 or 2 in the second year for optimum growth of plants.

### 10.8. Opium Poppy, *Papaver somniferum*

**Weed Management:** *Phalaris minor*, *Polypogon* spp. and *Cynodon dactylon* among monocots, and *Anagalis arvensis* and *Heliotropium* spp. among dicots were the predominant weeds of poppy fields.

Manual weeding and hoeing operations should be carried out 3 to 4 weeks after sowing and continued till the rosette stage after which weeds are automatically smothered by thick canopy of the crop. The germinated weeds are removed by light ploughing before sowing. Proper plant density (3 to 3.5 lakh plants/ha) is maintained by thinning to keep plant distance at 10 cm at the start of rosette stage.

The crop is weeded and hoed weekly till the plants are about 20 cm tall and thereafter weeding and hoeing are done once a month. Good weed control and yield were obtained by 2 mechanical cultivations which destroyed most weeds. Intercropping of poppy with garlic was more productive than single crop and that latex yield was

as good as of poppy grown alone. Intercropping with garlic in black soils is beneficial in controlling weeds.

### Pest Management

**Capsule Borer, *Helicoverpa armigera*:** Spraying of 5% NSKE or 1% neem oil checks feeding by the larvae.

**Aphid, *Myzus persicae*:** Spraying 2% neem/ pongamia oil at 10 days interval controls aphids effectively.

**Rot and Blight, *Sclerotinia sclerotiorum*:** Soil application of *T. harzianum* reduced the % of infected plants (0 to 10% compared to 20 to 40% in control), increased plant height (94 to 100 cm compared to 85 to 88 cm in control) and increased the opium yield (114 to 191 mg compared to 92 to 94 mg in control).

### 10.9. Sarpagandha, *Rauvolfia serpentina*

**Nutrient Management:** Application of FYM/compost at 10-20 t/ha at the time of land preparation helps in healthy plant growth and good quantity of alkaloids in the roots.

**Weed Management:** It requires 5 weedings in the entire growing period. Growing of intercrops such as maize, cowpea or brinjal during kharif and radish, wheat or a cole crop during rabi gave largest overall profits. Intercropping with soybean, garlic or onion gave higher net returns than when grown alone. Even alkaloid content was more when it was intercropped. Suppression of weeds by intercrops could be the reason for enhanced alkaloid yield in sarpagandha.

### Pest Management

**Grasshopper, *Orthacric simulans*:** Spraying of 4% NSKE or 1% neem oil prevents feeding by the grasshoppers.

**Root-knot Nematode, *Meloidogyne* sp.:** Soil application of neem cake enriched with *T. harzianum* at 1 t/ha is recommended.

### 10.10. Senna, *Cassia angustifolia*

**Nutrient Management:** Application of well rotten FYM/compost at 5-10 t/ha during sowing is recommended.

**Weed Management:** As soon as seedlings emerge, 2 or 3 hoeings are given and plants close up the rows as they grow. The first weeding should be done at 25-30 days, second at 70-80 days and the third at

110 DAS to keep the crop free from weeds. Mixed cropping of senna with gram, gingelly, chillies and cotton also suppresses weed population.

#### 10.11. *Dioscorea, Dioscorea floribunda*

**Nutrient Management:** Application of FYM/compost at 20-25 t/ha is recommended.

**Weed Management:** Manual weed control gave the best tuber yield. Use of organic mulch and intercropping with cowpea or black gram is effective in controlling weeds and is superior to any herbicide in giving highest yields in the first and second year.

#### 10.12. *Belladonna*

**Weed Management:** The plantation is given 2-3 weedings and hoeings before the first leaf crop is obtained and then 1-2 hoeings before each leaf picking.

#### 10.13. *Long Pepper, Piper longum*

**Nutrient Management:** Application of FYM at 20 t/ha is required for optimum growth and yield of the crop. Planting pits are filled with soil mixed with well decomposed FYM or compost at 50 g/pit. One month after planting, the gap of the pits are filled with soil and FYM mixture at 50 g/pit.

**Weed Management:** In the first year of planting, weeding is done. Once the crop grows and covers the interspaces of the bed, weeds are not allowed to grow. During summer, the beds may be mulched with dry leaves or straw to check the weeds and to conserve moisture.

#### **Pest Management**

**Leaf Blight, *Cercospora* sp.:** Spraying 1% Bordeaux mixture has been recommended to control the disease.

#### 10.14. *Antamul, Tylophora indica*

**Nutrient Management:** Application of FYM at 2 -5 t/ha during land preparation is suited for its proper growth and development.

**10.15. Tinospora**

**Nutrient Management:** While planting, about 4 t/ha of well decomposed FYM is applied to obtain good yields.

**10.16. Datura, *Datura stramonium*, *D. metel*, *D. innoxia***

**Nutrient Management:** Datura respond very well to application of manures. FYM at 10 t/ha is applied as basal dose and incorporated into the soil during land preparation.

**10.17. Keu, *Costus speciosus***

**Nutrient Management:** Application of heavy dose of FYM at 15 t/ha is advocated to compensate biomass production in rhizomes.

**Weed Management:** One weeding during the sprouting period is sufficient to keep the crop fairly free from weeds.

**10.18. Satamuli, *Asparagus racemosus***

**Nutrient Management:** Application of FYM at 2 t/ha during land preparation is recommended.

**10.19. Bach, *Acorus calamus***

**Nutrient Management:** Green manure at 8-10 t/ha and compost at 10 t/ha are applied in 2 split doses for proper growth and development of the plants. Half the quantity is applied at the time of land preparation and the rest after 2 months of vegetative growth.

**Weed Management:** Careful weeding is required so that the growing of plants is not disturbed.

**10.20. Kalmegh, *Andrographis paniculata***

**Nutrient Management:** Application of FYM/compost at 10-15 t/ha is desirable during the last ploughing.

**10.21. Nagdana, *Artemisia nilagirica***

**Nutrient Management:** Well decomposed FYM at 10 t/ha is applied before the last ploughing.

**Weed Management:** The crop generally requires 2-3 weedings and hoeings during the growth period.



**10.22. Brahmi, *Bacopa monnieri***

**Nutrient Management:** Only organic manures such as FYM/compost at 3 t/ha can be applied at the time of land preparation.

**10.23. Patharkunchi, *Kalanchoe pinnata***

**Nutrient Management:** Apply FYM at 1-2 t/ha which is mixed in soil by cross ploughing and leveled again.

**Weed Management:** The first weeding-cum-hoeing is done within 30 days of plant growth, second at 60-70 days.

**10.24. Kulekhara, *Hygrophila auriculata***

**Weed Management:** Once the plant is established, 1 or 2 weedings would be sufficient to manage the crop.

**10.25. Arjun, *Terminalia arjuna***

**Nutrient Management:** Planting pits (1.5' x 2') are filled with 5 kg FYM during April-May. Every year, FYM at 2-5 kg/plant should be applied at the base of the plant and mixed well with the soil.

**10.26. Bahera, *Terminalia bellirica***

**Nutrient Management:** Planting pits (1.5' x 1') are filled with 3 kg FYM during April-May. Every year, FYM at 2-5 kg/plant should be applied at the base of the plant and mixed well with the soil.

**10.27. Haritaki, *Terminalia chebula***

**Nutrient Management:** Planting pits (1' x 1') are filled with 3 kg FYM during April-May. Every year, FYM at 2-5 kg/plant should be applied at the base of the plant and mixed well with the soil.

## Chapter 11

### AROMATIC CROPS

#### 11.1. Jasmine, *Jasminum* spp.

**Nutrient Management:** Application of FYM/compost at 10-20 kg/plant or vermicompost at 2-4 kg/plant as basal dose is recommended to realize higher concrete yields.

**Weed Management:** Mulching of the basins and 2-3 hand weedings keeps most of the weeds under check.

#### Pest Management

**Bud Worm, *Hendecasis duplifacialis*:** Spraying of 5% NSKE or 1% neem oil was found effective against the pest. This pest is highly susceptible to *B. thuringiensis*.

**Blossom Midge, *Contarinia maculipennis*:** 2% neem oil mixed with Teepol 0.05% effectively reduces the damage.

**Wilt, *Sclerotium rolfsii*:** Soil drenching with 1% Bordeaux mixture reduced damage due to wilt.

**Leaf Spot, *Cercospora jasminicola*, *Alternaria alternata*:** The disease can be controlled by spraying 1% Bordeaux mixture at monthly intervals. The frequency of application may be increased during rainy season.

**Root-knot Nematode, *Meloidogyne incognita*:** Application of neem cake enriched with *T. harzianum* at 1 t/ha is recommended.

### 11.2. Mint, Japanese Mint, *Mentha arvensis*; Peppermint, *M. piperata*; Spearmint, *M. spicata*; Bergamot Mint, *M. citrata*

**Nutrient Management:** To promote establishment and good crop growth in early stages, addition of well rotted FYM/compost at 20-25 t/ha at the time of land preparation is recommended.

**Weed Management:** Weeds are known to cause 70-75% reduction in yield. Weeds may reduce both herb and oil yields. The critical period of weed competition has been found to be 30-90 DAP and 16-45 after first harvest. Four to five manual weedings are required. In sucker planted crop, 3 weedings have to be done at 45, 65 and 80 DAP, while 2 more weedings are done after 30 and 45 days after first harvest. In transplanted crop, 2 to 3 weedings are sufficient. Mulching with citronella distillation waste and sugarcane leaves can be used to control weeds. Crop rotation may also help to maintain a reasonable control on weed growth. Paddy as preceding crop in rotation with mint has been found to minimize weed competition by 30-40%. The following crop rotations may be followed: (i) Mint – Maize – Potato, (ii) Mint – early Paddy – Potato, (iii) Mint – Maize – Rapeseed/Mustard, (iv) Mint – Paddy.

#### Pest Management

**Stolon Rot, *Macrophomina phaseoli*:** Avoid excess irrigation. Uproot and burn the affected plants. Apply *Trichoderma* sp. to soil.

**Semilooper, *Thysanoplosia orichalcea*:** Spraying of 4% NSKE or 1% neem oil reduce damage by semilooper to foliage.

**Aphid, *Aphis affinis*:** Spraying of 4% PSKE or 1% neem oil reduces aphid infestation.

### 11.3. Sacred Basil, *Ocimum sanctum*

**Nutrient Management:** FYM at 15 t/ha is preferably added at the time of land preparation as basal dose.

**Weed Management:** Generally first weeding is done 1 month after transplanting of seedlings. No further weeding may be required as the plants become gradually bushy and thereby suppressing the weeds.

### 11.4. Sweet/French Basil, *Ocimum basilicum*

**Nutrient Management:** Application of FYM/compost at 15 t/ha is recommended.

**Weed Management:** First weeding is done 1 month after planting and second one 4 weeks after the first. One hoeing 2 months after transplanting is sufficient.

### **Pest Management**

**Aphid, *Aphis gossypii*:** Spraying 2% neem/pongamia oil causes considerable mortality of aphids.

**Tinged Bug, *Monanthia globulifera*:** Spraying 1% neem/pongamia oil cause considerable mortality of bugs.

### **11.5. Camphor Basil, *Ocimum kilimandscharicum***

**Nutrient Management:** Well rotten FYM or compost at 15-20 t/ha may be incorporated into the soil before the last ploughing.

**Weed Management:** Generally first weeding is done 2 months after transplanting. After that the plant covers the surface area and there would be no problem of weeds.

### **11.6. Bantulsi, *Ocimum gratissimum***

**Nutrient Management:** FYM at 10-15 t/ha is applied in 3 split doses. First dose of 50% is given as a basal dose and the remaining 50% is split into 2 equal portions and applied after first and second cuttings.

### **11.7. Lemon Grass, *Cymbopogan flexuosus***

**Nutrient Management:** Application of FYM/compost at 2.5 t/ha and ash at 1.87 t/ha as basal dose during land preparation is recommended.

**Weed Management:** Generally, 2-3 weedings are necessary during the year. In row planted crop, interculture operations are done by a tractor drawn cultivator or hand hoe. Distillation waste applied as organic mulch at 3-5 t/ha has been found effective for controlling weeds in the crop. Mulching was the most economical method of weed control and gave good yield of essential oil in lemon grass. There was practically no weed growth in the mulched plots. Lemon grass has been found to be a weed smothering crop. After it is established, it may inhibit weeds.

### **Pest Management**

**Aphid, *Macrosiphum muscanthii*:** 2 sprays of 1% neem/pongamia oil at 10 days interval cause considerable mortality of aphids.

**Termites, *Microtermes obesi*:** Avoid dry soil condition by irrigating frequently. Scrape earthen galleries on stems and spray 2% neem oil. Killing of the queen by destroying the colony provides permanent control.

### 11.8. Citronella, *Cymbopogan winterianus*

**Nutrient Management:** In the alluvial or red laterite soils where the plant grows throughout the year, 10-15 t/ha of FYM may be applied at the time of land preparation. Application of neem cake is beneficial for increasing the yields by improving the nitrogen economy.

**Weed Management:** The field should be kept weed-free till they become established. Once established, weeds are suppressed by the luxuriant growth of bushes. Weeding is essential after harvesting which can be accomplished by running cultivator in between rows. Mulching with citronella distillation waste has been found to be very effective in minimizing weed competition and promoting crop growth.

### 11.9. Palmarosa

**Weed Management:** Presence of weeds reduce the yields to the extent of 70% in the first cutting and 20% in subsequent cuttings. Weeds may affect the odour and quality of oil. The plantation should be kept weed-free, by regular weeding and hoeing, particularly in the initial stage of growth, so that the weeds do not over power the grass. Two manual weedings and one hoeing is recommended. Mulching the plantation with distillation waste at 5.0 to 7.5 t/ha has been found to be most appropriate for weed management and improving the productivity of palmarosa. Crop requires 3-4 weedings in planting year. In second and subsequent years, there is no weed growth provided desired plant population is maintained. Intercropping with black gram is also effective in reducing the weed population.

### 11.10. Geranium

**Nutrient Management:** Application of FYM/compost at 10 t/ha is recommended.

**Weed Management:** Initially, geranium is given 1-2 weedings and hoeings, and later as the crop grows, shades the underneath space and does not allow weeds to come up. In the initial period of crop growth, 2 hand weedings are essential to keep the plot free from weeds. Black gram, garlic, onion or peas can be taken as intercrops during the initial stages of the crop to keep down the weed population.

One row of black gram or pea and 2 rows of garlic or onion are sown between 2 rows of geranium, subsequent to transplanting of geranium.

#### 11.11. Patchouli

**Nutrient Management:** Application of FYM/compost at 12 t/ha during preparation of land is recommended.

**Weed Management:** Manual weeding is the most common method of weed control followed in this crop. Weeding is necessary for the first 3-4 months until canopy closes. The crop requires weeding after 6 weeks from transplanting and one hoeing after each harvest.

#### Pest Management

**Root Rot and Root-knot Nematode:** Combined mortality due to root rot and root-knot nematode could be minimized by the application of *Trichoderma harzianum* + karanj cake at 5 t/ha.

#### 11.12. Vetiver

**Weed Management:** Three to four weedings are necessary during the initial establishment of the crop followed by 1-2 in the second year optimizes the growth of plants.

#### 11.13. Rosemary, *Rosamarinus officinalis*

**Nutrient Management:** Prior to transplanting, 20 t/ha of FYM is applied to the soil.

**Weed Management:** About 5-6 cultivations between the rows are required to keep the weeds under control.

#### 11.14. Sweet Flag, *Acorus calamus*

**Nutrient Management:** The field should be manured with FYM at 15 t/ha. Along with FYM, about 5 t/ha of green leaf manure should be incorporated before planting.

**Weed Management:** Eight weedings are given.

#### 11.15. Sage, *Salvia officinalis*

#### Pest Management

**Root Rot, *Fusarium solani*, *Rhizoctonia solani*:** *T. viride* was more effective in reducing the disease incidence (38.88%) over control followed by *T. harzianum* (36.11%).

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**11.16. Acangi, *Kaempferia galangal***

**Nutrient Management:** Application of green manure or FYM at 10 t/ha at the time of land preparation would be effective to get better yield.

**Weed Management:** Two weedings would be sufficient to manage the crop.

**11.17. Kasturi Bhendi, *Abelmoschus moschatus***

**Nutrient Management:** As the plant is a heavy feeder, it should be manured with well decomposed FYM at 10 t/ha.

**Weed Management:** At the early stages of the seedling growth, weeding and hoeing are done twice a month. With the growth of the plant and spreading of its branches, weeds are suppressed gradually.

## Chapter 12

# PLANTATION CROPS

There is a good scope for switching over the production of plantation crops viz., coffee, tea, coconut and arecanut to organic farming, as it is possible to realize higher returns from the unit quantity exported when grown organically. The plantation crops are generally grown in ecologically fragile hilly tracts, adopting organic farming methods would protect environment and also prevent contamination thereby producing products of high nutritional quality. Further, the plantation crops are amenable for organic farming as they produce huge amount of waste biomass for recycling, which can meet major portion of nutrients required.

### 12.1. Coffee

There is a strong demand in the world market for production of high value, high quality, specialty organic coffee. Today, the area under certified organic coffee is 2500 ha with an estimated production of 1500 MT of which 1000 MT is being exported currently.

**Selection of Site:** The site selected for planting should be provided with appropriate isolation distance of 100 meters from the conventional estates/blocks, to prevent contamination with chemicals.

**Raising Nursery:** Seeds for raising nursery should be collected from organic estates/blocks, if possible.

**Planting:** The planting pits should be exposed to sun for about a fortnight to kill soil pests like cockchafters (root grubs), nematodes, etc. Application of neem cake at 250 g/pit is advocated to control root grubs and nematodes. They are filled with top fertile soil and well decomposed FYM or compost (1-2 kg/pit) prepared on the estate.



## Nutrient Management

**Green Manuring:** In newly planted fields, green manure crops (*Crotalaria striata*, *C. anagyroides*, *Tephrosia vogelii*) and legumes (cowpea and horse gram) could be cultivated for 2 or 3 years during Kharif season (June – September) and incorporated into soil before flowering to build up the soil fertility. These crops not only contribute about 6 – 10 t/ha of dry matter but also suppress weed growth in the early years.

**Nutrition Management:** It is estimated that shade trees contribute a biomass of about 10 t/ha/year in terms of leaf litter that would contribute about 40-60 kg N, 30-33 kg P<sub>2</sub>O<sub>5</sub> and 40-60 kg K<sub>2</sub>O to the soil on decomposition. Additionally, coffee processing wastes like pulp and cherry husks are available on the farm for composting. For every tonne of clean coffee produced on the farm, about 1 tonne of pulp and cherry husks are obtained as byproducts which when recycled in the form of compost would contribute about 14-15 kg N, 3.0-3.7 kg P<sub>2</sub>O<sub>5</sub> and 29-37 kg K<sub>2</sub>O. Further, recycling of cherry husk contributes 1.66-2% N, 0.4-0.5% P<sub>2</sub>O<sub>5</sub> and 2.4-2.6 % K<sub>2</sub>O (0.18 t / year). On the whole it is estimated that nearly 84 – 95 kg N, 40-42 kg P<sub>2</sub>O<sub>5</sub> and 108-123 kg K<sub>2</sub>O are available for recycling in the coffee fields in an hectare.

However, based on need to support large crops, application of FYM or compost prepared on the farm at 2500 kg/ha/year in 2 splits is suggested, while the deficiency in nutrient supply can be met by application of rock phosphate, bone meal and wood ash. Use of biofertilizers may also be resorted to improve the availability of nutrients. Correction of soil pH using agricultural lime or dolomite based on soil test values should be taken up at least once in 2 years to enhance proper availability of applied nutrients.

**Weed Management:** Weeds can be controlled by following cultural practices such as cover digging (30 cm deep) during 2<sup>nd</sup> year of planting and scuffling (10 to 15 cm deep) for the next 2 to 3 years during post-monsoon season. In slopes, practice only manual weeding/slashing. Cultivation of green manure crops/cover crops/grain legume crops and mulching with weed slashings and shade tree leaf litter, etc. would also help in smothering of weeds. Once the coffee bushes cover up, the weed growth would naturally get suppressed and manual slash weeding alone would be sufficient.

Soil must be mulched properly for good growth of coffee. Growing cover crops like lima bean, cowpea, soybean, groundnut and pigeon pea are preferred which reduce the density of weeds.

## Pest Management

**White Stem Borer, *Xylotrechus quadripse*:** The pest can be controlled by adopting integrated measures:

- Maintenance of optimum shade.
- Regular tracing and destruction of infested plants.
- Scrubbing of main trunk and thick primaries with coir gloves to remove loose scaly bark.
- Repeated application of neem oil (2-5%) at short intervals of 1-2 weeks.
- Use of pheromone traps for monitoring incidence.
- Application of 10% lime on stem.
- Mass release of the parasitoid, *Apensia* sp. help to manage the white stem borer.

**Berry Borer, *Hypothenemus hampeii*:** The pest could be effectively tackled by adopting the following measures:

- Maintenance of optimum shade and good drainage.
- Thorough and clean harvesting of the crop intime.
- Use gunny bags/picking mats/polythene sheets while harvesting.
- Collecting the gleanings and dipping the infested berries in boiling water for 2 minutes or in cold water for 48 hours for killing all the stages of the borer inside the berry.
- Spreading the polythene sheet smeared with castor oil over the harvested coffee heap during the day for trapping all the beetles.
- Maintenance of trap plants around drying yard followed by clean harvesting from the trap plants and treating the berries in boiling/cold water.
- Timely spraying of entomopathogenic fungus, *Beauvaria bassiana*.
- Mass trapping of beetles using lures.
- Fumigating the storage material and transport structures effectively check the pest.

**Shot Hole Borer, *Xylosandrus compactus*:** The incidence on Robusta coffee could be minimized by providing optimum thin shade, good drainage, regular pruning and burning of affected twigs and suckers, especially during April-May and September-December.

**Lesion Nematode, *Pratylenchus coffeae*:** The nematode can be managed by bud grafting 'Arabica' scion on 'Robusta' rootstock.

**Leaf Rust, *Haemeleia vastatrix*:** Maintaining optimum shade, judicious pruning and spraying of 0.5% Bordeaux mixture as pre-monsoon, mid-monsoon and post-monsoon application can effectively control the disease in Arabica coffee.

**Black Rot, *Corticium koleroga*:** Thinning out the shade, regular pruning, handling, centering (opening up the centre of the bush), cutting and burning the infected plants and plant parts followed by prophylactic sprays with 1% Bordeaux mixture in the black rot prone endemic patches would effectively check the disease.

**Brown, *Fomes noxius*; Red, *Poria hypolaterita*; Black and Santavery Root Disease:** The following measures are suggested to prevent the spread of root diseases to neighbouring areas and to recover the infected areas:

- Uprooting of shade tree stumps after timber extraction followed by uprooting and burning of affected coffee bushes.
- Making an isolation trench around the affected plants by enclosing few healthy plants and application of 1-2 kg agricultural lime to the uprooted pit and exposing the spot for at least 6 months before replanting.
- Application of 5-10 kg/plant of well decomposed FYM/compost fortified with *Trichoderma* sp. to the surrounding healthy plants.
- Soil application of 2 kg *T. harzianum* or *T. viride* /plant during June and October gave good control of brown rot and red rot diseases.

## 12.2. Tea

With the current low price trends which are highly unremunerative to the growers, that most of the growers have shifted the cultivation practices to organic farming system. Today, more than 10,000 ha have been certified under organic tea cultivation.

**Selection of Site:** The area needs to be sufficiently isolated by maintaining a buffer zone of 100 meters width on all sides of the field.

**Raising Nursery:** The seeds and vegetatively propagated cuttings for raising nursery should be preferably collected from the organic estates.

**Nutrient Management:** At the time of planting, application of compost at 0.5 to 1.0 kg/pit is advocated. In tea fields, the average annual biomass contribution through shade trees is estimated at 2.5-5.0 t/ha and through the prunings of tea bushes at 14 t/ha. Effective recycling of the above biomass would add a substantial amount of nutrients to the soil.

However, in order to meet the N requirement of young plants, it is suggested to apply 10 tonnes of compost, 2.5 tonnes of castor cake/ha every year. Application of 25-35 g of rockphosphate/plant would take care of P requirement of young tea bushes. For mature plants, 5 tonnes each of neem and castor cakes/ha/year may be applied as a source of N and 60-80 kg/ha of rock phosphate during the first and third years as source of P based on test values. Requirement of K is met through application of wood ash at 500 kg/ha in matured plants during dry season.

Weed extract prepared in a 200 litre barrel by filling one-third with plant materials (*Erythrina*, *Crotolaria* and other weeds) and remaining with water and allowing to ferment for 3-4 months is sprayed at a dilution of 20 litres in 200 litres of water/ha.

Cow manure solution can be prepared by filling one-third of the drum with fresh cow dung and topping the rest of the volume with water. After 10 days, the solution is turned everyday by maintaining the volume by adding water. After 3 months, the solution is filtered and sprayed at 20 litres in 200 litres of water/ha.

The biofertilizers are mixed with soil at 1:5 ratio (1 part of *Azospirillum* with 5 parts of soil) and applied in the root zone of the bushes. Phosphate solubilizers viz., *Pseudomonas* sp. and *Bacillus* sp. can be used at 25 kg/ha.

**Weed Management:** *Mikania micrantha* is a serious weed of tea plantations. Weeds are controlled manually by hand pulling, slashing, cultivation of green manure crops/cover crops/grain legumes and mulching with weed slashing, pruning litter and shade litter. Mulching helps in conservation of soil moisture, suppression of weeds, induction of feeder root proliferation and addition of organic matter to the soil. Once the tea bushes cover the field, the weeds are suppressed naturally.

## **Pest Management**

**Soil Pests:** Application of neem cake at 250 g/pit in new clearings can effectively control the attack of cockchafer.

**Stem Borers:** Phassus borer and red coffee borer can be controlled by application of neem products and regulation of shade.

**Shot Hole Borer:** The incidence could be minimized by removing affected branches, avoiding pruning during dry weather followed by spraying of *Beauvaria bassiana* at 1.5 kg/ha during May-October when humidity levels are high and also by placing cut stems of *Montonoa bipinnatifida* in infested plantation during 3<sup>rd</sup> and 4<sup>th</sup> year.

**Leaf Feeders:** Manual removal of the caterpillars and pupae while harvesting reduces the incidence. In case of severe infestation, spray neem formulations at 1 litre/ha in 200 litres of water. Light traps can also be used to attract the moths of these caterpillars.

**Blister Blight, *Exobasidium vexans*:** The incidence of the disease can be reduced by thinning the shade, timely weed control and pruning at right time. Need based application of 1% Bordeaux mixture also helps in controlling the disease.

**Root Diseases:** Four types of root diseases viz., root splitting, black, red and brown root disease may occur in patches. Black root disease can be controlled by avoiding burial of pruning in infested field and incorporation of *Trichoderma virens* at 200 g/plant at the time of planting. Other root diseases can be controlled by isolating the infected area, opening trenches of 1.3 m deep and 45 cm width and uprooting and burning of infected bushes. Rehabilitating the soil with Guatemala grass and use of biocontrol agents at 200 g/plant (*Trichoderma harzianum* for red root and root splitting; *T. viride* for black root; *T. harzianum*, *T. viride*, *T. hamatum*, *T. resei* and *T. koningii* for brown rot and *T. virens* for red, brown and root splitting) effectively check the diseases.

## IPM

- Populations of leaf folding caterpillars such as flush worms, leaf roller and tea tortrix can be reduced by their removal while plucking.
- Bushes may be pruned to reduce the damage of *Helopeltis* and shot hole borer.
- Unshaded areas are more prone to attack by thrips and mites. Proper shade management will help to prevent excessive build up of thrips and mites.
- Growth of weeds like *Mikania cordata*, *Bidens bifernata*, *Emillia sp.*, *Polygonum chinense*, *Lantana camera* and wild

host plants near tea fields may be controlled to reduce mosquito bug population.

- Application of higher levels of K ( $N:K_2O = 1:2$ ) in the pruned year helps to reduce shot-hole borer incidence.
- *Amblyseius herbicolus* and *Euseius ovalis* are 2 phytoseid mites feeding on the eryophid mites – *Acaphylla theae* and *Calacarus carinatus*. The stigmatid, *Agistemus fleschneri* is an important predator of eggs and nymphs of *Oligonychus coffeae* in North Eastern India.
- Coccinellids - *Cryptogonus bimaculatus*, *Jauravia quadrinotata*, *Menochilus sexmaculatus* and *Stethorus gilvifrons* prey upon mites.
- *Chrysoperla carnea* released at 500-1000 adults/ha feeds on thrips and mosquito bugs.
- Anthocorids – *Anthocorus* and *Orius* spp. and predatory thrips – *Aeolothrips intermedius* and *Mymarothrips garuda* are important predators of thrips.
- Scale insects and mealy bugs are attacked by parasitoids – *Coccophagus cowperi* and *Encyrtis infelix* heavily parasitize *Saissetia coffeae*.
- The larval parasitoid, *Apanteles aristaeus* is efficient against flush worms.
- The leaf roller, *Caloptilia theivora* is heavily parasitized by the Eulopid, *Sympiesis dolichogaster* (20 to 83%).
- The tea tortrix, *Homona coffearia* is severely affected by Ichneumonid larval parasitoid, *Phytodietus spinepes*.
- The eggs of mosquito bug are parasitized by Mymarid, *Erythmelus helopeltidis* (52-83%). The Neuropteran, *Chrysoperla carnea* (at 500-1000 adults/ha) feeds on mosquito bugs in the field and gives effective control in North Eastern India.
- *Bt* is effective for the management of looper caterpillars, cut worms, flush worms and other lepidopterous pests.. *Beauvaria bassiana* is effective against shot-hole borer.
- Entomopathogenic fungi – *Verticillium lacanii*, *Paecilomyces fumosoroseus* and *Hirsutella thompsoni* were found effective against pink, purple and red spider mites. *Beauvaria bassiana* at 1 kg/ha is recommended in North Eastern India against mosquito bugs.

- Azadirachtin is effective against pink, and purple mites and caterpillars.

### 12.3. Rubber

**Weed Management:** *Impertea cylindrica*, *Chromolaena odorata* and *Mikania cordata* are some of the serious weeds of rubber plantations. For good growth and yield of rubber, the plantations have to be kept weed-free. The general practice to control weeds in rubber is by growing cover crops. Legume cover crops like *Calapogonium mucunoides*, *Pueraria phaseoloides* and *Centrosema pubescens* are grown in between rows of young rubber trees.

### Pest Management

**Leaf Fall and Stem Rot, *Phytophthora palmivora*:** Prophylactic spray of 1% Bordeaux mixture before onset of monsoon is recommended.

**Powdery Mildew, *Oidium heveae*:** Spraying 0.25% wettable sulphur at 15 days interval was found effective.

### 12.4. Cashew Nut

**Nutrient Management:** Application of FYM/compost at 50 kg/tree/year (2.5 t/ha) is recommended.

**Weed Management:** An occasional clearing of under growth manually or mechanically and pruning dead and diseased branches is necessary to maintain the health and vigour of trees. Pineapple is the most profitable intercrop in cashew plantation during earlier stages. Tapioca, groundnut, pulses can also be raised successfully during the initial 3-4 years to reduce weed population.

### Pest Management

**Stem and Root Borer, *Ploceaderus ferrugineus*:** The bark is peeled, the grubs are removed and destroyed. The peeled portion of the bark is smeared with Bordeaux paste. Keep the orchard clean.

**Blossom and Twig Blight:** Spray 1% Bordeaux mixture to seedlings.

### 12.5. Coconut

**Nutrient Management:** Application of FYM/compost at 12.5 t/ha before planting and 50 kg of FYM/compost along with green leaf manure at 50 kg/palm/every year is recommended.

**Green Manuring and Cover Cropping:** Planting of leguminous green manure plants, either seasonal or perennial can add a lot of green manure rich in N to soil in shortest possible time due to their ability to associate with atmospheric N fixing symbiotic *Rhizobium* spp. This N rich green matter will decompose easily and release the bound nutrients fast. Growth of legumes also increases the availability of phosphates. Because of their deep tap root system, they absorb nutrients that have leached down beyond the root zone of coconut palms and make them available to the palm when the biomass is incorporated into soil. Leguminous cover crops grown in coconut plantations during rainy season protect the soil from direct impact of heavy rains and serve as catch crops. Incorporation of legume biomass has also been found to enhance the soil microbial population, AMF population, soil enzyme activity and mineralization.

Leguminous cover crops like *Mimosa invisa*, *Calapogonium* sp. and *Pueraria* sp. grown in basins can generate about 15-20 kg green biomass/basin and legumes such as *Crotolaria* app. grown in interspaces can generate 3-4 tonnes of green matter/ha. The perennial leguminous green leaf manure tree glyricidia is very fast growing, hardy and resistant to regular harvesting of green leaves. This can be very well grown along the borders of coconut plantation and can generate adequate amounts of N rich green leaves. Basin management with legumes is an easily adoptable and less expensive agro-technique for supplying organic manure and N at the site itself.

**Mulching:** Meaningful utilization of organic wastes is possible by using the biomass directly as mulch or after proper composting. From a well managed coconut garden, dry material of about 14-16 t/ha/year becomes available in the form of leaves, spathe, bunch waste and husk. Keeping in mind the complimentary roles of soil organic matter in moisture conservation, coconut leaves, husks and coir pith can be utilized directly for mulching. Spreading these materials in basin will protect the soil from direct sunlight and heavy rains. Mulches can reduce the loss of soil moisture and create good microclimate in soil for the proper growth of plant roots and soil flora and fauna. Over a period of time, mulches will decompose and assimilate into the soil organic matter reserves. Coconut husks and coir pith can also be buried in trenches taken in between the rows of palms. Coir pith has 400-600% water holding capacity and this technique will be of immense value in long-term moisture conservation. In addition, both these materials are rich in K and would be available for plants over the years.



**Biofertilizers:** Inoculation of *Azospirillum* and P solubilizing bacteria in nursery results in vigorous seedling growth. Seedlings are planted after filling the pits up to 60 cm with top soil amended with compost or biofertilizers.

Application of FYM or compost prepared at the farm at 2.5 t/ha in 2 splits could correct the deficiency. A deficiency in nutrient supply can be met out by application of rock phosphate, bone meal and wood ash. Biofertilizers may also be used for improving the use efficiency of applied nutrients. Oil cakes could also be applied depending upon requirement.

**Correcting Soil pH:** Correcting soil pH using agricultural lime or dolomite based on soil test values, once in 2-3 years is required.

**Weed Management:** The pits in which the young palms are transplanted should be cleared of all weeds periodically. Regular intercultivation is essential for stepping up and maintaining the productivity of palms at a higher level. Tillage including digging, ploughing, piling and leveling of mounds are other cultural operations included in coconut cultivation. Weeds should be managed through mechanical methods or hand weeding. Ploughing the entire area twice in a year produced the highest nut yield. Mulching coconut basins with mechanically removed or hand weeded material will help not only conserve soil moisture but also serves as source of organic matter improving soil health. Highest survival of coconut seedlings (86.7%) was obtained with coir pith mulch laid 10 cm thick. Since the interspaces of coconut are to be utilized by adopting inter/mixed cropping system, weeding in such coconut plantations do not arise. Growing cover crops such as *Calapogonium mucunoides* in coconut gardens suppressed the weeds very effectively within 3 months when grown as a green manure – cum cover crop. This method of weed control is more practical and economical than other methods. Cover crops like *Calapogonium* (legume), *Mimosa invisa* and *Stylosanthus* aid in suppressing weed growth due to fast growing nature. Growing competitive crops like sunflower, soybean, green or black gram, cowpea and other legumes had a suppressing effect on weeds in coconut gardens. Thick mulch of green or dry leaves in planting pits of young palms reduce weed growth considerably. Green manuring crops like *Indigofera*, *Tephrosia* and sunnhemp grow fast and provide organic manure besides competing with weeds. Intercropping and mixed cropping of coconut gardens with arecanut, ginger, turmeric, dioscorea, banana, tapioca, cocoa and cinnamon was found useful for keeping that coconut plantation free from weeds to a great extent. All weeds except *Rottboellia exaltata* were suppressed by winged bean

(*Psophocarpus tetragonolobus*) when it was fully established 4 months after sowing in coconut gardens.

## Pest Management

**Rhinoceros Beetle, *Oryctus rhinoceros*:** Releasing of 10-15 Baculovirus infected beetles/ha has been found to be effective in checking the population of the rhinoceros beetle. These releases initiate a self perpetuating disease in the beetles through copulation, contamination through excreta, etc. The virus can infect all stages of the pest and the infection is passed down to the progeny also. However, re-release of the pathogen is needed after 3-5 years.

*Metarrhizium anisopliae* or the green muscardine fungus, is another biocontrol agent which can infect all stages of rhinoceros beetle. The fungus can be easily multiplied in coconut water, tapioca chips, etc. On inoculating the fungus in decaying organic matter, it thrives well and cause a good degree of mycosis of the grubs resulting in reduction in black beetle population.

*Clerodendron infortunatum*, a commonly found weed is a promising botanical. Grubs or black beetles become deformed and sterile when fed on feed containing this plant. The leaves, shoot, flowers and root can be incorporated in the composting material and the larvae that hatch out in such pits shall be affected by the contaminated feed.

**Red Palm Weevil, *Rhyncophorus ferrugineus*:** Pyrecon-E (derivative from Pyrethrum plant) has been a time tested effective chemical for the control of red palm weevil.

**Eriophyid Mite, *Aceria guerreronis*:** Neem/garlic oil/soap emulsion has emerged as one of the potent measures for the control of mites. The fungus, *Hirsutella thompsonii* has been found to be an effective microbial agent for annihilating this pest.

**Black Headed Leaf Eating Caterpillar, *Opisina arenosella*:** Neem oil/soap sprays gave effective control of this pest.

An exotic parasitoid, *Trichogramma embryophagum* has been found effectively parasitize the eggs in silken galleries. *Apanteles taragamae* is an important endoparasitoid of 1<sup>st</sup> and 2<sup>nd</sup> instar caterpillars. The frass of the young larvae acts as a kairomone and attracts the females for parasitism. This parasitoid holds good potential for pest suppression. *Goniozus nephantidis* is quite hardy and gregarious. It parasitizes medium and fully developed larvae. *Bracon hebetor* parasitizes medium sized or fully developed larvae in

the coastal areas. A single parasitoid parasitized  $22.6 \pm 7.18$  late instar caterpillars during its life period. The elasmid parasitoid, *Elasmus nephandidis* is the only true prepupal parasitoid of *O. arenosella*. It is monophagous and a gregarious ectoparasitoid. It is well adapted to thrive during summer season, which is the peak period of activity of the pest. The bethylid parasitoid, *Brachymeria nosatoi* is found to possess the major attributes of an efficient biocontrol agent of the pest. It is a sturdy parasitoid prevalent in nature almost throughout the year. Its natural incidence is quite high (up to 38.8%), even during summer season, which is incidentally peak period of pest abundance. There has always been a preponderance of females, which have greater searching ability and locates and parasitizes host pupae remaining inside the cocoons in silken galleries. The 5<sup>th</sup> and 6<sup>th</sup> instar caterpillars were most readily accepted by the parasitoid. The pupal parasitoid, *Xanthopimpla punctata* is an outstanding example of a polyphagous species of parasitoid which turned out to be a better killer of the pest than even other host specific and gregarious species of parasitoids.

The optimum doses of release of indigenous parasitoids for effective suppression of *O. arenosella* were 20.5% for *G. nephandidis*, 49.4% for *E. nephandidis* and 31.9% for *B. nosatoi*, when the parasitoids were released individually and 40.4% when a combined release was made. The release at above doses effected 81 and 83% reduction in population density of the pest in the case of individual releases of *G. nephandidis* and *E. nephandidis*, respectively. Release of the parasitoids in the early stage of pest build up was proved absolutely necessary for effective suppression of the pest.

**Stem Bleeding, *Theilaviopsis paradoxa*:** The integrated management practices recommended are removal of not only dead palms but also those in advanced stages of disease and/or stumps along with bole and root system and destroying; isolation of diseased palms from healthy palms by digging trenches of 1 m deep and 30 cm wide; providing adequate soil moisture through irrigation coupled with mulches; avoiding flood irrigation, overcrowding, preventing wounding of stem which predispose the palms to infection and ploughing to prevent the spread of inoculum; providing good drainage facilities; application of 50 kg FYM and 5 kg neem cake/palm/year and raising *Ganoderma* resistant crop like banana as intercrop.

Neem cake enriched with *Trichoderma virens*, *T. hamatum* and *T. harzianum* has been found to be very effective in reducing the population of the pathogen in the soil. These antagonistic fungi thrive well in neem cake supplemented with a small quantity of rice/wheat

bran thus effecting their multiplication an easy task. *Trichoderma harzianum*, *T. viride*, *T. hamatum* and *T. virens* grow very well in rice bran and neem cake (1:1 w/w) and reduced stem bleeding when applied to the soil. Soil application of neem cake and FYM mixed with *T. virens* showed reduction of stem bleeding up to 31.3%. Soil application of *T. virens* along with neem cake and FYM showed the least disease index and the highest yield.

West Coast Tall was found more resistant to stem bleeding.

**Basal Stem Rot, *Ganoderma lucidum*:** Light irrigation coupled with Bordeaux mixture drenching helps in reducing the disease incidence. Raising banana as intercrop is recommended. *T. harzianum* has been found to control the multiplication of the pathogen in sick soils. When combined with phosphobacteria or plant growth promoting rhizobacteria, synergistic effects have been noticed. *T. harzianum* applied along with neem cake reduced the disease index and increased the yield of coconut.

**Bud Rot, *Phytophthora palmivora*:** Prophylactic spraying of young palms with 1% Bordeaux mixture, improved drainage, wide spacing and weed control helps to reduce the disease severity. Removal of infected spindle showing initial yellowing symptoms and application of 1% Bordeaux paste reduce the disease incidence. *Bacillus subtilis*, *B. macerans*, *B. amyloliquifaciens* and *Myrothecium roridum* have all been found to be checking the growth of the pathogen. The hybrid Malayan Dwarf x West African Tall (Hybrid PB 12) is tolerant.

**Root wilt (Phytoplasma):** The yield of palms can be sustained through adoption of integrated management practices like removal of disease advanced and juvenile palms, addition of organic matter, raising green manure crops in the basin and their incorporation into the soil, irrigation during summer months and adopting inter and mixed cropping. Mixed farming in diseased gardens involving the raising of fodder crops in the interspaces, maintaining milch cows and recycling of organic waste has helped in increasing the yield of palms by 26%. Mixed cropping with cocoa also increased the yield by 30% and slowed down the decline of palms. Cultivation of tapioca, elephant foot yam and yam in the interspaces of palms in disease affected gardens for a period of 3 years increased the nut yield.

**Burrowing Nematode, *Radopholus similis*:** Application of oil cakes, FYM and green foliage to the basins, growing of intercrops like cocoa that enriches the soil with sizeable quantities of shed foliage which help in the build up of beneficial organisms which may inhibit nematode multiplication. *Crotalaria juncea* may be grown in the

basins and interspaces and used as green manure. Avoid banana as a shade crop in coconut nurseries. Use nematode-free planting material of coconut and other intercrops.

## 12.6. Arecanut

**Nutrient Management:** Following is the manurial schedule recommended for arecanut: FYM or Compost: 25 t/ha for nursery beds. 20 kg/plant (pre-monsoon application during May-June) to be given every year after transplanting. In addition, bio-fertilizers, neem cake and vermicompost may also be given based on soil test values. Cultivation of green manure crops *in situ* and application of green leaf manure should also be taken up systematically in order to get increased yield.

**Weed Management:** The main cultural operation such as light forking or digging are performed towards the end of monsoon to break the irrigation crust and to control weeds. The raising of green manure – cum cover crops such as *Calapogonium mucunoides*, *Mimosa invisa* and *Stylosanthes gracilis* was also found to be advantageous. Growing of green manure crops on the onset of monsoon will help to suppress the weed growth, prevent soil erosion and add large quantities of organic matter to the soil. Cover crops like guinea grass can also be grown to suppress the weeds. Intercultivation is done regularly to remove weeds. Intercrops such as elephant foot yam, black pepper, arrowroot (*Manihot* spp.) and banana, and mixed cropping with cocoa, pepper and betelvine can be taken up to increase the income of growers without any detrimental effect to the yield of main crop.

## Pest Management

**Stem Borer:** Chisel out the damaged area of the tree and swab the portion with 5% neem oil (with 0.5% Teepol or soap) on the tree trunk up to a height of 1 m during April-May and Oct-Nov. Use *Metarrhizium anisopliae* or *Beauveria bassiana* against stem borer.

**Tea Mosquito Bug:** Augmentative release of egg parasitoids, *Telenomus* or *Crematogaster*.

**Koleroga, *Phytophthora arecae*:** Removal and destruction of infected debris, shed nuts, died bunches and dead crowns help to minimize the disease spread and development. Covering the bunches with polythene or leaf sheath or grass before the onset of monsoon helps to reduce the disease. Pre and post monsoon spraying with 1% Bordeaux mixture gives effective control of koleroga.

**Foot Rot or Anabe Disease, *Ganoderma lucidum*:** Removal and destruction of infected stumps along with roots, following recommended spacing of 2.7 x 2.7 m, digging trenches around the affected palms, avoiding repeated ploughing and deep digging helps to reduce the disease incidence. Application of organic manure at 15-20 kg/palm and 15-20 kg green leaf along with neem cake at 2-2.5 kg/palm every year is to be followed to reduce spread of the disease. Soil drenching with 2% Bordeaux mixture at monthly interval throughout the monsoon is recommended.

**Bud Rot, *Phytophthora* sp., *Gloeosporium* sp., *Thielaviopsis* sp.:** Early detection of the disease and prompt removal of infected tissues will help in recovery of palms and also prevents the spread of the disease. Drenching with 1% Bordeaux mixture reduces the crown rot by bacteria. Avoid heavy intercropping, cultivation in low lying areas and closer planting to reduce spread and development of the disease.

**Die-back or Pink Disease:** Chisel out the affected parts and apply Bordeaux paste. Give prophylactic sprays of 1% Bordeaux mixture during May-June and Oct.

## 12.7. Oil Palm

**Nutrient Management:** Application of FYM/compost at 50 kg/palm (5 t/ha) at planting and 50 kg/palm (5 t/ha) every year is recommended.

**Weed Management:** Early initial weeding (about 8 weeks after sowing) was required for polybag grown oil palm seedlings to ensure vigorous seedlings for transplanting in the main field. Hand weeding at 4-6 weeks interval is followed. Cover cropping with *Centrosema pubescens* and *Calapogonium caeruleum* in oil palm plantations helps in reducing the incidence of weeds.

## 12.8. Cocoa

### Pest Management

**Seedling Dieback, *Phytophthora palmivora*:** The infected and dead seedlings should be removed and destroyed. Improvement of drainage facilities in the garden followed by drenching with 1% Bordeaux mixture was also found effective.

**Black Pod Rot, *Phytophthora palmivora*:** All the diseased pods should be removed and destroyed at weekly interval especially

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during rainy season. Regulation of shade by proper pruning and allowing the sunlight to penetrate and thus help in minimizing the disease incidence. Spraying with 1% Bordeaux mixture before the onset of monsoon was found effective.

**Charcoal Pod Rot, *Botryodiplodia theobromae*:** Spraying with 1% Bordeaux mixture was found effective.

**Stem Canker, *Phytophthora palmivora*:** Disease can be effectively managed by wound sealing with Bordeaux paste.

## Chapter 13

### SPICE CROPS

Since spices form a part of traditional/ethnic medicines, the demand for organically produced spices is growing. Export of organic spices from India has started in right earnest. The country at present exports around 50 tonnes of different varieties of organic spices. Export will get a significant boost in the coming years as more and more farmers switch to organic methods.

#### 13.1. Black Pepper

**Nursery Management:** The soil should be solarized prior to use and inoculated with cultures of AMF and *Trichoderma* spp. (25 kg of compost enriched with 250 g). The vines in rapid multiplication units may be sprayed with vermiwash (50 ml/unit) for enhancing the growth of seedlings.

The 2 important nursery diseases viz., leaf rot caused by *Rhizoctonia solani* and basal wilt caused by *Sclerotium rolfsii* can be minimized if solarized soil is inoculated with AMF and *Trichoderma* spp. Spot application of Bordeaux mixture can also be used to control the diseases.

**Selection of Site:** An isolation distance of 25 metre width is to be left around.

**Nutrient Management:** Application of 2 kg compost mixed with 125 g rock phosphate/vine at the time of planting is suggested. Compost or FYM may be applied during May-June from 2<sup>nd</sup> year onwards at 4 kg/vine which can be gradually increased to 10 kg/vine. Compost made from green loppings, crop residues, grasses, cow dung, poultry droppings, etc., fortified wood ash and or rock phosphate should be used regularly instead of FYM alone.



Application of leaf and vermicomposts and FYM at 10 kg/vine improved the soil physico-chemical properties, nutrient availability and the yield. Application of leaf and vermicomposts supports high population of free-living N-fixing bacteria, phosphorbacteria and fungal populations. Application of coir compost at 2.5 t/ha along with FYM and biofertilizer significantly increased the yield and quality of pepper.

In case of bush pepper, application of leaf/vermicompost at 2 kg/plant or neem cake at 200 g/plant gave highest yield.

**Weed Management:** Weeding may be done by slashing and using the same for mulching. Mulching is an important cultural operation practiced in pepper to suppress weeds and conserve soil moisture. Saw dust mulch was found to give highest yield in pepper. Cover crops (*Calapogonium mucunoides*, *Mimosa invisa*) are grown to provide effective soil cover and to prevent soil erosion.

Digging whole pepper garden once or twice in a year, digging 1 m around the plant or sickle weeding twice a year is recommended.

## Pest Management

**Pollu Beetle, *Longitarsus nigripennis* and Leaf Gall Thrips:** Regulation of shade in the plantation reduces the population of the pest in the field. The pests can be managed by spraying neem oil at 400 ml/100 litres of water. An integrated strategy involving regulation of shade and spraying of Neem Gold at 0.6% at 21 day intervals during June-October was found effective against pollu beetle.

**Scale Insect, *Lepidosaphes piperis*, *Aspidiotus destructor*, *Lecanium* sp.:** Scales are controlled by shade management during May-June and application of neem oil (0.6%) during October-November. The pest can be managed by spraying tobacco decoction. Spraying of neem-garlic suspension at 2% was found effective. *Chilocorus nigrita* is a potential natural enemy against scale insects.

**Foot Rot, *Phytophthora capsici*, *P. palmivora*:** Adoption of phytosanitary measures like removal and destruction of dead vines along with root systems from garden as well as use of disease-free planting materials, keeping tillage operations to the minimum to avoid soil disturbance and root damage, providing adequate drainage to reduce water stagnation, providing green legume cover / grass cover to avoid rain splash spread to adjoining vines, application of *Trichoderma* spp. at 75 g/vine along with neem cake at 2 kg/vine during May-June (pre-monsoon) with suitable carrier medium such as coffee husk and well rotten cow dung followed by second round of

application during August-September (post-monsoon) gives effective control of the disease. Prophylactic application of Bordeaux paste to collar region during May-June (pre-monsoon) and spraying with 1% Bordeaux mixture helped in reduction of the disease. Spraying of modified panchagavya at  $10^1$  dilution at 2-3 litres/vine twice as pre-monsoon (May-June) and post-monsoon (August-September) is recommended.

The freshly emerging runner shoots should not be allowed to trail on the ground. They must be either tied back to the standard or pruned off. The branches of support trees should be pruned at the onset of monsoon to avoid build up of humidity and for better penetration of sunlight. Reduced humidity and presence of sunlight reduces the intensity of leaf infection. At the onset of monsoon (May-June), application of *T. harzianum* ( $10^{10}$  cfu/g) around the base of the vine is recommended. A second application of *T. harzianum* during August-September is also recommended.

In disease affected gardens, plants treated with *T. harzianum* (IISR 1369 strain with  $10^{10}$  cfu/g) at 50g/vine along with 10 kg of FYM or 1 kg neem cake during May – June period immediately after the receipt of first early monsoon shower and second dose of inoculum applied during August – September gave effective control of foot rot and slow decline (*Meloidogyne incognita*, *Radopholus similis*).

Five strains of *Pseudomonas fluorescens* (IISR-11, 8, 51, 6 and 13) gave protection against foot rot (above 55% over control) to the plants, were also found to be efficient in growth promotion. Maximum disease suppression was obtained in the plants treated with strain IISR-51 (86%).

Integration of *T. harzianum* (IISR 1369) with *Pseudomonas fluorescens* (IISR-41) gave very effective control of foot rot (10% disease incidence as compared to 90% in control) and increased plant height under field conditions. Integration of *T. harzianum* (IISR 1369) with *Pseudomonas fluorescens* (IISR-11 or 6) suppressed the root rot to the extent of 63% over control and improved the vigour of pepper vines.

*T. harzianum* culture mixed with pre-wetted neem cake or FYM at 1 kg/100 kg and incubated for 2 days. Pre-monsoon application of this mixture at 5 kg/vine below 10 years and 10 kg/vine above 10 years gave good control of wilt disease.

Use of disease free nursey stock and removal of infected plants and their parts from the plantations reduces the population build up of the pathogen. In pure plantations, lopping off of the branches of

standards ensures better light penetration, resulting in a microclimatic conditions less congenial for the disease development. Pruning of runner shoots or tying them back to the main bush reduces the chances of initial foliar infections and subsequent spread. Maintenance of green or grass cover reduces chances of soil splash and spread of foliar and root infections. Minimum tillage reduces root rot. Provision of good drainage, discouraging farm labourers from diseased to healthy gardens and use of farm implements used in diseased garden after disinfection are some of the recommended cultural practices.

Raising plants in solarized nursery mixture, fortified with *Trichoderma* spp. and endomycorrhizae, has been found effective in suppressing root rot. Endomycorrhizae and *T. harzianum* are effective against *Phytophthora* spp. and *Meloidogyne* spp.

**Leaf Rot, *Rhizoctonia solani* and Blight/Anthracnose, *Colletotrichum gloeosporoides*:** Removal and destruction of the infected berries to avoid repeated overlapping of infections is recommended. A prophylactic spray with 1% Bordeaux mixture prevents both the diseases. Spraying with 1% Bordeaux mixture during June-July, late July and late August was found effective in the management of the disease. Foliar spray with liquid formulation of *Pseudomonas fluorescens* and drenching at both pre- and post-monsoon treatments provided good protection. The treated plants had 35% disease index as compared to 61% in control and the yield was 2.34 kg/vine as compared to 0.78 kg/vine in control. However, this was on par with Bordeaux mixture spray with 29% disease index and 3.65 kg yield/vine.

**Nematodes, *Radopholus similis*, *Meloidogyne incognita*:** Mulching (with Guatemala grass) has an ameliorating effect on the symptoms of slow wilt/pepper yellows (*R. similis*). Planting nematode-free rooted cuttings, uprooting of affected vines and replanting after a period of 9-12 months, use of non-living standards/suppots, avoiding *R. similis* susceptible intercrops like banana, ginger, turmeric and exclusion of susceptible trees as standards for trailing the vines reduces the nematode population. Application of organic amendments like neem cake (200 g), green foliage (3-5 kg) or FYM (1 kg) per vine and earthing up in September-October are recommended. Growing of non-host cover crops like Siratro (*Macroptilium atropurpureus*) in the interspaces is recommended to reduce nematode population. Growing marigold as a trap crop and uprooting the trap crop at flowering stage and burning reduce the incidence of nematodes. Application of *Paecilomyces lilacinus* and *Pochonia chlamydosporia* has potential to

control nematodes. Effective strains of AMF (*Glomus* sp. and *Gigaspora* sp.) isolated from black pepper rhizosphere were very effective in suppression of root-knot nematodes.

Black pepper vines combinedly inoculated with *P. lilacinus* and *P. penetrans* had put out 23-112 per cent increase in plant growth over control and were very effective in the management of root-knot nematodes. Soil application of *Pochonia chlamydosporia* reduced nematode population and increased the yield (5.14 kg/vine) with cost:benefit ratio of 7.12.

*Pasteuria penetrans*, *Paecilomyces lilacinus* and *Pochonia chlamydosporia* are effective in suppressing the root-knot and burrowing nematodes. Five isolates of rhizobacteria (IISR-552, 528, 658, 853 and 859) were good growth promoters (26.7 to 55.6%) having dual nematicidal action (suppressing both *M. incognita* and *R. similis*).

### 13.2. Cardamom

**Buffer Zone:** An isolation distance of 25 metre width is to be left from all around the plantation.

**Nursery Raising:** For raising polybag seedlings, potting mixture may be prepared by using 3:1:1 soil rich in organic matter, well rotten cow dung or vermicompost and sand. To this, AMF and FYM enriched with *Trichoderma* spp. (250 g in 25 kg) can also be added. Spraying with vermiwash (20 ml/plant) is desirable for proper growth of seedlings. Restricted application of 1% Bordeaux mixture may be done to control rot disease at the initial stage itself.

**Nutrient Management:** Application of organic manures such as neem cake at 1 kg or poultry manure/FYM/compost/vermicompost at 2 kg/plant may be done once in a year during May-June. Application of rock phosphate or bone meal may be done based on soil analysis. Restricted lopping and leaf litter may be used for green manuring or composting.

Application of enriched coir pith compost to the basin helps in increasing the production and quality of the produce. Coir pith compost fortified with rock phosphate can be used as a substitute for FYM in the potting mixture for raising the seedlings in the nursery.

**Weed Management:** Cardamom plantations are given at least 4 weedings in the first year, 3 in second and 2 annually thereafter. Clean weeding is to be limited to the plant bases (50 cm) and the inter rows are to be maintained by slash weeding. The weeded materials should be used for mulching. Mulching with stratified dry leaf mulch

and weed mulch on ground resulted in formation of most suckers and leaves in cardamom.

## Pest Management

**Hairy Caterpillar, *Eupterote* sp. and Root Grub, *Balepta fuliscorna*:** Mechanical collection and destruction of larvae reduces the pest damage.

**Stem Borer, *Conogethes punctiferalis*:** As soon as bore holes of stem borer are noticed, injection of *Bacillus thuringiensis* preparation into the bore hole (0.5 ml in 10 ml water) will kill the larvae so that subsequent resurgence can be reduced.

Cardamom cv. Mudigere-1 (Malabar) is tolerant to shoot borer.

**Whitefly, *Dialeurodes cardamomi*:** Collection of adults using yellow sticky traps and control of nymphs by spraying neem oil with soft soap (500 ml neem oil and 500 g soft soap in 100 litres of water) is to be followed to reduce the incidence of the pest.

**Thrips, *Scirtothrips cardamomi*:** Application of fish oil rosin soap may be made to manage thrips damage.

Cardamom cv. Mudigere-1 (Malabar) is tolerant to thrips.

**Damping-off, *Pythium vexans*:** Solarization of nursery beds before sowing seeds and incorporation of *T.harzianum* has resulted in prevention of damping off and production of pathogen-free healthy seedlings.

**Capsule rot (Azhukal), *Phytophthora meadii* and Clump Rot, *Pythium vexans*, *Rhizoctonia solani* and *Fusarium* spp.:** Removal and burning of infected panicles and rhizomes from the plantation reduced the disease incidence. Spraying the panicles during pre-monsoon and post-monsoon is recommended. Incorporation of *Trichoderma* spp. multiplied in suitable organic medium (1 kg/clump) prior to the onset of monsoon season is a prophylactic operation. Spraying of 1% Bordeaux mixture may be resorted. Integration of *T. harzianum* (IISR 1369) with *Pseudomonas fluorescens* (IISR-11 or 6) suppressed the clump rot to the extent of 36% over control. Soil application of *T. harzianum* or *T. viride* to nursery beds gave disease control ranging from 53 to 84%. Soil application of *T. harzianum* or *T. viride* to the main field resulted in high disease control ranging from 62.3 to 64.8%.

Soil solarization can be done for sterilizing the nursery mixture. To the sterilized mixture, biocontrol agents such as arbuscular mycorrhizal fungus at 100 g/kg and *T.harzianum* ( $10^{10}$  cfu/g) may be

added at the time of filling of nursery mixture in polybags. Since the biocontrol agents protect the root system only, the aerial portion may be protected with 1% Bordeaux mixture spray.

Cardamom cv. ICRI-2 (Mysore) is tolerant to capsule rot disease.

**Rhizome Rot:** Raising plants in solarized nursery mixture, fortified with *Trichoderma* spp. and endomycorrhizae, has been found effective in suppressing root rot. Application of *T. harzianum* (100-150 g of mass cultured on coffee husk) during pre and post monsoon periods was consistently effective in controlling the disease.

Combined application of *Trichoderma* spp. and *Paecilomyces lilacinus* was found effective in controlling the disease complex (rhizome rot and root-knot nematode).

Cardamom cv. ICRI-3 (Malbar) is tolerant to rhizome rot disease.

**Katte Disease (Virus):** Use of disease-free planting material is important. Regular roguing of virus affected plants should be made to reduce the spread. Rogued plants should be destroyed by burning.

**Root-knot Nematodes, *Meloidogyne* spp.:** Soil solarisation of nursery beds and application of bioagents such as *P. lilacinus* or *Trichoderma* spp. improved growth of cardamom seedlings by suppressing root-knot nematode population. Soil application of crushed neem seed can take care of nematode problem.

## IPM

- Use pest and disease tolerant varieties for planting [Cardamom cvs. ICRI-2 (Mysore) against capsule rot, ICRI-3 (Malabar) against rhizome rot and Mudigere (Malabar) against shoot borer and thrips].
- Practice regular roguing to check katte, Nilgiri necrosis and vein clearing diseases.
- Destroy wild hosts of katte disease like *Amomum*, *Alpinia*, *Curcuma*, *Colocasia*, *Caladium*, etc.
- Destroy capsule rot affected portions and plant debris.
- Use yellow sticky traps to control whiteflies at 15 to 20 traps/ha.
- Apply *Trichoderma viride*/ *T. harzianum* in plant basins to control capsule rot and rhizome rot diseases.
- Spray neem oil at 3-5 ml/litre against whiteflies.
- Spray 1% Bordeaux mixture against capsule rot.

### 13.3. Ginger and Turmeric

**Nutrient Management:** Application of FYM/compost at 25 t/ha every year is recommended. Application of coir pith compost at 2.5 t/ha along with FYM and biofertilizer significantly increased the yield and quality. Organic manures such as FYM, neem cake and groundnut cake in turmeric cultivation gave rhizome yield of 48.2, 48.1 and 46.3 quintals/ha in comparison to 48.8 q/ha with chemical fertilizers. Organic manures improved the curcumin content in the rhizome more than chemical fertilizers.

Application of FYM at 25 t/ha and vermicompost at 2.5 t/ha gave higher yield of turmeric compared to control (Table 13.1).

**Table 13.1. Effect of organic manures on yield of turmeric.**

Treatment	Cured rhizome yield (t/ha)
FYM at 25 t/ha	3.34
Vermicompost at 2.5 t/ha	4.79
Control	3.01
CD at 5%	0.97

**Weed Management:** The predominant weeds are *Trianthema portulacastrum*, *Eclipta alba*, *Euphorbia hirta* and *Phyllanthus niruri* among dicots, and *Cyperus* spp., *Echinochloa colonum*, *E. crusgalli* and *Digitaria marginata* among monocots. Mulching the beds with green leaves at 10-12 t/ha 40 and 50 days after planting is done in turmeric to suppress weeds. Earthing up on 45, 90 and 135 days after planting is a general practice in turmeric. Wheat and paddy straw can be used as dry mulch both for weed control and soil moisture conservation. At least 3 hoeings and weedings should be given at 60, 120 and 150 days after planting. Cover cropping and mulching with leaves and straw applied just after planting gave earliness in sprouting of turmeric and less number of weeds.

Generally 3-4 weedings and once or twice earthing up in a year is done for ginger. Mulching with sisham leaves produced tallest plants with high number of tillers per plant. Mulching with green leaf, sugarcane trash and polythene film gave highest yield of green ginger and could conserve moisture up to 50%. Suppression of weed growth, increase in crop emergence and enhanced yields were noticed in plots mulched with dry leaves of straw.

**Integrated Weed Management:** Mulching after planting + hoeing at 40 DAP + grubber at 60 DAP + hand weeding at 90 DAP + mulching showed superiority in terms of plant height, tillers/clump, number of leaves/clump and tiller, leaf area index and leaf area/clump. This treatment also recorded significantly higher values for rhizome characters i.e. rhizome length, breadth, weight and yield of green ginger.

### Pest Management

Selection of healthy planting material from disease-free gardens (soft rot, *Pythium aphanidermatum*, *P. myriotylum*; bacterial wilt, *Ralstonia solanacearum*; and nematodes, *Meloidogyne* spp., *Pratylenchus* spp.) is essential. Hot water treatment of the seed rhizomes at 51°C for 10 min eliminated nematodes and surface bound pathogens also. Strict phytosanitation, provision of better drainage and cultivating ginger and turmeric in raised beds are some of the important cultural operations to be adopted to reduce crop losses due to the biotic factors.

As a seed disinfection procedure, a novel technique called rhizome solarization has been devised at the Indian Institute of Spices Research, Calicut. The disinfected rhizomes when treated with *T. harzianum* and rhizobacterial strain consortia as seed treatment and soil application resulted in higher yields and growth promotion and soft rot suppression and minimal bacterial wilt. In addition, in combination with *Glomus* spp., the disease was absent probably through growth mediation. *T. harzianum* in combination with *Pseudomonas fluorescens* showed a synergistic effect in reducing the soft rot infection.

Application of *T. harzianum*, *T. viride*, *T. hamatum* and *T. virens* as seed treatment and soil application along with neem cake at 100 kg/ha gave protection and increased yield. Application of *T. viride* along with saw dust/neem cake was found to be highly effective in suppression of rhizome rot. There was synergistic effect in protection where soil solarization followed by biocontrol was adopted. *Trichoderma* spp. and *T. viriens* were found to be highly effective in suppressing *Fusarium* yellows and *Pratylenchus coffeae*.

**Stem Borer:** An integrated strategy involving pruning and destroying freshly infested pseudostems during July-August (fortnightly intervals) and five rounds of spraying with 0.3% Dipel (*Bacillus thuringiensis*) during July-October at 21 days interval commencing from the first symptom of pest infestation are noticed were effective against stem borer of ginger and turmeric.



**Rhizome Rot, *Pythium aphanidermatum*, *P. graminicolum*:**

Soil solarization, selection of healthy planting material, seed treatment with *Trichoderma* spp. and its soil application coupled with organics was found effective in suppressing rhizome rot of ginger and turmeric. Seed treatment with *T. viride* + *P. fluorescens* at 4 g/kg seed and soil application of FYM at 10 t/ha + *T. viride* (12.5 kg/ha) and *P. fluorescens* (25 kg/ha) resulted in minimizing rhizome rot to 11.7% compared to 37% in control and increased the yield (28.6 t/ha) compared to 10.3% in control. Integration of *T. harzianum* (IISR 1369) with *Pseudomonas fluorescens* (IISR-11 or 6) suppressed the soft rot, imparted 66.2 t/ha survival of ginger tillers and improved the vigour of ginger plants.

Solarization of beds before planting and addition of *T. harzianum* formulation (with  $10^{10}$  cfu/g) at 50 g/3 sq. m. bed along with neem cake/FYM reduced the disease incidence.

**Yellows, *Fusarium oxysporum* f. sp. *zingiberi*:** *T. harzianum*, *T. hamatum* and *T. virens* were found effective in suppressing yellows of ginger under field conditions.

**Storage Rot, *Sclerotium rolfsii*:** *T. harzianum* was highly effective in suppressing *S. rolfsii* in ginger and turmeric under field conditions. The conidial mixture of 2 bioagents *T. pseudokoningii* (effective in reducing the mycelial growth) and *T. virens* (good colonizer of sclerotia) was effective in reducing the incidence of storage rot.

**Nematodes, *Meloidogyne incognita*, *Radopholus similis*:** Use nematode-free rhizomes for fresh planting. Washing seed material to free of soil and drying in shade before planting helps to reduce the inoculum. Hot water treatment of rhizomes at 50-55°C for 10 min or 45°C for 30 min eliminates nematode infection. Soil solarization of beds for 40 days during summer reduces nematode population in soil. Crop rotation with cereals and millets should be practiced, preferably with rice at least once in 3 years. Deep summer ploughing with furrow turner ploughs should be practiced. Application of well decomposed FYM/compost at 25-30 t/ha or neem cake at 2 t/ha and mulching with green leaves at 10-12 t/ha at planting and repeating the mulching during the growth period helps in reducing nematode multiplication. Avoid using ginger and turmeric as intercrops in *R. similis* infested coconut and arecanut based farming systems.

Complete suppression of nematodes could be achieved by the application of *Fusarium oxysporum* (isolate IISR-11) at 50 g/bed of 3 sq. m. at the time of planting. Soil application of *T. harzianum* + neem cake at 1 t/ha is recommended. *Paecilomyces lilacinus* and *Aspergillus nidulans* suppressed nematode population.

Turmeric cvs. Kodur, Duggirala, Guntur-1, Guntur-9, Rajampet, Sugandham and Appalapadu are resistant to *M. incognita*.

### 13.4. Cinnamon

**Weed Management:** Only conventional methods like hand weeding, hoeing and mulching are followed in cinnamon.

#### Pest Management

**Leaf spot, *Colletotrichum gloeosporoides*; Seedling blight, *Diplodia* sp. and Grey blight, *Pestalotia palmarum*:** Pruning the die-back affected branches and spraying with 1% Bordeaux mixture are recommended for the control of the above diseases.

### 13.5. Vanilla

**Nutrient Management:** Vanilla loves a lot of organic matter and decomposed mulch as they are main source of nutrients. Easily decomposable organic material is applied around the plant base at least 3-4 times in a year.

**Pest Management:** Phytosanitation, spraying of 1% Bordeaux mixture and soil drenching with 0.2% copper oxychloride is effective against rot caused by *Phytophthora meadii*. Soil application of compost mounds enriched with *T. harzianum* twice resulted in substantial reduction in wilt (*Fusarium oxysporum* f. sp. *vanille*). Soil application of rhizobacterial strain consortia (IISR-147 and IISR-148) with *T. harzianum* was effective in disease suppression of both *P. meadii* and *F. o. f. sp. vanilla*.

### 13.6. Nutmeg

**Weed Management:** No deep and frequent hoeing or weeding is necessary for nutmeg as the tree has shallow root system. In lighter soils, heavy mulches with dry leaves and 25 kg well rotted cattle manure is desirable per year.

#### Pest Management

**Die-back, *Diplodia* sp.; Thread Blight, *Marsimus pulcherrima*, *M. equicrinus*; Fruit Rot, *Phytophthora* sp., *Diplodia natalensis* and Shot Hole, *Colletotrichum gloeosporoides*:** The dieback infected branches should be pruned and cut ends pasted with Bordeaux paste. The diseases can be managed by phytosanitation and

shade regulation. Spraying with 1% Bordeaux mixture gives effective control of the above diseases.

### 13.7. Coriander

**Weed Management:** First hoeing and weeding should be done at 30 DAS. Thinning to remove excess plants should also be done at this stage. The second weeding and hoeing in irrigated crop may be done between 50-60 DAS.

#### Pest Management

**Wilt, *Fusarium* sp.:** Follow crop rotation. Deep ploughing during summer should be taken up. Seed treatment and soil application with *T. harzianum* was effective for the management of the disease.

Seed treatment with *P. fluorescens* at 10 g/kg gave the lowest Fusarial wilt incidence of 14.4% (36.6% in control) with an yield of 603 kg/ha (423 kg/ha in control). *T. viride* as seed treatment (4 g/kg) and soil application (5 kg/ha) reduced the Fusarial wilt incidence by 58% with an yield of 575 kg/ha compared to 433 kg/ha in control.

### 13.8. Fenugreek

**Weed Management:** Two weedings and hoeing operations, one at thinning and another 45-50 DAS are sufficient to keep the crop free from weeds and the soil well aerated.

#### Pest Management

**Root Rot:** Seed treatment with *T. viride* (4 g/kg) followed by soil application (5 kg/ha) along with 150 kg/ha of neem cake consistently suppressed root rot.

### 13.9. Cumin

**Weed Management:** At least 2 weedings and hoeings at 30 and 50-60 DAS are necessary to control weeds and for proper aeration of the soil helps in getting higher yields. At the time of first weeding, thinning should also be done to remove excess plants. Pea and beans were found to be the most suitable intercrops for cumin as they are leguminous crops which fix atmospheric N in soil and improves soil fertility status besides giving better returns per unit area. The other intercrops like cabbage, cauliflower, root crops or *Fagopyrum* spp. reduced the seed yield of cumin.

## Pest Management

**Wilt and Blight:** *T. harzianum* with neem cake as soil application reduced the incidence of wilt. Seed and soil treatment with *T. harzianum* was also found significantly effective for both wilt and blight diseases.

### 13.10. Clove

## Pest Management

**Seedling Wilt, Leaf Rot, *Cylindrocorpon quinqueseptatum*; Leaf Spot and Bud Shedding, *Colletotrichum gloeosporoides*:** Spraying with 1% Bordeaux mixture prevents the above diseases.

### 13.11. Fennel

**Nutrient Management:** The combined application of *Azospirillum* + FYM at 10 t/ha followed by *Azospirillum* + FYM at 5 t/ha gave maximum seed yield of fennel (Table 13.2).

**Table 13.2. Effect of manures and biofertilizers on the yield of fennel.**

Treatment	Seed yield (Q/ha)
Control	9.4
FYM at 5 t/ha	10.6
FYM at 10 t/ha	10.5
<i>Azospirillum</i>	9.6
<i>Azospirillum</i> + FYM at 5 t/ha	11.2
<i>Azospirillum</i> + FYM at 10 t/ha	11.5
CD at 5%	2.1

**Weed Management:** 3-4 weedings and hoeings before flowering are needed for good crop yield. Earthing up of plants at the time of weeding prevents lodging of the crop. First weeding and hoeing should be done at 30 DAP when plants are about 5 cm tall. The excess plants should be removed at this stage keeping plant to plant distance of 20 cm within the rows. One or two more weedings and hoeings may be required if there is further emergence of weeds or occurrence of crust formation.

**13.12. Saffron**

**Weed Management:** In the first year, hoeing just before flowering to a depth of 5-7.5 cm and in subsequent years, 3 hoeings and hand weeding in the beginning of August were found to be ideal for good growth and yield of saffron.

## Chapter 14

### TUBER CROPS

#### 14.1. Sweet Potato

**Nutrient Management:** Application of FYM/ compost at 10 t/ha is recommended.

##### **Pest Management**

**Weevil:** Crop rotation (Paddy – Sweet potato – Cowpea) can minimize weevil damage. Boemeryl acetate, a kairamone present in the periderm of sweet potato (*Coleus*) can attract both male and female weevils which offers immense scope for the management of weevils.

#### 14.2. Yam and Chinese Potato

**Nutrient Management:** Application of FYM/ compost at 50 t/ha is recommended.

##### **Pest Management**

**Root-Knot Nematode, *Meloidogyne* spp.:** The root-knot nematode can be controlled by growing sweet potato cv. Shree Bhadra as a trap crop.

#### 14.3. Taro

##### **Pest Management**

**Leaf Blight, *Phytophthora* sp:** Taro cvs. Jhankri and Muktakeshi are tolerant.

#### 14.4. Elephant Foot Yam

**Weed Management:** Removing weeds by manual method is the most common method of weed control in this crop. Intercropping with other root crops like sweet potato, colocasia and tapioca suppress the weeds.

#### Pest Management

**Storage rot, *Sclerotium rolfsii*:** *T. harzianum* was highly effective in suppressing *S. rolfsii* in elephant foot yam under field conditions. The conidial mixture of 2 bioagents *T. pseudokoningii* (effective in reducing the mycelial growth) and *T. virens* (good colonizer of sclerotia) was effective in reducing the incidence of storage rot. Application of *T. harzianum* as corm treatment + soil treatment after 30 DAP significantly managed the disease.

**IDM:** Use of virus-free seed material and mulching with paddy straw/polythene sheet reduce collar rot.

#### 14.5. Cassava and Yam

**Nutrient Management:** Application of FYM at 12.5 t/ha was beneficial in increasing the yields as well as maintaining the soil fertility. Coir pith, press mud, saw dust and spent mushroom composts were also equally effective and can substitute FYM.

**Weed Management:** 3-4 hand weedings minimize the reduction in yield due to weeds in maize/cassava and maize/cassava/yam intercropping systems. Early season weed suppression with the low growing 'Egusi' melon (*Citrullus lanatus*) followed by sweet potato gave yields of maize, cassava and yam equal to those from 3 hand weedings. This method of weed control also protects the soil from erosion in high rainfall areas. Intercropping with legumes (cowpea and black gram) reduced the weed intensity in cassava. Intercropping saved 77% of weeding cost, besides obtaining additional income. Intercropping with cowpea and 'Egusi' melon which suppressed weed growth gave highest economic returns under cassava.

Mulching with maize stalks, sugarcane leaves or *Stylosanthus* straw controlled weeds as did intercropped field beans. The reduction in cassava yield due to bean competition (20%) was offset by dry bean yield. Perennial legume green covers gave effective and long lasting weed control than mulches. Intercropping saved 77% of weeding cost, besides obtaining additional income.

## Pest Management

**Spiralling Whitefly, *Aleeurodicus dispersus*:** The field release of endoparasitoid, *Encarsia* sp. gave 69.53% parasitization during August and 76.22% during September. The predators like *Cybocephalus* sp., *Cryptolaemus montrouzieri* and *Mallada astur* can also be effectively used for the biocontrol of spiralling whitefly.

**Tuber Rot, *Phytophthora* sp., *Sclerotium rolfsii* and *Rhizoctonia* sp.:** The set treatment (30 g/litre for 15 min.) and soil application (1 kg/ha) of *Trichoderma viride* recorded the lowest tuber rot incidence (7.33%) and highest harvest index (66.9%).



## Chapter 15

# SOURCES OF CRITICAL INPUTS FOR ORGANIC FARMING

### 15.1. Organic Manures

**Table 15.1. Source of availability of organic manures.**

Organic manure	State	Source of availability
Agrimeal-Green Label (N-P-K: 7-10-0)	Karnataka	Agri Organics, Mysore
Agrimeal with Neem (N-P-K: 5-10-0)	Karnataka	Agri Organics, Mysore
Jeevan soil conditioner	Maharashtra	Kumar Krishimitra Bioproducts, Pune
Neem organic manure	Karnataka	Agro Extracts Ltd, Bangalore
Neemin	Maharashtra	Godrej Agrovat Ltd, Mumbai
Neemex – Neem cake organic manure	Maharashtra	Kumar Krishimitra Bioproducts, Pune
Nisarga (Enriched Vermicompost)	Karnataka	Vital Plant Products, Harihalli
Prajwala (100% organic manure + Biofertilizer)	Karnataka	Vital Plant Products, Harihalli
Vermicompost	Karnataka	Agri Technol Infmn Centre, IIHR, Bangalore
Vijnana (Neem-based organic manure)	Karnataka	Vital Plant Products, Harihalli
Wellgro	Andhra Pradesh	ITC Ltd, Rajahmundry.

## 15.2. Biofertilizers

**Table 15.2. Trade names and source of availability of biofertilizers**

Biofertilizers	Trade Names	Source of Availability
<i>Azotobacter</i> (N – fixing bacteria)	Bioplin, Vitromone, Milastin	<b>Karnataka:</b> Agri Technol Infmn Centre, IIHR, B'lore, <b>Maharashtra:</b> Kumar Krishimitra Bioproducts, Pune
<i>Azospirillum</i> (N-Fixing/ Stabilizing Bacteria)	Jeevakh – N, Jeevakh – N <sub>2</sub> , Tracospirillum, Symbion – N	<b>Karnataka:</b> Agri Technol Infmn Centre, IIHR, B'lore Travancore Org Fert Co P Ltd, Bangalore <b>Tamil Nadu:</b> T. Stanes & Co, Coimbatore
<i>Bacillus megaterium</i> / <i>Pseudomonas striata</i> / <i>Azotobacter</i> / <i>Bacillus</i> (P- Solubilizing Bacteria)	Jeevakh – P, Tracophos, Symbion – P, Phosfert ( <i>Azotobacter</i> + <i>Bacillus</i> ).	<b>Karnataka:</b> Agri Technol Infmn Centre, IIHR, B'lore Travancore Org Fert Co P Ltd, Bangalore <b>Maharashtra:</b> Kumar Krishi-mitra Bioproducts, Pune <b>Tamil Nadu:</b> T. Stanes & Co, Coimbatore
K- Mobilizing Bacteria	Jeevakh – K	<b>Karnataka:</b> Travancore Org Fert Co P Ltd, Bangalore

## 15.3. Arbuscular Mycorrhizal Fungi

**Table 15.3. Trade names and source of availability of Arbuscular Mycorrhizal Fungi**

Arbuscular Mycorrhizal Fungi	Trade Name	State	Source of Availability
<i>Glomus mosseae</i>	Symbion VAM	Karnataka	Agri Technol Infmn Centre, IIHR, B'lore
		Tamil Nadu	T. Stanes & Co, Coimbatore
<i>G. fasciculatum</i>	Symbion VAM	Karnataka	Agri Technol Infmn Centre, IIHR, B'lore
		Tamil Nadu	T. Stanes & Co, Coimbatore

## 15.4. Predators

**Table 15.4. Sources of availability of predators.**

Predators	State	Sources of availability
<i>Amblyseius</i> sp.	Tamil Nadu	Rajendra Foundn for Agri Res, Chittar
<i>Apertochrysa</i> sp.	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Blastostethus pallescens</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Brumoides suturalis</i>	Karnataka	Project Directorate of Biol Control, Bangalore Central IPM Centre, Bangalore
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
<i>Cardiastethus exiguous</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Cheilomenes sexmaculata</i>	Gujarat	Entomol Dept, Anand Agri Univ, Anand
	Karnataka	Project Directorate of Biol Control, Bangalore Central IPM Centre, Bangalore
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
<i>Chilocorus nigrita</i>	Himachal Pradesh	Central IPM Centre, Solan Ent Dept, Y S Parmar Univ of Hort & Forestry, Solan
	Jammu & Kashmir	Central IPM Centre, Jammu Central IPM Centre, Srinagar Entomol Dept, SK Univ Agri Sci & Technol, Srinagar
	Karnataka	Project Directorate of Biol Control, Bangalore Bio Control Res Lab, PCI Pvt Ltd, Bangalore
	Tamil Nadu	Rajendra Foundn for Agri Res, Chittar
	West Bengal	Central IPM Centre, Burdwan
<i>Chrysoperla carnea</i>	Andhra Pradesh	Central Tobaccco Res Inst, Rajahmundry Ent Dept, Acharya NG Ranga Agri Univ, Hyderabad Pest Control (India) Pvt Ltd, Hyderabad SOM-IPM Systems (I) Ltd, Hyderabad
	Assam	Pest Control (India) Pvt Ltd, Guwahati

Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
Gujarat	Entomol Dept, Anand Agri Univ, Anand Pest Control (India) Pvt Ltd, Vadodara
Haryana	Pest Control (India) Pvt Ltd, Chandigarh
Karnataka	Project Directorate of Biol Control, Bangalore Central IPM Centre, Bangalore Univ of Agri Sci, Entomol Dept, Dharwad Kadur Agro Pvt Ltd, Bangalore Pest Control (India) Pvt Ltd, Bangalore
Kerala	Pest Control (India) Pvt Ltd, Cochin
Madhya Pradesh	Indore Biotech Inputs & Res (P) Ltd, Indore Pest Control (India) Pvt Ltd, Bhopal
Maharashtra	Entomol Dept, Mahtma Phule Agri Univ, Rahuri Nathkrupa Biocontrol Lab, Nagpur Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane-400 601 Pest Control (India) Pvt Ltd, New Mumbai Pest Control (India) Pvt Ltd, Nashik-422 009 Pest Control (India) Pvt Ltd, Pune-411 033 Pest Control (India) Pvt Ltd, Pune-411 030
New Delhi	Biotech Intern Ltd, New Delhi Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Pest Control (India) Pvt Ltd, Jaipur
Tamil Nadu	Entomol Dept, TNAU, Madurai Basarass Biocontrol Res, Vallavar Greentech Agro Prod P Ltd, Coimbatore Pest Control (India) Pvt Ltd, Chennai Rajendra Foundn for Agri Res, Chittar TN Co-op Sugar Fedn Ltd, Chengalpattu
Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly

		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>Coccinella septumpunctata</i>	Tamil Nadu	Jeyppee Bio Techs, Virudhunagar
<i>Cryptolaemus montrouzieri</i>	Andhra Pradesh	Acharya N G Ranga Agri Univ, Hyderabad
		Pest Control (India) Pvt Ltd, Hyderabad
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Project Directorate of Biol Control, Bangalore
		Agri Technol Infmn Centre, IIHR, B'lore
		Kadur Agro Pvt Ltd, Bangalore
		Pest Control (India) Pvt Ltd, Bangalore
	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Central IPM Centre, Indore
		Indore Biotech Inputs & Res (P) Ltd, Indore
		Pest Control (India) Pvt Ltd, Bhopal
	Maharashtra	Pest Control (India) Pvt Ltd, Mumbai-63
		Pest Control (India) Pvt Ltd, Mumbai-400 005.
		Pest Control (India) Pvt Ltd, Thane
		Pest Control (India) Pvt Ltd, New Mumbai
		Pest Control (India) Pvt Ltd, Nashik
		Pest Control (India) Pvt Ltd, Pune-411 033
		Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
		Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
	Punjab	Pest Control (India) Pvt Ltd, Chandigarh
	Tamil Nadu	Basarass Biocontrol Res, Vallavar
		Greentech Agro Prod P Ltd, Coimbatore
		Pest Control (India) Pvt Ltd, Chennai
		Rajendra Foundn for Agri Res, Chittar

		Shri Durga Agro Services, Coimbatore
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly
		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>Curinus coeruleus</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Mallada</i> spp.	Gujarat	Entomol Dept, Anand Agri Univ, Anand
	Karnataka	Project Directorate of Biol Control, Bangalore
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
	Punjab	Entomol Dept, Punjab Agri Univ, Ludhiana
<i>M. astur</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>M. boninensis</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Orius tantillus</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Parena nigrolineata</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Pharoscymnus horni</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Scymnus coccivora</i>	Karnataka	Project Directorate of Biol Control, Bangalore

### 15.5. Parasitoids

**Table 15.5. Sources of availability of parasitoids.**

Parasitoids	State	Sources of availability
<i>Apanteles angaleti</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Maharashtra	Entomol Dept, Agri College, Pune
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
<i>Botryoideclava bharatiya</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Brachymeria nosatoi</i>	Andhra Pradesh	Ent Dept, Acharya NG Ranga Agri Univ, Hyderabad
	Karnataka	Central IPM Centre, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam
<i>B. nephantidis</i>	Andhra Pradesh	Ent Dept, Acharya NG Ranga Agri Univ, Hyderabad
	Karnataka	Project Directorate of Biol Control, Bangalore

		Central IPM Centre, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam
<i>Bracon brevicornis</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi Pest Control (India) Pvt Ltd, New Delhi
	Tamil Nadu	Central IPM Centre, Tiruchirapalli Basarass Biocontrol Res, Vallavar Rajendra Foundn for Agri Res, Chittar TN Coconut Parasite Breeding Centre, Coimbatore TN Co-op Sugar Fedn Ltd, Chengalpattu
<i>B. hebetor</i>	Andhra Pradesh	Ent Dept, Acharya N G Ranga Agri Univ, Hyderabad
	Karnataka	Project Directorate of Biol Control, Bangalore Central IPM Centre, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam
	Maharashtra	Entomol Dept, Agri College, Pune Nathkrupa Biocontrol Lab, Nagpur
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
	Tamil Nadu	Jeypee Bio Techs, Virudhunagar Rajendra Foundn for Agri Res, Chittar Sakthi Biocontrol & Biofert Centre, Kallipatti Gobi
<i>B. kirkpatricki</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam
<i>Campoletis chloridae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Cephalonomia stephanoderis</i>	Gujarat	Entomol Dept, Anand Agri Univ, Anand
	Karnataka	Coffee Research Sub Station, Chethalli
	Kerala	Entomol Dept, Kerala Agri Univ, Trichur
	Maharashtra	Central Inst of Cotton Res, Nagpur
	Tamil Nadu	Regional Coffee Res Stn, Thandigudi Centre for Pl Prot Studies, TNAU, Coimbatore
<i>Chelonus blackburni</i>	Karnataka	Project Directorate of Biol Control, Bangalore

<i>Coccidoxenoides peregrinus</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Copidosoma koehleri</i>	Bihar & Jarkhand	Central IPM Centre, Patna
	Karnataka	Project Directorate of Biol Control, Bangalore
	Maharashtra	Entomol Dept, Mahtma Phule Agri Univ, Rahuri
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
<i>Cotesia flaviceps</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Orissa	Central IPM Centre, Bhubaneswar
	Punjab	Entomol Dept, Punjab Agri Univ, Ludhiana
	Tamil Nadu	Divn of Pl Prot, SBI, Coimbatore
	Uttar Pradesh	Entomol Divn, IISR, Lucknow
<i>C. plutellae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>C. africanus</i>	Andhra Pradesh	Central Tobacco Res Inst, Rajahmundry
	Karnataka	Project Directorate of Biol Control, Bangalore
	Maharashtra	Central IPM Centre, Nagpur
<i>Dipha aphidivora</i>	Karnataka	Agri Res Stn, UAS, Bheemarayanagudi
<i>Elasmus nephantidis</i>	Andhra Pradesh	Ent Dept, Acharya N G Ranga Agri Univ, Hyderabad
	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam
	Tamil Nadu	Basarass Biocontrol Res, Vallavar
<i>Encarsia spp.</i>	Himachal Pradesh	Central IPM Centre, Solan
	Jammu & Khasmir	Entomol Dept, SK Univ Agri & Technol, Srinagar
	Karnataka	Central IPM Centre, Bangalore
<i>Encarsia guadeloupae</i>	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore
<i>Epiricania melanoleuca</i>	Maharashtra	Vasanthdada Sugar Institute, Pune
	Tamil Nadu	Central IPM Centre, Tiruchirapalli Rajendra Foundn for Agri Res, Chittar



	Uttar Pradesh	Entomol Divn, IISR, Lucknow Central IPM Centre, Gorakhpur
<i>Eriborus argenteopilosus</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Goniozus nephantidis</i>	Andhra Pradesh	Ent Dept, Acharya N G Ranga Agri Univ, Hyderabad
	Karnataka	Project Directorate of Biol Control, Bangalore Pest Control (India) Pvt Ltd, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam
	Tamil Nadu	Central IPM Centre, Tiruchirapalli Greentech Agro Prod P Ltd, Coimbatore Rajendra Foundn for Agri Res, Chittar TN Coconut Parasite Breeding Centre, Coimbatore
<i>Leptomastix dactylopii</i>	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore Entomol Divn, Central Coffee Res Inst, Chikmagalur
	Kerala	Entomol Dept, Kerala Agri Univ, Trichur
	Tamil Nadu	Greentech Agro Prod P Ltd, Coimbatore
<i>Micromus igarotus</i>	Karnataka	Regional Res Stn, UAS, Raichur
<i>Oomyzus sokolowskii</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Sturmiopsis inferens</i>	Karnataka	Agri Technol Infmn Centre, IIHR, Bangalore
<i>Telenomus</i> spp.	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. remus</i>	Andhra Pradesh	Central Tobacco Res Inst, Rajahmundry
	Karnataka	Project Directorate of Biol Control, Bangalore
	Madhya Pradesh	Central IPM Centre, Indore
<i>Tetrastichus howardi</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. israeli</i>	Gujarat	Entomol Dept, Anand Agri Univ, Anand
	Karnataka	Project Directorate of Biol Control, Bangalore Central IPM Centre, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam

	Tamil Nadu	Jeyppee Bio Techs, Virudhunagar Rajendra Foundn for Agri Res, Chittar TN Coconut Parasite Breeding Centre, Coimbatore
<i>Trichogramma achaeae</i>	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore Central IPM Centre, Bangalore
	Punjab	Entomol Dept, Punjab Agri Univ, Ludhiana
	Tamil Nadu	Rajendra Foundn for Agri Res, Chittar Shri Durga Agro Services, Coimbatore Sun Agro Ind India, Chennai
<i>T. brasiliensis</i>	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore
	Tamil Nadu	Greentech Agro Prod. P. Ltd, Coimbatore Rajendra Foundn. for Agri. Res., Chittor.
<i>T. chilonis,</i> <i>T. japonicum</i>	Andhra Pradesh	Central Tobaccco Res Inst, Rajahmundry Ent Dept, Acharya N G Ranga Agri Univ, Hyderabad Pest Control (India) Pvt Ltd, Hyderabad SOM-IPM Systems (I) Ltd, Hyderabad
	Assam	State Biocontrol Laboratory, Guwahati Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Goa	Central IPM Centre, Madgaon
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Entomol Dept, CCS Haryana Agri Univ, Hisar Regional Agri Centre, CCSHAU, Karnal State Biocontrol Laboratory, Sirsa Biocontrol Laboratory, Yamuna Nagar
	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore Central IPM Centre, Bangalore Entomol. Dept, Univ of Agri Sci, Dharwad Inst of Pulses & Oilseeds Res, Gulbarga Regional Res Stn, UAS, Raichur

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	AAO, Parasite Laboratory, Bailhongal
	AO, Parasite Laboratory, Gangavathi
	AAO, Parasite Laboratory, Mandya
	Bio Solujan, Bangalore
	Hospet Sugar Mills, Hospet
	Kadur Agro Pvt Ltd, Bangalore
	Karnataka Agri Res Foundn, Sameerwadi
	Pest Control (India) Pvt Ltd, Bangalore
Kerala	Pest Control (India) Pvt Ltd, Cochin
Madhya Pradesh	Indore Biotech Inputs & Res (Pvt) Ltd, Indore
	Pest Control (India) Pvt Ltd, Bhopal
Maharashtra	Central Inst of Cotton Res, Nagpur
	Entomol Dept, Mahtma Phule Agri Univ, Rahuri
	Entomol Dept, Marathwada Agri Univ, Parbhani
	Entomol Dept, Konkan Agri Univ, Dapoli
	KNS Biotech, Nanded
	Nathkrupa Biocontrol Lab, Nagpur
	Pest Control (India) Pvt Ltd, Mumbai-400 063
	Pest Control (India) Pvt Ltd, Mumbai-400 059
	Pest Control (India) Pvt Ltd, Thane-400 601
	Pest Control (India) Pvt Ltd, New Mumbai
	Pest Control (India) Pvt Ltd, Nashik-422 009
	Pest Control (India) Pvt Ltd, Pune-411 030
	Pest Control (India) Pvt Ltd, Pune-411 033
	R.S. Kherdekar, Talpathri
	Sandoz (I) Ltd, Mumbai
New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
	Biotech Intern Ltd, New Delhi
	Navdanya (NGO), New Delhi
	Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Biocontrol Lab, ARS, RAU, Sri Ganganagar
	JDA (PI Path), Biocontrol Lab, Durgapura
	DDA (Agro), IPM Lab, Ajmeer
	DDA (Agro), IPM Lab, Malikpur
	DDA (Agro), IPM Lab, Rampura

	DDA (Agro), IPM Lab, Cjatrapura
	DDA (Agro), IPM Lab, Chittorgarh
	DDA (Agro), IPM Lab, Hanumangarh
	DDA (Pl Path), IPM Lab, Banaswara
	Adarsh Biocontrol Laboratories, Alwar
	Pest Control (India) Pvt Ltd, Jaipur
Tamil Nadu	Divn of Pl Prot, SBI, Coimbatore
	Regional Coffeee Res Stn, Thandigudi
	Bio-control Lab., Papparapatty
	Bio-control Lab, Coimbatore
	Bio-control Lab., Salem
	Bio-control Lab, Villupuram
	Bio-control Lab., Trichy
	Bio-control Lab., Panjupettai
	Bio-control Lab., Kuruppanaichenpalyam
	Bio-control Lab., Vinayagapuram
	Bio-control Lab., Tirunelveli
	Bio-control Lab., Tanjavur
	Bio-control Lab., Namakkal
	Agro Res Lab, Coimbatore
	Basarass Biocontrol Res, Vallavar
	Biocontrol Res Centre, Kootham Poondi
	Greentech Agro Prod P Ltd, Coimbatore
	Jeypee Bio Techs, Virudhunagar
	Main Biocontrol Res Lab, Chengalpattu
	Pest Control (India) Pvt Ltd, Chennai
	Rajendra Foundn for Agri Res, Chittar
	Sakthi Biocontrol & Biofert Centre, Kallipatti
	Gobi
	Shri Durga Agro Services, Coimbatore
	Sinagro Industries India, Chennai
	Sun Agro Ind India, Chennai
	Vigneswara Biocontrol, Pollachi
Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
Uttar Pradesh	Entomol Divn, IISR, Lucknow
	Biocontrol Lab, SBBP Agri Univ, Meerut
	Bioved Res Soc, Allahabad
	Crop Health Bioprod Res Centre, Ghaziabad

		Pest Control (India) Pvt Ltd, Bareilly
		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>T. dendrolimi</i>	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore
	Tamil Nadu	Rajendra Foundn for Agri Res, Chittar
<i>T. embryophagum</i>	Himachal Pradesh	Central IPM Centre, Solan Ent Dept, Y S Paramar Univ of Hort & Forestry, Solan
	Jammu & Khasmir	Central IPM Centre, Jammu Central IPM Centre, Srinagar Entomol Dept, SK Univ Agri Sci & Technol, Srinagar
<i>T. evanescens</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Himachal Pradesh	Central IPM Centre, Solan Y S Parmar Univ of Hort & Forestry, Solan
	Jammu & Khasmir	Central IPM Centre, Jammu Central IPM Centre, Srinagar Entomol Dept, SK Univ Agri & Technol, Srinagar
<i>T. maidis</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. pretiosum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Himachal Pradesh	Central IPM Centre, Solan Ent Dept, Y S Paramar Univ of Hort & Forestry, Solan
	Jammu & Khasmir	Central IPM Centre, Jammu Central IPM Centre, Srinagar Entomol Dept, SK Univ Agri Sci & Technol, Srinagar
<i>Trichogrammatoidea armigera</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. bactrae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Trichospilus pupivorus</i>	Karnataka	Central IPM Centre, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam

<i>Xanthopimpla punctata</i>	Karnataka	Project Directorate of Biol Control, Bangalore Central IPM Centre, Bangalore
	Kerala	CPCRI Regional Station, Kayangulam

## 15.6. Pathogens

### 15.6.1. Antagonistic Fungi Against Plant Diseases and Nematodes

**Table 15.6. Trade names and sources of availability of antagonistic fungi against plant Diseases and nematodes.**

Antagonistic Fungi / State Trade Name		Source of Availability
<i>Ampelomyces quisqualis</i> (Bio-Dewcon)	Tamil Nadu	T. Stanes & Co, Coimbatore
<i>Arthrobotrys cladodes</i> var. <i>macroides</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Arthrobotrys oligospora</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Aspergillus nizer</i> (Kalisena SD, Kalisena SL, Sanjeevni)	Gujarat	Cadila Pharmaceuticals Ltd, Ahmedabad
	New Delhi	Plant Path Divn, Indian Agri Res Inst, New Delhi
<i>Dactylella brochophaga</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Fusarium oxysporum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Fusarium sporotrichoides</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Gliocladium catenulatum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>G. deliquescens</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>G. roseum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Phoma glomerata</i>	Karnataka	Project Directorate of Biol Control, Bangalore

<i>Pochonia chlamydosporia</i> (Bionema)	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore Central Sericultural Res & Trng Inst, Mysore
<i>Paecilomyces lilacinus</i> ( Bio-Nemator, Biocon, Niyrantran, Multiplex Sparsha, Abtec Paecilomyces)	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore
<i>T. aureoviride</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. hamatum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. harzianum</i> (Binab-T, Ecoderma, F-Stop, Supravit, Tricodex, Trichoderma)	Andhra Pradesh	ADA (BCL), P.M. Palem ADA (BCL), Kakinada ADA (BCL), Nidadavole ADA (BCL), Ibrahimpatnam ADA (BCL), Ongole ADA (BCL), Nellore DDA (FTC), Nandyal ADA (BCL), Anantapur DDA (FTC), Rajendranagar ADA (Oilseeds) (BCL), Mahabubnagar ADA (BCL), Nalagonda ADA (BCL), Mulugu Road ADA (BCL), Karimnagar ADA (BCL), Adilabad Pest Control (India) Pvt Ltd, Hyderabad
	Assam	State Biocontrol Laboratory, Guwahati Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara
	Haryana	State Biocontrol Laboratory, Sirsa Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Project Directorate of Biol Control, Bangalore

	Agri Technol Infmn Centre, IIHR, Bangalore
	Central IPM Centre, Bangalore
	Central Sericultural Res & Trng Inst, Mysore
	Coffeee Research Sub Station, Chethalli
	Central Coffee Res Inst, Entomol Divn., Chikmagalur
	Univ of Agri Sci, Entomol Dept, Dharwad
	Inst of Pulses & Oilseeds Res, Gulbarga
	Regional Res Stn, UAS, Raichur
	Agri Res Stn, UAS, Bijapur
	Kadur Agro Pvt Ltd, Bangalore
	Pest Control (India) Pvt Ltd, Bangalore
	P.J. Margo Pvt Ltd, Bangalore
Kerala	Travancore Organic Fertilizers, Kottayam
	VRM Biotech Products, Changanacherry
Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal
Maharashtra	Bio Era Technologies, Nagpur
	Hoechst Schering Agr. Envt, Mumbai
	KNS Biotech, Nanded
	Nathkrupa Biocontrol Lab, Nagpur
	Om Agro Organics, Yavatmal
	Pest Control (India) Pvt Ltd, Mumbai-63
	Pest Control (India) Pvt Ltd, Mumbai-59
	Pest Control (India) Pvt Ltd, Thane
	Pest Control (India) Pvt Ltd, New Mumbai
	Pest Control (India) Pvt Ltd, Nashik
	Pest Control (India) Pvt Ltd, Pune-411 033
	Pest Control (India) Pvt Ltd, Pune-411 030
	Sanvardhini Agro Pvt Ltd, Satara
	Soman Biofertilizers, Pune
	Vidyas Biotech Lab, Nagpur
	West Coast Herbochem P Ltd, Mumbai
New Delhi	Biotech Intern Ltd, New Delhi
	Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar



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Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Biocontrol Lab, ARS, RAU, Sri Ganganagar JDA (Pl Path), Biocontrol Lab, Durgapura DDA (Agro), IPM Lab, Ajmeer DDA (Agro), IPM Lab, Malikpur DDA (Agro), IPM Lab, Rampura DDA (Agro), IPM Lab, Cjjatrapura DDA (Agro), 1 IPM Lab, Chittorgarh DDA (Agro), IPM Lab, Hanumangarh DDA (Pl Path), IPM Lab, Banaswara Pest Control (India) Pvt Ltd, Jaipur
Tamil Nadu	Centre for Pl Prot Studies, TNAU, Coimbatore Bio-control Lab, Papparaipatty Bio-control Lab, Coimbatore Bio-control Lab, Salem Bio-control Lab, Villupuram Bio-control Lab, Trichy Bio-control Lab, Panjupettai Bio-control Lab, Kuruppanaichenpalyam Bio-control Lab, Vinayagapuram Bio-control Lab, Tirunelveli Bio-control Lab, Tanjavur Bio-control Lab, Namakkal Basarass Biocontrol Res, Vallavar Greentech Agro Prod P Ltd, Coimbatore Jeyppee Bio Techs, Virudhunagar Pest Control (India) Pvt Ltd, Chennai Rajendra Foundn for Agri Res, Chittar Shri Durga Agro Services, Coimbatore Shrishti Bioprod P Ltd, Coimbatore Sun Agro Ind India, Chennai TN Co-op Sugar Fedn Ltd, Chengalpattu TAP Industries, Chennai
Uttarakhand	Pl Path Dept, GB Pant Uni Agri & Technol, Pantnagar Pest Control (India) Pvt Ltd, Dehradun

	Uttar Pradesh	Crop Health Bioprod Res Centre, Ghaziabad Pest Control (India) Pvt Ltd, Bareilly Pest Control (India) Pvt Ltd, Lucknow Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>T. koningii</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. longibactriatum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. polysporum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. pseudokoningii</i> (Nursery Guard)	Karnataka	Project Directorate of Biol Control, Bangalore Central Sericultural Res & Trng Inst, Mysore
<i>T. virens</i> (Gligard, WRC-GV)	Karnataka	Project Directorate of Biol Control, Bangalore
<i>T. viride</i> (Bio-Cure, Bio-Cure F, Agroderma, Antogon TV, Bioderma, Dermapak, Ecofit, Monitor, Multiplex Nisarga, Rakshak, Trichosan, Trichoft, Trichoderm, Trichonik, Tricho-X, Trichodermin)	Andhra Pradesh	ADA (BCL), P.M. Palem ADA (BCL), Kakinada ADA (BCL), Nidadavole ADA (BCL), Ibrahimpatnam ADA (BCL), Ongole ADA (BCL), Nellore DDA (FTC), Nandyal ADA (BCL), Anantapur DDA (FTC), Rajendranagar ADA (Oilseeds) (BCL), Mahabubnagar ADA (BCL), Nalagonda ADA (BCL), Mulugu Road ADA (BCL), Karimnagar ADA (BCL), Adilabad Pest Control (India) Pvt Ltd, Hyderabad
	Assam	State Biocontrol Laboratory, Guwahati Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara

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Haryana	State Biocontrol Laboratory, Sirsa Pest Control (India) Pvt Ltd, Chandigarh
Karnataka	Project Directorate of Biol Control, Bangalore Coffee Research Sub Station, Chethalli Central Coffee Res Inst, Entomol Divn, Chikmagalur Kadur Agro Pvt Ltd, Bangalore Pest Control (India) Pvt Ltd, Bangalore P.J. Margo Pvt Ltd, Bangalore Travancore Org Fert Co P Ltd, Bangalore
Kerala	Travancore Organic Fertilizers, Kottayam VRM Biotech Products, Changanacherry
Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal
Maharashtra	Bio Era Technologies, Nagpur Hoechst Schering Agr. Env't, Mumbai KNS Biotech, Nanded Nathkrupa Biocontrol Lab, Nagpur Om Agro Organics, Yavatmal Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane Pest Control (India) Pvt Ltd, New Mumbai Pest Control (India) Pvt Ltd, Nashik Pest Control (India) Pvt Ltd, Pune-411 033 Pest Control (India) Pvt Ltd, Pune-411 030 Sanvardhini Agro Pvt Ltd, Satara Soman Biofertilizers, Pune Vidyas Biotech Lab, Nagpur West Coast Herbochem P Ltd, Mumbai
New Delhi	Biotech Intern Ltd, New Delhi Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Biocontrol Lab, ARS, RAU, Sri Ganganagar JDA (Pl Path), Biocontrol Lab, Durgapura DDA (Agro), IPM Lab, Ajmeer

	DDA (Agro), IPM Lab, Malikpur
	DDA (Agro), IPM Lab, Rampura
	DDA (Agro), IPM Lab, Cjjatrapura
	DDA (Agro), 1 IPM Lab, Chittorgarh
	DDA (Agro), IPM Lab, Hanumangarh
	DDA (Pl Path), IPM Lab, Banaswara
	Pest Control (India) Pvt Ltd, Jaipur
Tamil Nadu	Centre for Pl Prot Studies, TNAU, Coimbatore
	Bio-control Lab, Papparapatty
	Bio-control Lab, Coimbatore
	Bio-control Lab, Salem
	Bio-control Lab, Villupuram
	Bio-control Lab, Trichy
	Bio-control Lab, Panjupettai
	Bio-control Lab, Kuruppanaichenpalyam
	Bio-control Lab, Vinayagapuram
	Bio-control Lab, Tirunelveli
	Bio-control Lab, Tanjavur
	Bio-control Lab, Namakkal
	Basarass Biocontrol Res, Vallavar
	Greentech Agro Prod P Ltd, Coimbatore
	Jeypee Bio Techs, Virudhunagar
	Pest Control (India) Pvt Ltd, Chennai
	Rajendra Foundn for Agri Res, Chittar
	Shri Durga Agro Services, Coimbatore
	Shrishti Bioprod P Ltd, Coimbatore
	Sun Agro Ind India, Chennai
	TN Co-op Sugar Fedn Ltd, Chengalpattu
	TAP Industries, Chennai
	T. Stanes & Co, Coimbatore
Uttarakhand	Pl Path Dept, GBPant Univ Agri & Technol, Pantnagar
	Pest Control (India) Pvt Ltd, Dehradun
Uttar Pradesh	Crop Health Bioprod Res Centre, Ghaziabad
	Pest Control (India) Pvt Ltd, Bareilly
	Pest Control (India) Pvt Ltd, Lucknow
	Pest Control (India) Pvt Ltd, Kanpur

	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>Verticillium lecanii</i>	Karnataka	Project Directorate of Biol Control, Bangalore
		Pest Control (India) Pvt Ltd, Bangalore
	Maharashtra	Sio Agro Research Lab, Mumbai
	Tamil Nadu	Sakthi Biocontrol & Biofert Centre, Kallipatti Gobi
<i>V. suchlosporium</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Arthrobotrys</i> sp. + <i>P</i> <i>lilacinus</i> + <i>Verticillium</i> sp. (Nemastin)	Maharashtra	Kumar Krishimitra Bioproducts, Pune
<i>T. harzianum</i> + <i>T.</i> <i>viride</i> (Ecoderma, NIPROT)	Karnataka	Bio Control Res Lab, PCI P Ltd, Bangalore PJ Margo Pvt Ltd, Bangalore
<i>T. harzianum</i> + <i>T.</i> <i>viride</i> + <i>T. virens</i> (Combat)	Maharashtra	Kumar Krishimitra Bioproducts, Pune

### 15.6.2. Entomopathogenic Fungi

**Table 15.7. Trade names and sources of availability of entomopathogenic fungi against insect pests**

Entomopathogenic Fungi	State	Source of Availability
<i>Beauveria bassiana</i> (Bio-Power, Tracobeas, Dispel, Larvocel, Don Muscardin, BABA, Abtech Beauveria)	Karnataka	Project Directorate of Biol Control, Bangalore Entomol Dept, Univ of Agri Sci, Dharwad Travancore Org Fert Co P Ltd, Bangalore
	Maharashtra	Vidyas Biotech Lab, Nagpur
	New Delhi	Defence Inst of Physiol, New Delhi Navdanya (NGO), New Delhi
	Rajasthan	Pesticides India Ltd, Udaipur
	Tamil Nadu	Divn of Pl Prot, SBI, Coimbatore Basarass Biocontrol Res, Vallavar Greentech Agro Prod P Ltd, Coimbatore

		Jeypee Bio Techs, Virudhunagar Rajshree Sugars & Chem Ltd, Varadaraj Nagar Shri Durga Agro Services, Coimbatore T. Stanes & Co, Coimbatore
<i>Botryodiplodia theobromae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Fusarium coccophilum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>F. moniliformae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>F. roseum</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Metarrhizium anisopliae</i> (Bio-Magic)	Gujarat	Entomol Dept, Anand Agri Univ, Anand
	Karnataka	Project Directorate of Biol Control, Bangalore Entomol Dept, Univ of Agri Sci, Dharwad
	Kerala	CPCRI Regional Station, Kayangulam
	Maharashtra	Bio Era Technologies, Nagpur National Biocontrol Laboratory, Nagpur
	New Delhi	Biotech Intern Ltd, New Delhi Navdanya (NGO), New Delhi
	Tamil Nadu	Divn of Pl Prot, SBI, Coimbatore Basarass Biocontrol Res, Vallavar Biocontrol Res Centre, Kootham Poondi Rajendra Foundn for Agri Res, Chittar Shri Durga Agro Services, Coimbatore
<i>Nomuraea rileyi</i>	Andhra Pradesh	Directorate of Oil Seeds Res, Hyderabad
	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore Entomol Dept, Univ of Agri Sci, Dharwad
<i>Paecilomyces fumos-roseus</i> (Priority)	Tamil Nadu	Jeypee Bio Techs, Virudhunagar T. Stanes & Co, Coimbatore
<i>Scopulariopsis brevicaulis</i>	Karnataka	Project Directorate of Biol Control, Bangalore

<i>Verticillium lecanii</i> (Bio-Catch, Tracovet, Verticel, Varsha, Abtech Verticillium)	Karnataka	Project Directorate of Biol Control, Bangalore Entomol Dept, Univ of Agri Sci, Dharwad Agri Res Stn, UAS, Bijapur Travancore Org Fert Co P Ltd, Bangalore
	Maharashtra	Wockhardt Ltd, Mumbai
	Tamil Nadu	T. Stanes & Co, Coimbatore

### 15.6.3. Bacterial Biopesticides

**Table 15.8. Trade names and sources of availability of bacterial biopesticides**

Bacterial Biopesticides/ Trade Names	State	Source of Availability
<i>B. sphaericus</i>	New Delhi	Biotech Intern Ltd, New Delhi
	Tamil Nadu	Sinagro Industries India, Chennai
<i>B. subtilis</i> (Kill Dew DP Epic, Kodiak)	Maharashtra	Kumar Krishimitra Bioproducts, Pune
<i>B. thuringiensis</i> var. <i>kurstaki</i> (Biolep, Biosap, Delfin, Dipel, Bibot, Spicturin, Halt)	Andhra Pradesh	Indian Inst of Chem Technol, Hyderabad
	Madhya Pradesh	Indore Biotech Inputs & Res (Pvt) Ltd, Indore
	Maharashtra	Lupin Laboratories (I) P Ltd, Mumbai Sandoz (I) Ltd, Mumbai Wockhardt Ltd, Mumbai
	New Delhi	Biotech Intern Ltd, New Delhi Hindustan Insecticides, New Delhi
	Tamil Nadu	Tuticorn Alkali Chem & Fert Ltd, Chennai
	Assam	State Biocontrol Laboratory, Guwahati
<i>Pseudomonas fluorescens</i> (Bio-Cure B, Bioshield, Tracomonas, Sudocel, Dagger-G)	Haryana	State Biocontrol Laboratory, Sirsa
	Karnataka	Agri Technol Infmn Centre, IIHR, Bangalore Travancore Org Fert Co P Ltd, Bangalore

Kerala	Plantrich Chem & Fert Ltd, Kottayam
New Delhi	Biotech Intern Ltd, New Delhi
Tamil Nadu	Bio-control Lab, Papparaipatty
	Bio-control Lab, Coimbatore
	Bio-control Lab, Salem
	Bio-control Lab, Villupuram
	Bio-control Lab, Trichy
	Bio-control Lab, Panjupettai
	Bio-control Lab, Kuruppanaichenpalyam
	Bio-control Lab, Vinayagapuram
	Bio-control Lab, Tirunelveli
	Bio-control Lab, Tanjavur
	Bio-control Lab, Namakkal
	Basarass Biocontrol Res, Vallavar
	Greentech Agro Prod P Ltd, Coimbatore
	Jeypee Bio Techs, Virudhunagar
	Rajendra Foundn for Agri Res, Chittar
	Sun Agro Ind India, Chennai
	T. Stanes & Co, Coimbatore

#### 15.6.4. Entomopathogenic Viruses

**Table 15.9. Trade names and sources of availability of entomopathogenic viruses**

Entomopathogenic Viruses / Trade Name/s	State	Source of Availability
<i>Ha</i> NPV of <i>Helicoverpa armigera</i> (Helivax, Heliokill, Helicide, Helinash, Heliocel)	Andhra Pradesh	ADA (BCL), P.M. Palem
		ADA (BCL), Kakinada
		ADA (BCL), Nidadavole
		ADA (BCL), Ibrahimpatnam
		ADA (BCL), Ongole
		ADA (BCL), Nellore
		DDA (FTC), Nandyal
		ADA (BCL), Anantapur
		DDA (FTC), Rajendranagar
		ADA (Oilseeds) (BCL), Mahabubnagar



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	ADA (BCL), Nalagonda
	ADA (BCL), Mulugu Road
	ADA (BCL), Karimnagar
	ADA (BCL), Adilabad
	Kamal Herbal & Pheromone Exp (P) Ltd, Hyderabad
	Pest Control (India) Pvt Ltd, Hyderabad
	Sneha Biotech, Vijayawada
Assam	State Biocontrol Laboratory, Guwahati
	Pest Control (India) Pvt Ltd, Guwahati
Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
Gujarat	Pest Control (India) Pvt Ltd, Vadodara
Karnataka	Project Directorate of Biol Control, Bangalore
	Agri Technol Infmn Centre, IIHR, Bangalore
	Entomol Dept, Univ of Agri Sci, Dharwad
	Inst of Pulses & Oilseeds Res, Gulbarga
	Regional Res Stn, UAS, Raichur
	Agri Res Stn, UAS, Bheemarayanagudi
	Bio-Pest Management P Ltd, Bangalore
	Cee Kay Associates, Bangalore
	Innovative Pest Control Lab, Bangalore
	Kadur Agro Pvt Ltd, Bangalore
	Pest Control (India) Pvt Ltd, Bangalore
	P.J.Margo Pvt Ltd, Bangalore
Kerala	Pest Control (India) Pvt Ltd, Cochin
Madhya Pradesh	Indore Biotech Inputs & Res (Pvt) Ltd, Indore
	Pest Control (India) Pvt Ltd, Bhopal
	Samridi Bioculture Pvt Ltd, Indore
Maharashtra	Central Inst of Cotton Res, Nagpur
	Entomol Dept, Mahtma Phule Agri Univ, Rahuri
	Entomol Dept, Marathwada Agri Univ, Parbhani
	Entomol Dept, Punjabrao Desmukh Agri Univ, Akola

	Entomol Dept, Konkan Agri Univ, Dapoli
	Ajay Biotech Lab (P) Ltd, Pune
	Anand Biocontrol Lab, Jalgaon
	Ankur Seeds Pvt Ltd, Ratnagiri
	Arag Biotech, Nagpur
	Bio Era Technologies, Nagpur
	Chintawar Biocontrol Lab, Yeotmal
	Harit Biocontrol Laboratories, Yeotmal
	JR Biocontrol Lab, Yeotmal
	KNS Biotech, Nanded
	Nathkrupa Biocontrol Lab, Nagpur
	National Biocontrol Laboratory, Nagpur
	Pest Control (India) Pvt Ltd, Mumbai-63
	Pest Control (India) Pvt Ltd, Mumbai-59
	Pest Control (India) Pvt Ltd, Thane
	Pest Control (India) Pvt Ltd, New Mumbai
	Pest Control (India) Pvt Ltd, Nashik
	Pest Control (India) Pvt Ltd, Pune-411 033
	Pest Control (India) Pvt Ltd, Pune-411 030
	Sanvardhini Agro Pvt Ltd, Satara
	Tirupati Agro Inputs, Latur
	Universal Biotech, Nagpur
New Delhi	Biotech Intern Ltd, New Delhi
	JK Traders, Delhi
	Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Chandigarh
Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Biocontrol Lab, ARS, RAU, Sri Ganganagar
	Adarsh Biocontrol Laboratories, Alwar
	Pest Control (India) Pvt Ltd, Jaipur
Tamil Nadu	Centre for Pl Prot Studies, TNAU, Coimbatore
	Entomol Dept, TNAU, Madurai
	Bio-control Lab, Papparapatty
	Bio-control Lab, Coimbatore
	Bio-control Lab, Salem

		Bio-control Lab, Villupuram
		Bio-control Lab, Trichy
		Bio-control Lab, Panjupettai
		Bio-control Lab, Kuruppanaichenpalyam
		Bio-control Lab, Vinayagapuram
		Bio-control Lab, Tirunelveli
		Bio-control Lab, Tanjavur
		Bio-control Lab, Namakkal
		Basarass Biocontrol Res, Vallavar
		Greentech Agro Prod P Ltd, Coimbatore
		Jeypee Bio Techs, Virudhunagar
		Pest Control (India) Pvt Ltd, Chennai
		Rajendra Foundn for Agri Res, Chittar
		Shri Durga Agro Services, Coimbatore
		Spinco Biotech Pvt Ltd, Chennai
		Sun Agro Ind India, Chennai
		T. Stanes & Co, Coimbatore
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Biocontrol Lab, SBBP Agri Univ, Meerut
		Crop Health Bioprod Res Centre, Ghaziabad
		Pest Control (India) Pvt Ltd, Bareilly
		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>Sl</i> NPV of <i>Spodoptera</i> <i>litura</i> (Spodvax, Spodokill, Spodonash)	Andhra Pradesh	Central Tobacco Res Inst, Rajahmundry
		ADA (BCL), P.M. Palem
		ADA (BCL), Kakinada
		ADA (BCL), Nidadavole
		ADA (BCL), Ibrahimpatnam
		ADA (BCL), Ongole
		ADA (BCL), Nellore
		DDA (FTC), Nandyal
		ADA (BCL), Anantapur
		DDA (FTC), Rajendranagar
		ADA (Oilseeds) (BCL), Mahabubnagar
		ADA (BCL), Nalagonda

	ADA (BCL), Mulugu Road
	ADA (BCL), Karimnagar
	ADA (BCL), Adilabad
	Kamal Herbal & Pheromone Exp (P) Ltd, Hyderabad
	Pest Control (India) Pvt Ltd, Hyderabad
Assam	Pest Control (India) Pvt Ltd, Guwahati
Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
Gujarat	Pest Control (India) Pvt Ltd, Vadodara
Karnataka	Project Directorate of Biol Control, Bangalore
	Agri Technol Infmm Centre, IIHR, Bangalore
	Entomol Dept, Univ of Agri Sci, Dharwad
	Regional Res Stn, UAS, Raichur
	Bio-Pest Management Pvt Ltd, Bangalore
	Pest Control (India) Pvt Ltd, Bangalore
Kerala	Pest Control (India) Pvt Ltd, Cochin
Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal
Maharashtra	National Biocontrol Laboratory, Nagpur
	Pest Control (India) Pvt Ltd, Mumbai-63
	Pest Control (India) Pvt Ltd, Mumbai-59
	Pest Control (India) Pvt Ltd, Thane-400 601
	Pest Control (India) Pvt Ltd, New Mumbai
	Pest Control (India) Pvt Ltd, Nashik-9
	Pest Control (India) Pvt Ltd, Pune-411 030
	Pest Control (India) Pvt Ltd, Pune-411 033
New Delhi	Biotech Intern Ltd, New Delhi
	Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Biocontrol Lab, ARS, RAU, Sri Ganganagar
	Adarsh Biocontrol Laboratories, Alwar
	Pest Control (India) Pvt Ltd, Jaipur
Tamil Nadu	Centre for Pl Prot Studies, TNAU, Coimbatore
	Entomol Dept, TNAU, Madurai

	Basarass Biocontrol Res, Vallavar
	Jeypee Bio Techs, Virudhunagar
	Pest Control (India) Pvt Ltd, Chennai
	Shri Durga Agro Services, Coimbatore
	Sun Agro Ind India, Chennai
Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly
	Pest Control (India) Pvt Ltd, Lucknow
	Pest Control (India) Pvt Ltd, Kanpur
West Bengal	Pest Control (India) Pvt Ltd, Kolkata

### 15.6.5. Entomopathogenic Nematodes

**Table 15.10. Trade names and sources of availability of entomopathogenic nematodes.**

Entomopathogenic Nematodes/ Trade Name/s	State	Source of Availability
<i>Heterorhabditis</i> spp. (Green Cammandos)	Karnataka	Project Directorate of Biol Control, Bangalore
	Maharashtra	Bio Sense Crop Protecion, Mumbai
<i>Steinernema</i> spp. (Soil Commandos)	Karnataka	Project Directorate of Biol Control, Bangalore
	Maharashtra	Bio Sense Crop Protecion, Mumbai

### 15.7. Pheromones

**Table 15.11. Source of availability of pheromones of horticultural crop pests.**

Pheromone	State	Sourece of Availability
<b>Fruit crop pests</b>		
Oriental fruit moth	Maharashtra	Agri Sense BCS, Mumbai
		Bio Sense Crop Protecion, Mumbai
Gypsy moth	Maharashtra	Bio Sense Crop Protecion, Mumbai
Codling moth	Maharashtra	Agri Sense BCS, Mumbai
		Bio Sense Crop Protecion, Mumbai

San jose scale	Maharashtra	Agri Sense BCS, Mumbai
Apple leaf roller	Maharashtra	Agri Sense BCS, Mumbai
Apple fruit miner	Maharashtra	Agri Sense BCS, Mumbai
Red banded leaf roller	Maharashtra	Agri Sense BCS, Mumbai
Pear leaf roller	Maharashtra	Agri Sense BCS, Mumbai
Peach tree borer	Maharashtra	Agri Sense BCS, Mumbai
Peach twig borer	Maharashtra	Agri Sense BCS, Mumbai
Grape torteix	Maharashtra	Agri Sense BCS, Mumbai
Mediterranean fruit fly	Maharashtra	Agri Sense BCS, Mumbai
California red scale	Maharashtra	Agri Sense BCS, Mumbai

### Vegetable crop pests

Brinjal fruit and shoot borer, <i>Leucinodes orbonalis</i>	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad Pheromone Chemicals, Tenali
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Pest Control (India) Pvt Ltd, Bangalore
	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal Samridi Bioculture Pvt Ltd, Indore
	Maharashtra	Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane Pest Control (India) Pvt Ltd, New Mumbai Pest Control (India) Pvt Ltd, Nashik Pest Control (India) Pvt Ltd, Pune-411 033 Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Biotech Intern Ltd, New Delhi Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
	Punjab	Pest Control (India) Pvt Ltd, Chandigarh

Diamondback moth, <i>Plutella xylostella</i>	Rajasthan	Pesticides India Ltd, Udaipur
	Tamil Nadu	Basarass Biocontrol Res, Vallavar Pest Control (India) Pvt Ltd, Chennai
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly
		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Ganesh Biocontrol System, Gondal
		Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Pest Control (India) Pvt Ltd, Bangalore
		PJ Margo Pvt Ltd, Bangalore
	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal
	Maharashtra	Bio Era Technologies, Nagpur
		Pest Control (India) Pvt Ltd, Mumbai-63
		Pest Control (India) Pvt Ltd, Mumbai-59
		Pest Control (India) Pvt Ltd, Thane-400 601
		Pest Control (India) Pvt Ltd, New Mumbai
		Pest Control (India) Pvt Ltd, Nashik-422 009
		Pest Control (India) Pvt Ltd, Pune-411 033
		Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Biotech Intern Ltd, New Delhi
		Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
	Punjab	Pest Control (India) Pvt Ltd, Chandigarh
	Rajasthan	Pesticides India Ltd, Udaipur
	Tamil Nadu	Pest Control (India) Pvt Ltd, Chennai
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun

Melon fly, <i>Bactrocera cucurbitae</i> ; Fruit fly, <i>Bactrocera dorsalis</i>	Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly Pest Control (India) Pvt Ltd, Lucknow Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Pest Control (India) Pvt Ltd, Bangalore PJ Margo Pvt Ltd, Bangalore
	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal
	Maharashtra	Bio Era Technologies, Nagpur Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane-400 601 Pest Control (India) Pvt Ltd, New Mumbai Pest Control (India) Pvt Ltd, Nashik-422 009 Pest Control (India) Pvt Ltd, Pune-411 033 Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
	Punjab	Pest Control (India) Pvt Ltd, Chandigarh
	Rajasthan	Pesticides India Ltd, Udaipur
	Tamil Nadu	Pest Control (India) Pvt Ltd, Chennai
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly Pest Control (India) Pvt Ltd, Lucknow Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
	Maharashtra	Agri Sense BCS, Mumbai
Sweet potato weevil		



Beet web worm	Maharashtra	Agri Sense BCS, Mumbai
Turnip moth	Maharashtra	Agri Sense BCS, Mumbai
Pea moth	Maharashtra	Agri Sense BCS, Mumbai
Soybean looper	Maharashtra	Agri Sense BCS, Mumbai
Sugar beet moth	Maharashtra	Agri Sense BCS, Mumbai
Tomato semilooper	Maharashtra	Agri Sense BCS, Mumbai
Potato tuber moth	Maharashtra	Agri Sense BCS, Mumbai Bio Sense Crop Protecion, Mumbai
<i>Agrotis</i> sp.	Maharashtra	Agri Sense BCS, Mumbai
<i>Helicoverpa armigera</i>	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad Pheromone Chemicals, Tenali ITC Ltd, Hyderabad Kamal Herbal & Pheromone Exp (P) Ltd, Pest Control (India) Pvt Ltd, Hyderabad
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Ganesh Biocontrol System, Gondal Pest Control (India) Pvt Ltd, Vadodara
	Karnataka	Bio Control Res Lab, PCI Pvt Ltd, Bangalore Monofix Agro Products Ltd, Hubli Murkumbi Bio Agro P Ltd, Belgaum Pest Control (India) Pvt Ltd, Bangalore P.J.Margo Pvt Ltd, Bangalore
	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Indore Biotech Inputs & Res (Pvt) Ltd, Indore Pest Control (India) Pvt Ltd, Bhopal
	Maharashtra	Bio Era Technologies, Nagpur Eco-Max Agrosystems Ltd, Mumbai Indofil Chemical Co., Mumbai Lupin Laboratories (I) P Ltd, Mumbai National Organic Chem Ind Ltd, Mumbai Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane

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		Pest Control (India) Pvt Ltd, New Mumbai
		Pest Control (India) Pvt Ltd, Nashik
		Pest Control (India) Pvt Ltd, Pune-411 033
		Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Biotech Intern Ltd, New Delhi
		Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Annapurna Sci Ind, Bhubaneswar
	Rajasthan	Adarsh Biocontrol Laboratories, Alwar
		Pesticides India Ltd, Udaipur
	Tamil Nadu	Basarass Biocontrol Res, Vallavar
		Centre for Agrochem Res, SPIC, Chennai
		Ecobiocides & Botanicals Pvt Ltd, Theni
		EID Parry (I) Ltd, Bioprod Divn, Chennai
		Elbitec Innovations Ltd, Chennai
		Greentech Agro Prod P Ltd, Coimbatore
		Jeyppee Bio Techs, Virudhunagar
		Pest Control (India) Pvt Ltd, Chennai
		Spinco Biotech Pvt Ltd, Chennai
		Tuticorn Alkali Chem & Fert Ltd, Chennai
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Amitul Agro Chem Pvt Ltd, Gorakhpur
		Pest Control (India) Pvt Ltd, Bareilly
		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
<i>Spodoptera litura</i>	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad
		Pheromone Chemicals, Tenali
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Ganesh Biocontrol System, Gondal
		Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Pest Control (India) Pvt Ltd, Bangalore
		PJ Margo Pvt Ltd, Bangalore

<i>Earias vitella</i>	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Indore Biotech Inputs & Res (Pvt) Ltd, Indore Pest Control (India) Pvt Ltd, Bhopal
	Maharashtra	Bio Era Technologies, Nagpur Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane-400 601 Pest Control (India) Pvt Ltd, New Mumbai Pest Control (India) Pvt Ltd, Nashik-422 009 Pest Control (India) Pvt Ltd, Pune-411 033 Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Biotech Intern Ltd, New Delhi Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
	Punjab	Pest Control (India) Pvt Ltd, Chandigarh
	Rajasthan	Pesticides India Ltd, Udaipur
	Tamil Nadu	Basarass Biocontrol Res, Vallavar Centre for Agrochem Res, SPIC, Chennai Greentech Agro Prod P Ltd, Coimbatore
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly Pest Control (India) Pvt Ltd, Lucknow Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad Pheromone Chemicals, Tenali
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Agriland Biotech Limited, Baroda Ganesh Biocontrol System, Gondal Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Pest Control (India) Pvt Ltd, Bangalore PJ Margo Pvt Ltd, Bangalore

	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal
	Maharashtra	Bio Era Technologies, Nagpur
		Pest Control (India) Pvt Ltd, Mumbai-63
		Pest Control (India) Pvt Ltd, Mumbai-59
		Pest Control (India) Pvt Ltd, Thane
		Pest Control (India) Pvt Ltd, New Mumbai
		Pest Control (India) Pvt Ltd, Nashik
		Pest Control (India) Pvt Ltd, Pune-411 033
		Pest Control (India) Pvt Ltd, Pune-411 030
	New Delhi	Biotech Intern Ltd, New Delhi
		Pest Control (India) Pvt Ltd, New Delhi
	Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
	Punjab	Pest Control (India) Pvt Ltd, Chandigarh
	Rajasthan	Pesticides India Ltd, Udaipur
	Tamil Nadu	Basarass Biocontrol Res, Vallavar
		Jeypee Bio Techs, Virudhunagar
	Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
	Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly
		Pest Control (India) Pvt Ltd, Lucknow
		Pest Control (India) Pvt Ltd, Kanpur
	West Bengal	Pest Control (India) Pvt Ltd, Kolkata
White grub	New Delhi	JK Traders, Delhi

### Plantation crop pests

Red palm weevil, <i>Rhynchophorus</i> <i>ferrugineus</i>	Andhra Pradesh	Pest Control (India) Pvt Ltd, Hyderabad
	Assam	Pest Control (India) Pvt Ltd, Guwahati
	Bihar & Jarkhand	Pest Control (India) Pvt Ltd, Jamshedpur
	Gujarat	Pest Control (India) Pvt Ltd, Vadodara
	Haryana	Pest Control (India) Pvt Ltd, Chandigarh
	Karnataka	Pest Control (India) Pvt Ltd, Bangalore
	Kerala	Pest Control (India) Pvt Ltd, Cochin
	Madhya Pradesh	Pest Control (India) Pvt Ltd, Bhopal

Maharashtra	Pest Control (India) Pvt Ltd, Mumbai-63 Pest Control (India) Pvt Ltd, Mumbai-59 Pest Control (India) Pvt Ltd, Thane-400 601 Pest Control (India) Pvt Ltd, New Mumbai Pest Control (India) Pvt Ltd, Nashik-422 009 Pest Control (India) Pvt Ltd, Pune-411 033 Pest Control (India) Pvt Ltd, Pune-411 030
New Delhi	Pest Control (India) Pvt Ltd, New Delhi
Orissa	Pest Control (India) Pvt Ltd, Bhubaneswar
Punjab	Pest Control (India) Pvt Ltd, Chandigarh
Rajasthan	Pesticides India Ltd, Udaipur
Tamil Nadu	Pest Control (India) Pvt Ltd, Chennai
Uttarakhand	Pest Control (India) Pvt Ltd, Dehradun
Uttar Pradesh	Pest Control (India) Pvt Ltd, Bareilly Pest Control (India) Pvt Ltd, Lucknow Pest Control (India) Pvt Ltd, Kanpur
West Bengal	Pest Control (India) Pvt Ltd, Kolkata

## 15.8. Weed Killer Agents (Insects and Fungi)

**Table 15.12. Source of availability of weed insects**

Weed Killer Insects	State	Source of Availability
<i>Cyrtobagous salviniae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
	Kerala	State Biocontrol Lab, Mannuthy
<i>Neochetina bruchi</i>	Andhra Pradesh	Indian Inst of Chem Technol, Hyderabad
	Assam	Assam Agri Univ, Jorhat
	Bihar & Jarkhand	Central IPM Centre, Patna
	Chattisgarh	Central IPM Centre, Raipur
	Gujarat	Central IPM Centre, Baroda
	Haryana	Regional Agri Centre, CCSHAU, Karnal
	Karnataka	Project Directorate of Biol Control, Bangalore Agri Technol Infmn Centre, IIHR, Bangalore Central IPM Centre, Bangalore

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	Kerala	Central IPM Centre, Ernakulam
	West Bengal	Central IPM Centre, Burdwan
<i>N. eichhorniae</i>	Andhra Pradesh	Central IPM Centre, Hyderabad
		Central IPM Centre, Vijayawada
		Indian Inst of Chem Technol, Hyderabad
	Assam	Assam Agri Univ, Jorhat
	Bihar & Jarkhand	Central IPM Centre, Patna
	Gujarat	Central IPM Centre, Baroda
	Haryana	Regional Agri Centre, CCSHAU, Karnal
	Karnataka	Project Directorate of Biol Control, Bangalore
		Agri Technol Infmn Centre, IIHR, Bangalore
		Central IPM Centre, Bangalore
	Kerala	Central IPM Centre, Ernakulam
	Rajasthan	Central IPM Centre, Sriganganagar
	Tamil Nadu	Regional Coffeee Res Stn, Thandigudi
	West Bengal	Central IPM Centre, Burdwan
<i>Orthogalumna terebrantis</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Zygogramma bicolorata</i>	Andhra Pradesh	Central IPM Centre, Hyderabad
		Ent Dept, Acharya N G Ranga Agri Univ, H'bad
	Karnataka	Project Directorate of Biol Control, Bangalore
		Agri Technol Infmn Centre, IIHR, Bangalore
		Central IPM Centre, Bangalore
		Biol Control Res Lab, PCI Pvt Ltd, Bangalore
	Kerala	Central IPM Centre, Ernakulam
		Entomol Dept, Kerala Agri Univ, Trichur
	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
	Tamil Nadu	Regional Coffeee Res Stn, Thandigudi
		Entomol Dept, TNAU, Madurai
		Rajendra Foundn for Agri Res, Chittar
		Shri Durga Agro Services, Coimbatore

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**Table 15.13. Fungi against weeds**

<b>Fungi</b>	<b>State</b>	<b>Source of Availability</b>
<i>Alternaria eichhorniae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Botryodiplodia theobromae</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Nigrospora spherica</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>Phoma chrysanthemicola</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>P. eupyrena</i>	Karnataka	Project Directorate of Biol Control, Bangalore
<i>P. glomerata</i>	Karnataka	Project Directorate of Biol Control, Bangalore

### 15.9. Neem-based and other Botanicals

**Table 15.14. Source of availability of neem – based and other botanicals**

<b>Neem-Based and other Botanicals</b>	<b>State</b>	<b>Source of Availability</b>
Achook	Maharashtra	Bahar Agrochemicals, Ratnagiri Mahagrapes, Pune
Aphidin	Maharashtra	Eco-Max Agrosystems Ltd, Mumbai
Avana	Tamil Nadu	EID Parry (I) Ltd, Bioprod Divn, Chennai
Aza	Andhra Pradesh	SOM-IPM Systems (I) Ltd, Hyderabad
Azadit	Rajasthan	Pesticides India Ltd, Udaipur
Biogold	Tamil Nadu	SPIC, Bio-Tech Divn, Chennai
Bioneem	Maharashtra	Ajay Biotech Lab (P) Ltd, Pune
Bionema	Uttar Pradesh	Bioved Res Soc, Allahabad
Biopest	Uttar Pradesh	Bioved Res Soc, Allahabad
Biosol	Tamil Nadu	A.V. Thomas Pvt Ltd, Chennai
Eco-Neem	Karnataka	Murkumbi Bio Agro P Ltd, Belgaum Pest Control (India) Pvt Ltd, Bangalore
Eco-Neem Plus	Karnataka	Murkumbi Bio Agro P Ltd, Belgaum Pest Control (India) Pvt Ltd, Bangalore
Ecotin	Karnataka	Monarch Biofert & Res Centre, Bangalore
Field Marshal	Gujarat	Ganesh Biocontrol System, Gondal
Fortuna Aza	Andhra Pradesh	Fortune Bio-tech Limited, Secunderabad

Jai Neem	Haryana	Jai Chemicals, Faridabad
Jawan	Maharashtra	Mc DA Agro Pvt Ltd, Mumbai
Jeevan Crop Protector	Maharashtra	Mc DA Agro Pvt Ltd, Mumbai
Juerken	Tamil Nadu	Madurai Chem & Agro Ind Ltd, Madurai
Limonool	Karnataka	Bio-Multi Tech Pvt Ltd, Bangalore
Margocide-CK	Karnataka	Monofix Agro Products Ltd, Hubli
Margosan-O	Karnataka	Monofix Agro Products Ltd, Hubli
Neemactin	Maharashtra	Wockhardt Ltd, Mumbai
Neemak	Karnataka	West Coast Herbochem P Ltd, Bangalore
	Maharashtra	West Coast Herbochem P Ltd, Mumbai
Neemarin	New Delhi	Biotech Intern Ltd, New Delhi
Neemark	Karnataka	West Coast Herbochem P Ltd, Bangalore
Neemasol	Tamil Nadu	EID Parry (I) Ltd, Pesticides Divn, Chennai
Neemax	Maharashtra	Eco-Max Agrosystems Ltd, Mumbai
Neemazal-F	Tamil Nadu	EID Parry (I) Ltd, Bioprod Divn, Chennai
Neemazal-T/S	Tamil Nadu	EID Parry (I) Ltd, Bioprod Divn, Chennai
Neemocide	West Bengal	Vinayak Fats & Proteins P Ltd, Kolkata
Neemol	Andhra Pradesh	Ramson Laboratories, Vijayawada
	Tamil Nadu	Agro Links, Trichy
Neemolin	Maharashtra	Khatau Agro Tech, Mumbai
Neemosan	Tamil Nadu	Agronule Industries, Trichy
Neemox	Maharashtra	Prakash Farm Chemicals, Mumbai
Neempourn	Tamil Nadu	Prabhakar Oil Mills, Trichy
Neemta	Gujarat	A.J. Chemicals, Ahmedabad
Neethrin	Uttar Pradesh	Amitul Agro Chem Pvt Ltd, Gorakhpur
Neem Base	New Delhi	Agrochem Divn, Indian Agri Res Inst, New Delhi
Neem Based pesticides	Maharashtra	Bahar Agrochemicals, Ratnagiri
		KNS Biotech, Nanded
		Om Agro Organics, Yavatmal
	Tamil Nadu	Ecobiocides & Botanicals Pvt Ltd, Theni
		Jeyppee Bio Techs, Virudhunagar



Neem Cake	Uttarakhand	Sri Ram Solvent Extraction Plant, Jaspur
Neem Gold	Tamil Nadu	EID Parry (I) Ltd, Bioprod Divn, Chennai SPIC, Bio-Tech Divn, Chennai
Neem Guard	Maharashtra	Gharda Chemicals Pvt Ltd, Mumbai
Neem Hit	Maharashtra	Skylark Agro Chemicals, Thane
Neem Oil	Karnataka	Agro Extracts Ltd, Bangalore
	Maharashtra	Mc DA Agro Pvt Ltd, Mumbai National Organic Chem Ind Ltd, Mumbai Sio Agro Research Lab, Mumbai
	Uttarakhand	Sri Ram Solvent Extraction Plant, Jaspur
Neem Plus	Maharashtra	BD Keathen & Co., Mumbai
Neem Rich	Maharashtra	National Chem Lab, Pune
Neem seed	Maharashtra	Cheminova Agro-Tech, Nandubar
Neem Soap	Karnataka	Agri Technol Infmn Centre, IIHR, Bangalore
Neem Top	Tamil Nadu	Sri Krishna Co, Coimbatore
Nim-76	New Delhi	Defence Inst of Physiol, New Delhi
Nimba	New Delhi	Entomol Divn, Indian Agri Res Inst, New Delhi
Nimbasal	New Delhi	Nimba Foods & Agrochem, New Delhi Pesto-Chem India Ltd, New Delhi
Nimbicidine	Tamil Nadu	T Stanes & Co, Coimbatore
Nimbitor	Maharashtra	Zandu Pharmaceutical Works, Mumbai
Nimbosol	Tamil Nadu	Victoria Laboratories, Salem
Nimitox	Karnataka	Rallis India Ltd, Bangalore
Nimlin	Maharashtra	Sunline Agro Chem P Ltd, Dhulia
Nimbo Bas	Tamil Nadu	Basarass Biocontrol Res, Vallavar
Ozoneem	Haryana	Ozone Biotech, Faridabad
Phytowin	Tamil Nadu	Phyto Products Ltd, Thiruthuripoondi
Pongamia oil based biopesticide	Tamil Nadu	Jeypee Bio Techs, Virudhunagar
Pongamia Soap	Karnataka	Agri Technol Infmn Centre, IIHR, Bangalore
Rakshak	Karnataka	Murkumbi Bio Agro P Ltd, Belgaum PJ Margo Pvt Ltd, Bangalore
RD-9 Repellin	Andhra Pradesh	ITC Ltd, Hyderabad
Replin 555	Tamil Nadu	Micro Chemicals Ltd, Madurai

Shaktiman	Gujarat	Khetiwadi Corner, Vadodara Krishna Biotech Pvt Ltd, Veravel Oceon Agro India Ltd, Baroda
Sukrina	Tamil Nadu	Canster Chemicals Ltd, Chennai
Suneem	Maharashtra	Sunida Exports Ltd, Mumbai
Swaticure	Maharashtra	Swathi Industries Ltd, Mumbai
Tric	Uttar Pradesh	Amitul Agro Chem Pvt Ltd, Gorakhpur
Tricure	Karnataka	Murkumbi Bio Agro P Ltd, Belgaum PJ Margo Pvt Ltd, Bangalore
Vapacide	Andhra Pradesh	Indian Inst of Chem Technol, Hyderabad

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## **15.10. Full addresses of Sources of Critical Organic Inputs**

### ***15.10.1. Andaman & Nicobar Islands***

#### **Central Government Organizations**

Central Integrated Pest Management Centre, Opp. Govt. Primary School, Dignabad, Port Blair-744 104.

### ***15.10.2. Andhra Pradesh***

#### **ICAR Institutes**

Central Tobacco Research Institute (CTRI), Rajahmundry-533 105, E-mail: root@ctri.ap.nic.in

Directorate of Oilseed Research (DOR), Rajendra Nagar, Hyderabad – 560 030.

#### **Central Government Organizations**

Central Integrated Pest Management Centre, 6-3-655/2/1, Civil Supplies Bhavan Lane, Somajiguda, Hyderabad-500 482.

Central Integrated Pest Management Centre, Suryapet, Kaleswar Rao Road, Vijayawada-520 002.

Indian Institute of Chemical Technology (IICT), Uppal Road, Hyderabad-500 007.

#### **State Agricultural Universities**

Department of Entomology, Acharya N.G. Ranga Agricultural University (ANGRAU), Rajendranagar, Hyderabad-500 030. Phone: 040-245035, Fax: 245031.

**State Government Organizations**

ADA (BCL), P.M. Palem, Visakhapatnam District, Phone: 0891-2781283, Fax: 0891-2504139.

ADA (BCL), Kakinada, East Godhavari District, Phone: 0884-378794, Fax: 0884-2384238.

ADA (BCL), Nidadavole, West Godhavari District, Phone: 08812-222794, Fax: 08812-244014.

ADA (BCL), Ibrahimpatnam, Krishna District, Phone: 08672-2881968, Fax: 08672-252483.

ADA (BCL), Ongole, Prakasham District, Phone: 08592-233126, Fax: 08592-280046.

ADA (BCL), Nellore, Nellore District, Phone: 0861-2326655, Fax: 0862307132.

DDA (FTC), Nandyal, Kurnool District, Phone: 08518-248090, Fax: 08518-277754.

ADA (BCL), Anantapur, Anantapur District, Phone: 08554-231743, Fax: 08554-275984.

DDA (FTC), Rajendranagar, Rangareddy District, Phone: 040-24015188, Fax: 044-24547507.

ADA (Oilseeds) (BCL), Mahabubnagar, Mahabubnagar District, Phone: 08542-242624, Fax: 08542-242398/242203.

ADA (BCL), Nalagonda, Nalagonda District, Phone: 08682-244560, Fax: 08682-232981.

ADA (BCL), ARS Campus, Mulugu Road, Warangal District, Phone: 0870-2543433, Fax: 0870-2511100.

ADA (BCL), Karimnagar, Karimnagar District, Phone: 0878-262161, Fax: 0878-2240343.

ADA (BCL), Adilabad, Adilabad District, Phone: 08732-226454, Fax: 08732-227311.

**Private Organizations**

Biotech Agri Sciences, 105, FF, Plot No. 99, 5-5-35/149, Prashanthinagar, IDA, Kukatpalli, Hyderabad-500 872.

Fortune Bio-tech Limited, 14, Ishaq Colony, 108, Bazar Road, Secunderabad-500 051, Phone: 040-819000, 841519, Fax: 040-843945.

ITC Ltd, ILTD Division, IBD 6-3-1110, Amrutha Hall, Begumpet, Hyderabad-500 016.

ITC Ltd, ILTD Division, Rajahmundry-533 105, East Godhavari District.

Kamal Herbal & Pheromone Export (Pvt.) Ltd., 11, Arpitha Apartments, Snehapuri Colony, Macharam, Hyderabad-500 076.

Pest Control (India) Pvt. Ltd., Flat No. 213, Bhanu Enclave, Sanjeeva Reddy Nagar, Hyderabad-500 038. Phone: 040-2381 3851, 2370 1411, Fax: 040-2370 4305, E-mail: hyderabad@pcil.co.in (Contact person: Mr. S. Srinivasa Reddy, Mobile: 31017824).

Pheromone Chemicals, 404, Arpita Heights, HMT Nagar, Nacharam, Hyderabad-500 076. Phone: 040-27176019.

Pheromone Chemicals, Chinnaravur Post, Tenali –Guntur.

Pragathi Biofertilizers, No. 6, Red Lands, Dargamitta, Nellore-524 003.

Pralshar Bio Products Pvt. Ltd., B-3, Industrial Estate, Vijayawada-520 007.

Ramson Laboratories, 29-14-53, Prakasam Road, Vijayawada-520 002.

SAM Agritech Ltd, 1-37-44, Sappers Lines, Balaram Rai, Secunderabad-500 003.

Shakti Biotech (Pvt) Ltd., 75-7-6/3, Nagarjuna Street, Bhawanipuram, Vijayawada-520 012.

Sneha Biotech, P.B. NO. 702, MG Road, Labbipet, Vijayawada-520 010.

SOM-IPM Systems (India) Ltd., 7-1-80/202, Kemson Apartments, Ameerpet, Hyderabad-500 016, E-mail: somphyto/Hyderabad@dartmaildartnet.com

Sovereign Fertilizers & Chemicals Pvt. Ltd., Plot No. 6, Block 38, IDA Autonagar, Guntur-522 001.

Sri Biotech, 112, Sree Arcade, Bata Complex, Erragadda, Hyderabad-500 018.

Varsha Bioscience & Technology, 17-1-382/PN/1/2, MNR Garden, Balajinagar, Champapet, Saidabad, Hyderabad-500 059.

Vermigreen Biofertilizers, 5-36, Prashanthinagar, Kukatpally Industrial Estate, Hyderabad-500 037.

Viswamithra Bio-agro (Pvt.) Ltd., H.No. 334/A, Tatireddy Palem, Lam (P.O.), Guntur-522 034.

### **15.10.3. Assam**

#### **Central Government Organizations**

Central Integrated Pest Management Centre, Gautam Complex, R.G. Baruah Road, Guwahati-781 003.

## **State Agricultural Universities**

Assam Agricultural University (AAU), Jorhat-785 003.

## **State Government Organizations**

State Biocontrol Laboratory, C/O Director of Agriculture, Ulubari, Guwahati-781 007, Phone: 0361-2332215, Fax: 0361-2332796, E-mail: [assamagri@sify.com](mailto:assamagri@sify.com)

## **Private Organizations**

Pest Control (India) Pvt. Ltd., Latasil Lamb Road, Behind Nice Tele Services, Guwahati-781 001, Phone: 0361-263 1230, E-mail: [bedanta.baruah@pcil.co.in](mailto:bedanta.baruah@pcil.co.in) (Contact person: Mr. Bedanta Baruah, Mobile: 98640 54187).

### ***15.10.4. Bihar & Jharkhand***

## **Central Government Organizations**

Central Integrated Pest Management Centre, New Punai Chawk, Near Dutta's House, Patna-800 023.

## **Private Organizations**

Pest Control (India) Pvt. Ltd., "Madhukunj", 3<sup>rd</sup> Floor, Q Road, Bistupur, Jamshedpur-831 001, Phone: 0657-242 3158, 228 8580, Fax: 0657-242 3158, E-mail: [kailash.sharma@pcil.co.in](mailto:kailash.sharma@pcil.co.in) (Contact person: Mr. Kailash Sharma, Mobile: 3105493).

### ***15.10.5. Chattisgarh***

## **Central Government Organizations**

Central Integrated Pest Management Centre, C-60, Sailendra Nagar, Raipur-492 001.

## **Private Organizations**

Farm Consultant, 29/86, Lily Chawk, Purani Basti, Raipur-492 001.

### ***15.10.6. Goa***

## **Central Government Organizations**

Central Integrated Pest Management Centre, Lakshmi Mahal, Kepe Road, Madgaon-403 601.

**Private Organizations**

Zuari Industries Ltd., Jai Kisaan Bhawan, Zaurinagar, Goa-403 726.

**15.10.7. Gujarat****Central Government Organizations**

Central Integrated Pest Management Centre, 57, Alkapuri Society, Post Office Building, Baroda.

**State Agricultural Universities**

Department of Entomology, Anand Agricultural University (AAU), Anand-388 110. Phone: 02692-21666, Fax: 02692-41270, 41520.

**Private Organizations**

Agriland Biotech Limited, F-29, Sugam Park-II, Hotel Airport, Raarni Road, Baroda-390 022, Phone: 0265-2541193. E-mail: info@agrilandbiotech.com

A.J. Chemicals, Kisan Brothers Pvt. Ltd., New Cloth Market, Ahmedabad-380 002.

Cadila Pharmaceuticals Ltd., Ahmedabad.

Ganesh Biocontrol System, Ganesh Chamber, Gondala Road, Gondal-360 311. Phone: 02825-221610, 228912, E-mail: ganeshbiocontrol@yahoo.com

Khetiwadi Corner, Shiyabave, Vadodara-390 001.

Krishna Biotech Pvt. Ltd., 8-B, National Highway, Veravel-360 002, Rajkot District.

Kisan Brothers Pvt. Ltd., 311 New Cloth Market, Ahmedabad-380 002.

Oceon Agro India Ltd., Baroda.

Pest Control (India) Pvt. Ltd., 118-119, VIP View, VIP Road, Karelibaug, Vadodara-390 018, Phone: 0265-236 3546, 236 1027, Fax: 0265-236 1027, E-mail: vadodara\_branch@pcil.co.in (Contact person: Mr.Y. Ramprasad, Mobile: 3132536).

**15.10.8. Haryana****Central Government Organizations**

Central Integrated Pest Management Centre, Machinery Stores Building, NH-4, Faridabad-121 001.

## **State Agricultural Universities**

Department of Entomology, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), College of Agriculture, Hisar-125 004.

Regional Agricultural Centre, CCSHAU, Uchchani, Karnal.

## **State Government Organizations**

State Biocontrol Laboratory, Sirsa, Phone: 01662-226572, Fax: 01662-225713.

## **Private Organizations**

Anu Biotech International, Tigaon Road, Faridabad-121 002.

Biocontrol Laboratory, Saraswati Sugar Mill, Yamuna Nagar.

Jai Chemicals, 14/1, Mathura Road, Faridabad-121 003.

Ozone Biotech, Plot No. 6, Site No. 2, Rajdhani Land and Finance, 14/3 Mathura Road, Faridabad-121 001. Phone: 0129-5047602, Fax: 0129-5047604. E-mail: ozonebiotech@rediffmail.com

Pest Control (India) Pvt. Ltd., SCO No. 9, Cabin No. 5 (Basement), Sector-26, Madhya Marg, Chandigarh-160 019. Phone: 0172-2790230, E-mail: psd\_chandigarh@pcil.co.in (Contact person: Mr. Sunil Awasti, Mobile: 0141 312 2470)

Rescholar Equipments, 85, HSIDC, Industrial Estate, Ambala Cant-133 006.

### ***15.10.9. Himachal Pradesh***

## **Central Government Organizations**

Central Integrated Pest Management Centre, Abhinandan Bhawan, Power House Road, Saproon, Solan-173 211.

## **State Agricultural Universities**

Department of Entomology, Y.S. Parmar University of Horticulture & Forestry (YSPUH&F), Solan.

### ***15.10.10. Jammu & Kashmir***

## **Central Government Organizations**

Central Integrated Pest Management Centre, 73 8/B, Gandhinagar, Jammu.

Central Integrated Pest Management Centre, Pampori Manzil, Rajbagh, Srinagar-190 008.

### **State Agricultural Universities**

Department of Entomology, S.K. University of Agriculture & Technology, Srinagar-191 001. Phone: 0194-734559, 750922.

#### **15.10.11. Karnataka**

### **ICAR Intitutes**

Agricultural Technology Information Centre (ATIC), Indian Institute of Horticultural Research (IIHR), Hessaraghatta Lake, Bangalore-560 089.

Project Directotote of Biological Control (PDBC), P.B.No. 2491, H.A. Farm Post, Bellary Road, Bangalore-560 024.

### **Central Government Organizations**

Central Integrated Pest Management Centre, Whitefield, Bangalore.

Central Sericultural Research and Training Institute (CSR&TI), Mysore-570 008.

Coffee Research Sub Station, Coffee Board, Chethalli-571 248, Kodagu District, Phone: 08276-266726, 266292, E-mail: ddcrrs@sancharnet.in

Central Coffee Research Institute (CCRI), Divn. of Entomology/ Nematology, Coffee Research Station-577 117, Chikmagalur District, Phone: 08265-543112, Fax: 08265-543 143, E-mail: crsento@yahoo.com

Central Coffee Research Institute (CCRI), Divn. of Plant Pathology, Coffee Research Station-577 117, Chikmagalur District, Phone: 08265-543008, Fax: 08265-543143, E-mail: crsento@yahoo.com

### **State Agricultural Universities**

Department of Agricultural Entomology, University of Agricultural Sciences (UAS), Krishinagar, Dharwad-580 005.

Institute of Pulses & Oilseeds Research, Aland Road, University of Agricultural Sciences, Gulbarga-581 101.

Agricultural Research Station (ARS), UAS, Bheemarayanagudi.



Agricultural Research Station (ARS), UAS, Bijapur.

Regional Research Station (RRS), UAS, Raichur.

Agricultural Research Station (ARS), UAS, Sankeshwar.

### **State Government Organizations**

Assistant Agricultural Officer, Parasite Laboratory, Channamma Nagar, Ist Cross, Bailhongal-591 102, Belgaum District, Phone: 08288-737347, 94484 36955, E-mail: ramucats@yahoo.com

Assistant Agricultural Officer, Parasite Laboratory, Mandya-571 401, Phone: 08232-238602.

Agricultural Officer, Parasite Laboratory, Seed Farm, Herur Road, Gangavathi-583 227.

### **Private Organizations**

Agri Organics, 752/A, 4<sup>th</sup> Cross, 11<sup>th</sup> Main, Ist Stage, Vijaynagar, Hilkal Post, Mysore-570 017.

Agro Extracts Ltd., Plot No. 16, Phase II, Peenya Industrial Area, Bangalore-560 058.

Bio-Control Research Laboratories, Pest Control (India) Pvt. Ltd., No. 36/2, Sriramanahalli, Rajanakunte P.O., Post Box No. 6426, Yelahanka, Bangalore-560 064, Phone: 080-2246 8839/40/41/42, Fax: 080-2846 8838, E-mail: bcr1@pcil.co.in (Contact person: Mr. N. Venkatesh, Mobile: 3188 2116).

Bio-Multi Tech Pvt. Ltd., Ganganagar, Bangalore-560 030.

Bio-Pest Management Pvt. Ltd., NH 7, 12<sup>th</sup> Km., Opposite Jakkur Aerodrome, Jakkur P.O., Bangalore-560 064.

Bio Solujan, 22/1 Police Station Road, Basavanagudi, Bangalore-560 004.

Camson Bio-Technologies Ltd., 223, Ist Main, Domlur IIInd Stage, Bangalore-560 071.

Cee Kay Associates, NH 7, 12<sup>th</sup> Km., Opposite Jakkur Aerodrome, Jakkur P.O., Bangalore-560 064.

Chirag Agro Agencies, 3, MCP Complex, Besides TGB Head Office, Sanganakal Road, Bellary-583 103.

EID Parry (India) Ltd., Research & Development Centre, 145, Devanahalli Road, Off Old Madras Road, Bangalore-560 049.

Eugenio Bio-derivative, 12/2, 12/3, Bellad Building, Vidyapeetha Road, Fort, Dharwad-580 008.

Hospet Sugar Mills, Hospet, Bellary District.

Innovative Pest Control Laboratory, 2552, Yesnaswini, 13<sup>th</sup> Main, Kumaraswamy Layout, IIInd Stage, Bangalore-560 078.

Kadur Agro & Video Vision Production Pvt. Ltd., R.V. Vidyaniketan, Mylasandra P.O., Bangalore-560 078.

Karnataka Agricultural Research Foundation, Godhavari Sugar Mills, Sameerwadi, Mudhol Taluk, Bijapur District.

Margo Pvt. Ltd., 344/8, IVth Main, Sadashivnagar, Bangalore-560 080. Phone: 080-23613051/2/3, Fax: 080-23613055, E-mail: margo@vsnl.com, info@margobiocon.com, msm.christopher@margobiocon.com

Monarch Bio-Fertilizers & Research Centre, 7/32, 47<sup>th</sup> Cross, Ist Main, 8<sup>th</sup> Block, Jayanagar, Bangalore-560 082.

Monofix Agro Products Ltd., VG Limbikai Building, Gokul Road, Hubli-580 030.

Murkumbi Bio Agro Pvt. Ltd., BC 105, Havelock Road, Camp, Belgaum-590 001.

Pest Control (India) Pvt. Ltd., B-385, Industrial Shed, KISSDC Ist Stage, Bangalore-560 058. Phone: 080-2372 4707, Fax: 080-2372 4708, E-mail: psd\_bangalore@pcil.co.in (Contact Person: Mr. Hemant Kumar, Mobile: 080 3186 7949).

Rallis India Ltd., Agrochemical Station, Plot No. 21 & 22, Phase II, Peenya Industrial Area, P.B. No. 5813, Bangalore-560 058. E-mail: rallis.research@gems.vsnl.net.in

Travancore Organic Fertilizers Co. Pvt. Ltd., Biotech Division, 1609, MVR Layout, Kalyan Nagar, Bangalore-560 043.

Vital Plant Products, Gowrishankar Estate, Harihalli-573 129, K. Hoskote, Alur Taluk, Hassan Dist.

West Coast Herbochem Pvt. Ltd., 105/B, Industrial Suburb, IIInd Stage, Rajajinagar, IIIrd Cross Road, Bangalore-560 022.

### **15.10.12. Kerala**

#### **ICAR Intitutes**

Central Plantation Crops Research Institute (CPCRI) Regional Station, Division of Entomology & Nematology, Krishnapuram P.O., Kayangulam-690 533.

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**Central Government Organizations**

Central Integrated Pest Management Centre, 39/3839A, Kerampatt Cross Road, Ernakulam-682 016.

Deputy Director (Research)/Field Entomologist, Regional Coffee Research Station, Coffee Board, Chundale-673 123, Wynaad District, Phone: 04936-202256, Fax: 04936-202256, E-mail: ddcrs@eth.net

**State Agricultural Universities**

Department of Entomology, Kerala Agricultural University (KAU), Vellanikara, Trichur-680 656.

**State Government Organizations**

State Biocontrol Laboratory, Mannuthy-680 651, Thrissur.

**Private Organizations**

Agro Bio-Tech Research Centre Ltd., Regd. Office: Industrial Area, Poovanthurutu, Kottayam-686 012.

Chemm Exports Pvt. Ltd., Erinjeri Angadi, Post Box 111, Trichur-680 00. Phone: 0487-440014, E-mail: chemm@vsnl.com

Green Tech Agro Research Centre Pvt. Ltd., MKM Complex, Kodimatha, Kottayam-686 039.

High Range Biopesticides Ltd., 11/105 L, Udumbannore, Thodupuzha-685 584, Idikki.

Pacific Agro Tech Pvt. Ltd., 94, Canal Road, Girinagar, Kochi.

Pest Control (India) Pvt. Ltd., 39/2541, MG Road, Cochin-682 016, Phone: 0484-236 5099, 238 0815, Fax: 0484-238 0816, E-mail: psd\_cochin@pcil.co.in (Contact person: Mr. N.R. Sunderarajan, Mobile: 3226703).

Plantrich Chemical & Fertilizers Ltd., Industrial Estate, Manarcad P.O., Kottayam-686 019. Phone: 91481-2371477/877, E-mail: plantrich@bioplantrich.com

Travancore Organic Fertilizers, Kottayam-686 001.

VRM Biotech Products, Southern Fertilizers & Chemicals, Salim Complex, Changanacherry-686 101, Kottayam.

**15.10.13. Madhya Pradesh****Central Government Organizations**

Central Integrated Pest Management Centre, 16, Professor Colony, Bharwar Kua Main Road, Indore-452 001.

**Private Organizations**

Farm Services Indore, 6, Sikh Mohalla, Main Road, Opp. Khatari Market, Indore-452 007.

Indore Biotech Inputs & Research (Pvt.) Ltd., 6, Sikh Mohalla Main Road, Opposite Kothari Market, Indore-452 007.

Pest Control (India) Pvt. Ltd., 109, Malaviya Nagar, Bhopal-462 003, Phone: 0755-255 0090, 255 4767, Fax: 0755-255 4767, E-mail: salim.naushad@pcil.co.in (Contact person: Mr. S.M. Naushad, Mobile: 3139019).

Samridi Bioculture Pvt. Ltd., Manufacturer's of Biofertilizers, 401, Anu Apartments, 21-22 Sankarnagar, Saket, Indore-452 001.

**15.10.14. Maharashtra****ICAR Institutes**

Central Institute of Cotton Research (CICR), Nagpur.

**Central Government Organizations**

Central Integrated Pest Management Centre, New Secretariat Building, IInd Floor, East Wing, Civil Lines, Nagpur-440 001.

National Chemical Laboratory, CSIR Laboratory, Pune-414 001.

Nuclear Agriculture Division, Bhaba Atomic Research Centre, Trombay, Mumbai-400 085.

**State Agricultural Universities**

Department of Entomology, Konkan Agricultural University (KAU), Dapoli, Ratnagiri District.

Department of Entomology, Mahtma Phule Agricultural University (MPAU), Rahuri-413 722, Ahmednagar District.

Department of Entomology, MPAU, Biocontrol Laboratories, College of Agriculture, Pune-411 005.

Department of Entomology, Marathwada Agricultural University (MAU), Parbhani-431 402.

Department of Entomology, Punjabrao Deshmukh Agricultural University (PDAU), Krishinagar, Akola-444 101.

### **Private Organizations**

Agri Sense BCS (Biosys Subsidiary), B/3 Industrial Estate, Assurance Building, Church Gate, Mumbai-400 020.

Ajay Biotech India Ltd., 100/3, Kalpana Apartments, Dr. Katkar Marg, Erandawane, Pune-411 040.

Ajay Biotech Laboratories (Pvt.) Ltd., A-12/5, Kubera Park, Kanchawa, Pune-411 040.

Ajay Farm Chem Pvt. Ltd., 11/3, Kalpana Apartments, Dr. Katkar Marg, Erandawane, Pune-411 004.

Anand Biocontrol Laboratory & Agricultural Consultancy, 30, Hedgewar Nagar, Dharangaon, Erandol, Jalgaon-425 105.

Ankur Seeds Pvt. Ltd., NPV Production Wing, 27 New Cotton Market Layout, Parashuram Road, Ratnagiri-415 722.

Arag Biotech, 220 Reshimbagh, Nagpur-440 009.

Bahar Agrochemicals, E/24, MIDC, Lote Parashuram Road, Ratnagiri-415 722.

BD Keathen & Co., Bandra (East), Mumbai-440 029.

Bio-Agro Fertilizers, 19, Sethlya Building, Gaikwad Nagar, Audh-ITI Road, Pune-411 007.

Bio Era Technologies, 12, Sri Ram Apartments, Dindayal Nagar, Ring Road, Nagpur-412 022.

Bio Sense Crop Protecion (Eco-Max Agro Systems Ltd.), Industrial Assurance Building, Church Gate, Mumbai-400 020.

Cheminova Agro-Tech, Plot No. 2, Gat N 352, Shahada Dondaicha Road, Mohide Shivar, Nandubar -425 409, Shahada District.

Chintawar Biocontrol Laboratory, Mahur Road, Arni Yeotmal-445 103.

Eco-Max Agrosystems Ltd., Good Value Marketing Company, Mumbai-440 020.

Excel Industries Ltd., 184-87, Swami Vivekananda Road, Jogeswari (W), Mumbai-440 102.

Gharda Chemicals Pvt. Ltd., 48, Hill Road, Mumbai-440 050.

Godrej Agrovat Ltd., Pirojshanagar, Eastern Express Highway, Vikhroli, Mumbai-440 079.

Harit Biocontrol Laboratories, Near Jamod Ginning Factory, Ghatanji, Yeotmal-445 301.

Hoechst Schering Agr. Environment, Hoechst Centre, 54/A, Andheri-Kurla Road, Andheri West, Mumbai-400 093.

Indofil Chemical Co., Nirlon House, Dr. Annie Besant Road, Mumbai-400 024.

Jai Biotech Industries Unit, No. 67, Plot No. C-10/1, Road A, Street No. 9, NICE Area, MIDC-Satpur, Nasik-422 009.

JR Biocontrol Laboratory, Mahur Road, Arni, Yeotmal-445 103.

Khatau Agro Tech., Khatau House, Moghul Lane, Mahim, Mumbai-440 016.

KNS Biotech, Shivaneri Nagar, Rampur Road, Degloor, Nanded-431 717.

Kumar Krishimitra Bioproducts (I) Pvt. Ltd., 12, Ganeshwadi, Prin K.R. Kanitkar Path, Off F.C. Road, Pune-411 004.

Lupin Laboratories (I) Pvt. Ltd., 259, CST Road, Kalima, Santa Cruz (East), Mumbai-440 098.

Mahagrapes, E-15, Nisarg, Market Yard, Gultekdi, Pune-411 037.

Maharashtra Research & Development Centre, 396, "Sainik" Santosh Nagar, Near DCC Bank, Bale, Sholapur-413 002.

Mc DA Agro Pvt. Ltd., Mumbai-440 001.

Microplex (India), 36, Mahata Market, Main Road, Wardha-442 001.

Nathkrupa Biocontrol Laboratories, 55, Sriram Nagar, Near Wireless Station, Pawan Bhumi Marg, Wardha Road, Nagpur-440 002.

National Biocontrol Laboratory, Narendra Nagar, 61, Manorama Canal Road, Gokulpeth, Nagpur-440 010.

National Organic Chemical Industries Ltd., 951/A, Appasaheb Marathi Marg, Prabhadevi, Mumbai-440 029.

Nomin Agro Bio Pvt. Ltd., 6, Gandharva Apartments, S. No. 28, Evendawana, Near Mehendale Garage, Opp. Hotel Abhishek, Pune-411 004.

Om Agro Organics, Samarthwadi, Yavatmal-445 002.

Patil Biotech Pvt. Ltd., 3, ZP Bachat Bhavan, Jalgaon-425 001.

Pest Control (India) Pvt. Ltd., 2<sup>nd</sup> & 5<sup>th</sup> Floor, Jagdamba House, Next to Annapurna Theatre, P.B.No. 9060, Goregaon (East), Mumbai-400 063, Phone: 022-2686 5550, 5699 0252, Fax: 022-2686 5555, 5699 0256, E-mail: nikhil.chatterjee@pcil.co.in (Contact person: Mr. Nikhil Chatterjee, Mobile: 3898 1560).

Pest Control (India) Pvt. Ltd., 127, Keytuo Industrial Estate, 220, Kondivita Road (off Andheri-Kurla Road), Andheri (East), Mumbai-400 059. Phone: 022-2821 3546/7, 2821 7385, 2832 8481, Fax: 022-2822 1647, E-mail: nanda.khamkar@pcil.co.in (Contact person: Mr. N.B. Khamkar, Mobile: 022 3210 2063).

Pest Control (India) Pvt. Ltd., Krishna Niwas, Ist Floor, Kaduva Lane, Near Collectorate, Thane-400 601. Phone: 022-2534 1131, 2536 1506, Fax: 022-2538 5142, E-mail: siddharth.sarangpani@pcil.co.in (Contact person: Mr. S. Sarangpani, Mobile: 022-3210 1586).

Pest Control (India) Pvt. Ltd., Shop Nos. 11 & 12, Vindhya Commercial Complex, Sector 11, CBD Belapur, New Mumbai-400 614. Phone: 022-2757 2225, 2757 1840, 2757 1837, Fax: 022-2757 1837, E-mail: priyendra.khona@pcil.co.in (Contact person: Mr. Priyendra Khona, Mobile: 022 3210 1587).

Pest Control (India) Pvt. Ltd., 11 & 12, Wastu Park 'A', Ashwin Sector, New CIDCO, Nashik-422 009. Phone: 0253-2393887, 2390807, Fax: 0253-2390807, E-mail: suresh.bramhankar@pcil.co.in (Contact Person: Mr. S.A. Bramhankar, Mobile: 0253 3106357).

Pest Control (India) Pvt. Ltd., Flat No. 5, Sandesh Building, Opp. Gokhale Park, Chinchwad, Pune-411 033. Phone: 020-2745 2250, Fax: 020-2745 2250, E-mail: suneel.joshi@pcil.co.in Contact Person: Mr.S.P. Joshi, Contact Person: Mr.S.P. Joshi, Mobile: 020 3101 0545).

Pest Control (India) Pvt. Ltd., Manashanti Apartments, 504-B, Shaniwar Peth, Pune-411 030. Phone: 020-2448 2756, 2448 2914, Fax: 020-2745 2250, E-mail: pcilpune@vsnl.net (Contact Person: Mr.B.B. Halder, Mobile: 0202449 4607).

Prakash Farm Chemicals, Gulmohar Cross, Road No. 9, Ville Parle West, Mumbai-440 049.

R.S. Kherdekar, Vaishnav Galli, Talpathri P.O., Parbhani District.

Sandoz (I) Ltd., Agro Division, Sandoz House, Dr. Annie Besant Road, Worli, Mumbai-400 018.

Sanvardhini Agro Pvt. Ltd., M-14, Addl. MIDC, Satara-415 004.

Sio Agro Research Laboratories, Dhiraj Apartments, Mulund (West), Mumbai-440 080.

Skylark Agro Chemicals, W-92, MIDC, Phase-II, Dombivali (East), Thane-421 204.

Soman Biofertilizers, 594, Sadashiv Peth, 101, Express Towers, Laxmi Road, Pune-411 030.

Sunida Exports Ltd., Bandra (East), Mumbai-440 029.

Sunline Agro Chemicals Pvt. Ltd., P.B. No. 73, Sakri Road, Dhulia.

Swathi Industries Ltd., Morray House, Bandra, Mumbai-440 050.

Tirupati Agro Inputs, Shivan Complex, Kava Road, Latur-413 512.

Universal Biotech, 70, KK Nagar, Jaripatka, Nagpur-440 014.

Vasanthdada Sugar Institute, Manjri (BK), Tal Haveli, Pune-412 307.

Venkatesh Biotech, Rajendranagar, Opp. Krishna Mandir, Basmath Road, Parbhani-431 401.

Vidyas Biotech Laboratories, 33, Savita Vihar, Somalwada, Wardha Road, Nagpur-440 015.

West Coast Herbochem Pvt. Ltd., 23A/101, Nalanda, C.S.T. Road, Kurla West, Mumbai-400 070.

Wockhardt Ltd., Ready Money Terrace, 2<sup>nd</sup> Floor, 167, Dr. Annie Besant Road, Worli, Mumbai-400 018.

Zandu Pharmaceutical Works Ltd., 70, Gokhale Road (South), Mumbai-440 025.

#### ***15.10.15. Mizoram***

#### **Central Government Organizations**

Central Integrated Pest Management Centre, Lal Zauva's Building, Mission Wing, Republic Road, Aizwal-796 001.

#### ***15.10.16. Nagaland***

#### **Central Government Organizations**

Central Integrated Pest Management Centre, Duncan Road, Dimapur-797 112.



**15.10.17. New Delhi****ICAR Intitutes**

Division of Agrochemicals, Indian Agricultural Research Institute (IARI), New Delhi-110 012.

Division of Entomology, Indian Agricultural Research Institute (IARI), New Delhi-110 012, E-mail: iari@dBt.ernet.in

Division of Plant Pathology, Indian Agricultural Research Institute (IARI), New Delhi-110 012.

National Centre for Integrated Pest Management (NCIPM), LBS Building, IARI Campus, Pusa, New Delhi – 110 012.

**Central Government Organizations**

Defence Institute of Physiology & Applied Sciences, Delhi Cantonment, New Delhi-110 022.

**Private Organizations**

Biotech International Ltd., VIPPS Centre, 2 Local Shopping Centre, Block-EFGH, Masjid Moth, Greater Kailash-II, New Delhi-110 048, Phone: 011-29220546/47/7359, Fax: 011-29229166/3083, E-mail: info@biotech-int.com

Dipti Enterprises, S-207 School Block, Shakarpur, Delhi-110 092.

Hindustan Insecticides Ltd., Scope Complex, Core-6, II Floor, Lodi Road, New Delhi-110 003.

International Panacea Ltd., E-34, 2<sup>nd</sup> Floor, Connaught Circus, New Delhi-110 001.

JK Traders, R-26 Main Market, Shakarpur, Delhi-110 092. Phone: 011-22042806, Mobile: 09811269150.

Navdanya (NGO), X-5, Hauz Khas, New Delhi-110 016. Phone: 011-26561868, 26262093.

Nimba Foods & Agrochemicals Division, 14-A/10, Western Extension, Pusa Road, New Delhi-110 055.

Pest Control (India) Pvt. Ltd., 7, Jantar Mantar Road, Post Box No. 581, New Delhi-110 001. Phone: 011-2336 8772, Fax: 011-2336 8771, E-mail: pcilmkt@bolnet.in / psd\_delhi@pcil.co.in (Contact person: Mr. Naresh Patti, Mobile: 011 3257 9897).

Pesto-Chem India Ltd., CM-3, Ansal Dilkush, Industrial Complex, GT Karnal Road, Azadpur, New Delhi-110 033.

### **15.10.18. Orissa**

#### **Central Government Organizations**

Central Integrated Pest Management Centre, Plot No. N/4F/39, IRC Village, Nyapalli, Bhubaneswar-751 015.

#### **Private Organizations**

Annapurna Scientific Industry, Labour Colony, A/13, Unit III, Kharaval Nagar, Bhubaneswar-751 001.

Pest Control (India) Pvt. Ltd., 440, Saheed Nagar, Bhubaneswar-751 007. Phone: 0674-, 2540235, 2544274, Fax: 0674-2544274, E-mail: anjan\_samantray@yahoo.com (Contact Person: Mr. Anjan Samantray, Mobile: 98611 49280).

### **15.10.19. Punjab**

#### **Central Government Organizations**

Central Integrated Pest Management Centre, WG-376, Niwan Sirajganj, Near Lal Ratan Cinema, Jalandar-144 001.

#### **State Agricultural Universities**

Department of Entomology, Punjab Agricultural University (PAU), College of Agriculture, Ludhiana-141 004.

#### **Private Organizations**

Pest Control (India) Pvt. Ltd., SCO No. 9, Cabin No. 5 (Basement), Sector-26, Madhya Marg, Chandigarh-160 019. Phone: 0172-2790230, Mobile: 0172 3105264, E-mail: psd\_chandigarh@pcil.co.in

### **15.10.20. Rajasthan**

#### **Central Government Organizations**

Central Integrated Pest Management Centre, Nohra No. 87, Purani Dhan Mandi, Sriganganagar-335 001. Phone: 0154-420619, Fax: 0154-435010.

## **State Agricultural Universities**

Biocontrol Laboratory, Agricultural Research Station (ARS), Rajasthan Agricultural University (RAU), Sri Ganganagar-335 001.

## **State Government Organizations**

Deputy Director of Agriculture (Agronomy), ATC, Regional IPM Lab, Tabiji Farm, Ajmeer, Phone: 0145-2440652.

Deputy Director of Agriculture (Agronomy), ATC, Regional IPM Lab, Malikpur, Bharatpur, Phone: 05644-223337.

Deputy Director of Agriculture (Agronomy), ATC, Regional IPM Lab, Rampura, Jodhpur, Phone: 02962-222006.

Deputy Director of Agriculture (Agronomy), ATC, Regional IPM Lab, Cjjatrapura, Bundi, Phone: 0747-2442368.

Deputy Director of Agriculture (Agronomy), ATC, Regional IPM Lab, Farm Chittorgarh, Phone: 01472-241319.

Deputy Director of Agriculture (Agronomy), ATC, Regional IPM Lab, Krishi Farm, Hanumangarh Town, Phone: 01552-231291.

Deputy Director of Agriculture (Plant Pathology), IPM Laboratory, Dahod Road, Banaswara, Phone: 02962-243054.

Joint Director of Agriculture (Plant Pathology), State Biocontrol Lab, Durgapura, Jaipur, Phone: 0141-2550830.

## **Private Organizations**

Adarsh Biocontrol Laboratories, Bali Ka Darwaja, Alwar-301 001. Phone: 0144-2334111.

Pest Control (India) Pvt. Ltd., Shankar Sadan, Ist Floor, Adinath Marg, Opp. SMS Hospital, C-Scheme, Jaipur-302 004. Phone: 0141-236 8004, 237 8346, Fax: 0141-237 8346, E-mail: peijpr@datainfosys.net (Contact person: Mr. Rajan Prakash, Mobile: 0141 312 2470).

Pesticides India Ltd., PO Box No. 20, Udaisagar Road, Udaipur-313 001.

### **15.10.21. Sikkim**

## **Central Government Organizations**

Central Integrated Pest Management Centre, Tadong Housing Colony, Opp. Regional Research Centre (Ayurveda), Tadong, Gangtok-737 102.

**15.10.22. Tamil Nadu****ICAR Institutes**

Division of Plant Protection, Sugarcane Breeding Institute (SBI), Coimbatore-641 007.

**Central Government Organizations**

Central Integrated Pest Management Centre, 2/2 A&B, IIIrd Street, Khaja Nagar, Tiruchirapalli-620 020.

Regional Coffee Research Station, Coffee Board, Thandigudi-624 216, Dindugal District, Phone: 04542-266437, Fax: 04542-266404, E-mail: rcrstgd@yahoo.com.in

**State Agricultural Universities**

Centre for Plant Protection Studies (CPPS), Tamil Nadu Agricultural University (TNAU), Coimbatore-641003. Phone: 0422-431222, Fax: 0422-431672.

Department of Agricultural Entomology, Tamil Nadu Agricultural University (TNAU), Agricultural College & Research Institute, Madurai-625 104.

**State Government Organizations**

Bio-control Lab., State Seed Farm, Papparapatty Lab., Pennagaram Taluk, Dharmapuri District.

Bio-control Lab., JDA Office Complex, Tadagam Road, Coimbatore-641 013. Phone: 0422-2430766.

Bio-control Lab., ADA Office Complex, Seelanai-Chanpatty, Salem, Phone: 0427-2280214.

Bio-control Lab., Collectorate Office Complex, Villupuram-605 602. Phone: 04146-222291.

Bio-control Lab., ADA Office Complex, Puttur, Trichy-620 017. Phone: 0431-2793241.

Bio-control Lab., JDA Office Complex, Kancheepuram, At Panjupettai-651 501, Kancheepuram District, Phone: 04112-222977.

Bio-control Lab., State Seed Farm Complex, Kuruppanaichenpalyam Post, Bhavani, Erode.

Bio-control Lab., ADA Office Complex, Vinayagapuram, Therkkuthuru Post, Melur Taluk, Madurai District.

Bio-control Lab., JDA Office, Tirunelveli Complex, Nirubar Colony, Tirunelveli-626 002.

Bio-control Lab., JDA Office, Thaniavur Complex, Kattuthottam Marianaman Koil Post, Tanjavur.

Bio-control Lab., Panchayat Union Complex, Namakkal-637 001.

### **Private Organizations**

Agro Links, Trichy.

Agronule Industries, Trichy-632 217.

Agro Research Laboratories, 10/224, Avinashi Road, Coimbatore-641 018.

A.V. Thomas Pvt. Ltd., Anna Salai, Chennai-600 032.

Bacto Agro Culture Pvt. Ltd., Bharatha Nagar, Kalapally-643 253, The Nilgiris.

Basarass Biocontrol Research, 3/204, Main Road, Eraiyur Pennadanam RS & PO, SA, Vallavar-606 111, Cuddalore Dist. Phone: 4143-222403/037, Fax: 44-24867867, E-mail: basaras@vsnl.net

Biocontrol Research Centre, White House, Sakthi Nagar, Kootham Poondi-638 018, Periyar Dist

Bioscience Laboratories, 3/229 & 230, Gandhi Nagar, Opp. Steel Plant Main Gate No. 3, Salem-636 013.

Biotechnology and Seed Division, SPIC Agro Industrial Complex, Chennai-600 015.

Canster Chemicals Ltd., Adayar, Chennai-600 020.

Centre for Agrochemical Research, SPIC Science Foundation, Guindy, Chennai-600 002.

Ecobiocides and Botanicals Pvt. Ltd., 2 East Market Street, Periyakulam Road, Theni-625 531. Phone: 4546-252020, Fax: 4546-251010, Mobile: 094433 42020, E-mail: ecobiocides@hotmail.com, Web site: www.azgro.com

E.I.D. Parry (India) Ltd., Bio-Products Division, 234, NSC Bose Road, Chennai-600 001.

E.I.D. Parry (India) Ltd., Pesticides Division, "Dare House", P.B.No. 12, Chennai-600 001.

Elbitech Innovations Ltd., 2A, Sara Apartment No. 6, 4<sup>th</sup> Cross Street, C.I.T. Colony, Mylapore, Chennai-600 004.

Green Tech Agro Products Pvt. Ltd., 47-D, Parsen Residency, Rajaji Road, Ramnagar, Coimbatore-641 009. Phone: 422-230107, Fax: 422-235237.

Jeypee Bio Techs, 25, Chinnaiah School Street, Virudhunagar-626 001.

Krishicare Bioinputs, Plot No. 61, Kamatchi Nagar, Madhandapuram, Kundrathur Road, Porur, Chennai-600 116.

Madurai Chemicals & Agro Industries Ltd., Rajaji Road, Madurai-625 104.

Main Bio-Control Reaearch Laboratories, 2 E/1, Rajeshwari Vedachalam Street, Chengalpattu-603 061.

Micro Chemicals Ltd., Rajaji Road, Madurai-625 104.

Pest Control (India) Pvt. Ltd., 28, Errabalu Street, Chennai-600 001. Phone: 044-2522 6745/4266, Fax: 044-2522 2815, E-mail: psd\_chennai@pcil.co.in (Contact person: Mr. V.M. Sagar).

Phyto Products Ltd., Thiruthuripoondi, S.A. District.

Prabhakar Oil Mills, Trichy-632 217.

Rajendra Foundation for Agricultural Research & Rural Development, Chittar-638 311, Kesarimangalam Post, Bhavani Taluk, Erode Dist. Phone: 04256-39258, 39858.

Rajshree Sugars & Chemicals Ltd., Varadaraj Nagar-625 562, Vaigai Dam.

Sakthi Biocontrol & Bio-fertilizer Centre, 9/11 Sathy Main Road, Kallipatti Gobi-638 505, Erode Dist. Phone: 04285-263464, 04554-231832.

Shri Durga Agro Services, 10/1, Kongu Nagar, Kalveerapalyam, Bharathiyar University Post, Coimbatore-641 046.

Shrishti Bio Products Pvt. Ltd., 331, Chinnasamy Naidu Road, New Siddapudur, Coimbatore-641 044.

Sinagro Industries India, 178, 9<sup>th</sup> Street, Mangalanagar, Porur, Chennai-600 116.

Southern Petrochemicals Industries Corporation Ltd. (SPIC), Agribusiness Division, SPIC Science Foundation, Guindy, Chennai-600 018.

Southern Petrochemicals Industries Corporation Ltd. (SPIC), Bio-Tech Division, Agro Industrial Complex, 97, Mount Road, Chennai-600 032.

Spinco Biotech Pvt. Ltd., P.B. No. 611435, Vaidyaram street, Chennai-600 017.

Sri Krishna Company, Race Course Road, Coimbatore-641 018.

Sun Agro Industries India, 178, 9<sup>th</sup> Cross Street, Mangala Nagar, Porur, Chennai-600 016.

Tamil Nadu Coconut Parasite Breeding Centre, Everbright Bus Stop, A-9, Kovaipudur post, Coimbatore-641 042.

Tamil Nadu Co-operative Sugar Federation Ltd., Main Biocontrol Research Laboratories, 2E/1, Rajeshwari Vedachalam Street, Chengalpattu-603 001.

TAP Industries, 7, Guna Complex, Tirumogeer Road, Y. Othathadai, Chennai-600 107.

T. Stanes & Co., 8/23-24, Race Course Road, Post Box No. 3709, Coimbatore-641 018.

Tuticorn Alkali Chemicals & Fertilizers Ltd., 553, Anna Salai, Teynampet, Chennai-600 018.

Victoria Laboratories, Mahtma Gandhi Road, Salem-632 004.

Vigneswara Biocontrol, 106 Parivallal Salai, Jyothi Nagar, Pollachi-642 001.

### ***15.10.23. Uttarakhand***

#### **State Agricultural Universities**

Department of Plant Pathology, GB Pant University of Agriculture & Technology (GBPUA&T), Pantnagar-263 145.

#### **Private Organizations**

Pest Control (India) Pvt. Ltd., 37/1, Ballapur Road, Near Hotel Surabhi, Dehradun-248 001. Phone: 0135-275 8568 (Contact person: Mr. Randeep Singh).

Sri Ram Solvent Extraction Plant (Neem), Jaspur.

### ***15.10.24. Uttar Pradesh***

#### **ICAR Institutes**

Division of Entomology, Indian Institute of Sugarcane Research (IISR), Rae Bareli Road, Post Dilkush, Lucknow-226 002.

**Central Government Organizations**

Central Integrated Pest Management Centre, Batia HATA, Hari Prasad Dubey Marg, Gorakhpur-273 001.

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Bioved Research Society, 103/42, MLN Road, Allahabad-211 002.

Crop Health Bio-Product Research Centre, R-12/50, Rajanagar, Ghaziabad-201 003.

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