ORGANIC FARMING

A. SHABNAM SHEREEN

&

P. THARANYA

ASSISTANT PROFESSOR

DEPARTMENT OF BIOTECHNOLOGY

M.M.E.S WOMEN'S ARTS & SCIENCE COLLEGE

UNIT 1

Organic farming: History, Introduction, Concept/ Philosophies

Organic farming refers to a method of agriculture that uses fertilizers made from animal and plant wastes and other biological materials. Recognizing the environmental harm of traditional farming, which used chemical pesticides and fertilizers, scientists saw that farming conditions could benefit from the use of animal manures, crop rotation, cover crops, and natural pest controls. Today, organic food has grown in popularity, especially among consumers who are concerned with the potential negative effects of pesticides, GMOs, and hormones.

What Does Organic Mean?

Organic describes any food that is produced without chemical fertilizers, pesticides, or antibiotics. The USDA certifies food as organic if it has been grown in soil that has not been covered in synthetic fertilizer or pesticides for a full three years prior to the food's harvest.[1]

Traditional farming has a greater impact on the environment due to increased greenhouse gas emissions, soil erosion, and water pollution.[2] However, traditional farming generally produces higher crop yields (approximately 5-34% greater) than organic farming.[3] This is one of the reasons why organic produce is more expensive. Conventional farming also uses synthetic insecticides to get rid of pests and diseases, whereas organic farming uses insects and birds.

The Origin and Timeline of Organic Farming

According to a 2020 International Federation of Organic Agriculture Movements (IFOAM) report, there were at least 2.8 million organic producers in the world in 2018.[4] How did we get here?

Organic agriculture as a concept began at the beginning of the twentieth century as the need to address soil erosion and depletion, lack of crop varieties, and insufficient food quality increased. During the time, the mechanization of agriculture evolved quickly, which drastically increased crop yields and made farming much more affordable. The resulting negative environmental effects spurred the birth of the organic farming movement.

1940s

The term was first coined by Walter James in his book "Look to the Land," in which he talked about a natural and ecological approach to farming. He focused on the “farm as an organism,” and his ideas were fundamental in the creation of the worldwide organic farming movement.[5] Also, in the 1940s, the founder of the Rodale Institute, J. I. Rodale, provided his own information on farming methods that avoided the use of chemicals.

Rodale gained inspiration from Sir Albert Howard, a British scientist who spent years in India observing agricultural systems that used green manures and wastes as fertilizer. In 1943, in his book "An Agricultural Testament," Howard wrote about the importance of using animal waste to maintain soil fertility, which was a concept that later became central to organic farming.

1950s - 1960s

In the 1950s, the sustainable agriculture movement began to gain traction due to environmental concerns. In 1962, Rachel Carson came out with her book "Silent Spring" which highlighted the effects of DDT and other pesticides on wildlife, the natural environment, and humans. Within this book, Carson called for humans to act in a more responsible manner and be stewards of the earth instead of destroying it. The sustainable agriculture movement and Silent Spring both had a major impact on the progression of the organic farming movement.

1970s

In the 1970s, consumers began to become more environmentally aware, and their demand for more sustainable practices fueled the growth of the organic farming industry. With the difference between organic and conventional produce now apparent, the movement aimed to promote locally grown food. This time in history was known as the era of polarization of agriculture into organic and non-organic categories.

However, no one could agree on approaches for the management of organic farming, and so no universal standards or regulations for organic agriculture existed in the 1970s. In the United States at the time, organic certification programs varied by state.

In 1972, IFOAM was founded in Versailles, France to build capacity to assist farmers in making the transition to organic agriculture, to raise awareness on sustainable agriculture, and to advocate for policy changes related to agro-ecological farming practices and sustainable development. Today, they have members from 100 countries and territories and are a leader in the industry.

1980s

The 1980s is described as a period in which organic farming received national recognition within the United States. In 1980, the USDA released the Report and Recommendations on Organic Farming with the intention of “increasing communication between the USDA and organic farmers.” In 1981, the American Society of Agronomy held a Symposium on Organic Farming to explore the question: Can organic farming contribute to more sustainable agriculture? The answer was a resounding yes from attendees of the symposium.

Organic agriculture began to be implemented into university curriculums around the world. USDA scientists also conducted research on organic farming with the Rodale Institute. In 1989, in Cuba, the combination of the U.S. trade embargo and the collapse of their Soviet market led to an organic revolution. This was because they found it very difficult to import the chemical fertilizers and heavy machinery needed for traditional agriculture, therefore they turned to organic farming.

In the 1980s around the world, farmers and consumers started to advocate for government regulation of organic farming. This sparked the creation of the certification standards that were enacted in the 1990s. In the European Union and the United States, the majority of aspects of organic food production are government-regulated.

1990s

The global retail market for organic food has expanded exponentially each year due to increasing consumer demand.[6] This was a result of the concern over the safety of food that was produced using synthetic fertilizers and pesticides.

In 1990, U.S. Congress passed the Organic Foods Production Act (OFPA) to develop a national standard for organic food production. The OFPA resulted in the creation of the National Organic Standards Board that would make recommendations for which substances could be used in organic production and handling. The board also would assist the USDA in writing regulations to explain the law to farmers, handlers, and certifiers. This was an important milestone in the organic movement as it defined the term “organic" and set site-specific regulations that promoted ecological balance and the conservation of biodiversity.[7]

2000s - 2010s

The regulations under the OFPA took more than a decade to write and the final regulations were finally implemented in 2002. In the 2000s, the worldwide market for organic food began to grow rapidly. Organic farmland increased from 11 million hectares in 1999 to 43.7 million hectares in 2014. Additionally, the global market of organic products was estimated to be $15.2 billion in 1999 and increased to $80 billion in 2014. In 2014, there were approximately 2.3 million organic producers around the world.[8]

From 2004 to 2010, researchers found that organic products cost more than non-organic products, with a premium of above 20% for all organic products except spinach.[9] Additionally, during the 2000s and 2010s, more countries around the world began to implement government-regulated organic certifications. For example, in 2002 the European Union Organic Certification was enacted to enforce strict requirements for organic food production.

Today

The global organic market was greater than 100 billion U.S. dollars in 2018 with the leading country being the U.S., followed by Germany and France. There are approximately 2.8 million organic producers worldwide, with the majority being in India. Farmland also increased to a total of 71.5 million hectares worldwide.[10]

Global organic agriculture has also had a significant contribution to the Sustainable Development Goals (SDGs). However, there have continued to be criticisms about organic food and whether it is safer and/or more nutritious than conventional foods. Additionally, some have criticized the high costs of organic food as they believe there is a lack of evidence to back that it is more beneficial to health.

Still, organic food continues to grow in popularity, and it is expected that it will become more affordable as production and distribution increase. Additionally, consumers have been seeking out new organic plant-based alternatives, such as oat and soy milk. The popularity of restaurants that only cook food with organic ingredients is also on the rise, specifically in places like Bali, Indonesia. Overall, organic food continues to rise in quality, choice, and affordability.

PRINCIPLES OF ORGANIC FARMING

Principles Of Organic Farming

The **success of organic farming in agriculture** is based on three basic principles:

1. Interdependence

The most important of these is interdependence, in organic farming, a farm is viewed as an ecosystem and it is assumed that a change made on one farm should have an effect on another. For example, the presence of more nitrogen in the soil will result in faster growth of weeds. To overcome this problem, the farmer will try to **grow a crop** that absorbs a high amount of nitrogen from the soil and thus balances the nutrients in the soil.

2. Diversity

The second principle of organic farming is that of diversity. Organic farming is done to maintain the balance of nutrients in the soil. To maintain a balance between farmers' crops and livestock, farmers should raise farms as well as livestock. Diversity in crops and livestock also brings diversity and flexibility to farmers' incomes. On the other hand, it prevents any pest or weed, or disease from becoming a problem in the ecosystem.

3. Recycling

The third principle of organic farming is recycling, that is, reusing. The reuse of plant and animal residues in it helps in retaining the nutrients of the farms.

NEED FOR ORGANIC FARMING

Agricultural production in India, especially the production of foodstuffs, has grown rapidly over the past several decades. This achievement has been achieved through improved varieties of seeds, chemical fertilizers, and mechanization in agriculture. The use of chemical fertilizers for a long time reduces the productivity of the soil and on the other hand, increases environmental pollution. These problems have led to attempts to find alternative methods in farming. In this direction, nowadays attention is being paid to organic farming from modern farming. Organic farming is based on the coordinated relationship between soil, minerals, water, plants, insects, animals, and mankind. It provides protection to the soil while providing protection to the environment.

Biological management emphasizes human resources, knowledge, and the use of natural resources found around. Organic farming is also helpful in increasing food security and generating additional income. Organic farming plays a positive role in meeting the objective of sustainable agricultural development and rural development and brings about changes in the socio-economic conditions of the **farmers** along with increasing soil fertility. The demand for organic food is increasing continuously at the rate of 20-25 percent in developed and developing countries.

130 countries worldwide produce certified organic substances on a commercial scale. The farmer cannot prosper only by growing traditional crops, it is also necessary to change the cropping pattern according to the changing demand and prices. The demand for foods grown using natural methods and organic fertilizers is increasing rapidly in Europe, America, and Japan. According to this increasing demand, it is necessary to motivate the farmers to take advantage of the production by producing.

TYPES OF ORGANIC FARMING

There are mainly two types of organic farming- pure organic farming and integrated organic farming. These farming methods have their advantages and disadvantages. Some farmers choose to use a purified farming process, whereas some opt for an integrated farming method.

1. Pure Organic Farming

This farming is one of the different types of organic farming. It essentially depends on organic compost, fertilizers, and bio-pesticides to cultivate crops. It rigidly forbids any inorganic chemical or pesticides that may influence the yield, positively or negatively. It includes the use of organic manures and bio-pesticides with the whole avoidance of inorganic chemicals and pesticides.

In the method of pure farming, fertilizer and pesticides receive from natural sources. It is called a pure form of organic farming. This is the most suitable for high productivity.

2. Integrated Organic Farming

This farming is one of the standards of organic farming that merges the best of organic farming with nutrient management and integrated pest management. In this type of farming, producers grow crops utilizing natural resources, as they would in pure farming. However, they will use more inputs to improve their nutritional value and preserve the crops from pests.

This method integrates pest management and nutrients management to achieve ecological necessities and economic requirements. This type involves growing the crop through natural and renewable means. This permits the maximum utilization of resources and enhances the productivity of production.

UNIT 2

SELECTION OF CROP

- **No synthetic herbicides, pesticides, fertilizers, or genetically modified organisms (GMOs)**

These chemicals are not only potentially harmful to the environment and our human health, but they are expensive, too!

- **Organic agriculture promotes biodiversity**

Pesticides and herbicides not only kill intended parasites, but also beneficial insects that are vital to the food chain such as bees, which are important for plant health.

- **Build healthy soil**

Chemical fertilizers, pesticides and herbicides can degrade the soil, requiring more input in the future to maintain soil fertility. The main principle of organic agriculture, however, is to promote and enhance soil health through methods such as cover crops and crop rotation, which is especially important for those farming on a small area of land.

- **Sell products at higher prices**

Generally, organic food production requires more labor than conventional, greater management knowledge and skill, and implies a potentially lower yield (although this is highly contextual and crop dependent). Therefore, producers generally include a “price premium” on organic products, making them more expensive than conventional.

- **Increased consumer interest**

Demand for organic products has dramatically increased in the past 15 years, and the trend is not showing any indication of slowing down. Increasing demand means we need to produce more supply—this is where the new organic producer steps in.

The first step in organic farming is crop selection

Choosing which crops to plant requires several factors to be considered, such as farm conditions, resources, and technology, storage, marketability and more.

What are the farm conditions?

When we speak about farm conditions we are considering soil and climatic conditions, as well as biotic factors.

What are the climatic conditions?

Climatic conditions include:

- temperatures
- rainfall
- relative humidity
- average hours of sunlight,
- other site-specific factors such as frequency of extreme weather conditions

What are the soil conditions?

Soil conditions include:

- soil texture
- color
- organic matter content,
- pH
- fertility levels

This can be improved or altered through the addition of organic fertilizers, such as compost or manure.

What are the biotic factors?

This refers to the living things within the ecosystem such as plants, animals, bacteria, fungi, etc. Is there a prevalence of certain pests or diseases? If so, you may want to choose crops that are more resistant.

Is there a stable supply of water?

While some locations are water abundant, others may require additional measures to supply water for crops.

Which crops are suitable to the existing farm conditions?

Especially with organic production methods, it will be very difficult to grow crops not suitable to the environmental conditions. A good place to start will be to **identify which crops are already grown in the region**. You may want to consult a neighboring farm or visit a local farmers market. Once you've determined which species are suitable, you may want to consider different varieties under the same plant classification.

Also important to examine is which crops are most resistant to the pests and diseases that are common in the region.

By using susceptible varieties, this leaves the harvest vulnerable, which may result in increased costs (through additional inputs), or in the worst case, the loss of the entire crop yield.

If you intend to grow cash crops, which have the most potential for marketability and profit?

The first determinant is crop yield: how much (generally) of a specific crop can be produced on a designated unit of agricultural land.

Keep in mind that different crops are higher yielding than others. As well, take into account inputs such as labor, fertilizers, resources, etc. that could affect the profitability of the crop.

More traditional crops, which appeal to the widest consumer audience, may be the best option such as tomatoes, cucumbers, peppers, lettuce, etc. due to their widespread applicability. In addition, you may want to include specialty crops that can fetch higher prices such as heirloom varieties, nuts, sprouts, gourmet mushrooms, etc.

Additionally, consider the current marketplace. Is there a strong competition for a certain crop? Is there a high demand for one variety? Which produce is "trendy"?

What are the available resources and technology?

Different crops may require different machinery. Depending on the scale of your farm, you may want to consider planting crops that require that same machinery or avoid plant varieties that require specialized equipment. Also, is there potential to borrow machinery and resources from neighboring farms? This can also include manure in the case that you are not intending to also raise livestock on your farm.

Knowledge is also an important resource, vital to successful crop growth. When selecting plant types, ensure proper and sufficient knowledge of production requirements to increase the probability of high yields.

What is the storage potential for each crop?

Depending on climatic conditions, different crops will be harvested at different points throughout the year. To ensure that you have a steady flow of available food to either sell or consumer yourself, choose at least some crops that are able to be stored for long-term periods without spoiling. This includes grains, root crops, and dry beans, which you can also use for other purposes such as to make flour.

SEED SELECTION AND TREATMENT

Introduction

Agriculture is the art of cultivation of crops and animal farming. Seed plays a major role in the production of desirable foods to fulfil the increasing demand of the population. It is a small fertilised part of a plant, made up of embryo, endosperm, and seed coat that can grow into new individual plants by seed germination. The good quality of seeds can reduce replanting, increase uniformity, and promote early growth of crops, therefore the essential step in agriculture is the selection of good quality seeds. The production of high-yielding and quality crops is maximised by applying agricultural practices.

Selection and Sowing of seeds

Plant growth generally depends on the quality of seeds. Seed selection can improve the better production of crops by selecting efficient seeds. There are various diseases in plants that can be transmitted through seeds, therefore obtaining seeds from healthy plants is essential for agriculture. Sowing is the process of scattering selected seeds into the initially prepared soil. The following features of seeds are necessary during the selection of seeds for sowing:

- Seeds should be free from infection.
- They should have a high germinating capability.

- A particular seed should not be mixed with other seeds or weeds.
- They should give desired crop production.
- The broken or crushed seeds should be avoided.
- They should be disease-resistant.
- They should have the ability to tolerate adverse conditions.

Selection of seed : Seed selection plays an important role in paddy cultivation. The seeds selected for cultivation should be of uniform size, age and free of contaminants. They should also have good germination capacity.

Separation of quality seed : To separate good seed from bad, soak them in water: the unviable seeds will float on the surface of water. These seeds can be easily emoved and the seeds that sink can be used for cultivation. By this method, damaged seeds are easily removed. Another method is used when there is an excess of chaffy grain in the seed stock. Take some water in a vessel and drop an egg in it. Keep adding salt slowly till the egg reaches the surface. When the seeds are dropped into the water, the good quality seeds will sink. Remove the unviable seeds that float on the surface of the water. Wash the selected seeds in good water 2–3 times to remove the salt deposits. If this is not done, the germination capacity of the seeds will be affected.

Seed rate : The seed rate varies according to the variety to be cultivated. The seed rate required for one hectare of land under irrigated condition is given below:

Short duration variety	:	60-70 Kg
Medium duration variety	:	40-60 Kg

Long duration variety	:	30-60 Kg
Dry and rain fed sowing	:	85 - 100 Kg

Germination test : The germination test is considered the most important quality test for evaluating the planting value of a seed lot. The test is designed to measure the ability of seeds to produce normal seedlings and plants later on. The various ways of performing a germination test are listed below:

- Tie a handful of seeds in a white cloth, soak it in water for 12 hours and keep in a dark place for 24 hours. Check the germination percentage the next day.
- Tie paddy straw together to make it into a mat. Keep the seeds in the centre of the mat and then roll and tie it. Dip it in water for a minute and transfer the seeds to straw. After 24 hours, count the seeds that have germinated.
- Take a wet gunny bag, fold it, put the seeds in between the two layers and keep the bag in the dark for a day. Check the germination the next day.

Treatment

Seed treatment helps to improve germination potential, vigour, and resistance to pests and disease. The different methods of rice seed treatment are:

- **Soaking the seeds in water** : Tie the seeds in a small gunny bag or cloth bag and soak it in water for 12 hours. Later, remove the bag from the water and cover it with a moist gunny bag. The following day, soak the seeds in water for eight hours again. Later, remove the seeds from the water and sow them in the nursery. This method helps to improve the germination capacity of the seeds.
- **Using cow dung solution** : Treating paddy seeds in a cow dung solution enhances their germination. Take 1⁄2 kg of fresh cow dung and two litres of cow urine and dilute them with five litres of water. Soak 10–15 kg seeds first in water for 10–12 hours and then in the cow dung solution for 5–6 hours. Dry the seeds in the shade before sowing them in the nursery.
- **Using goat dung solution** : Treating 30-day old seeds for one day in a goat dung solution increases their germination. Using cow's urine solution Dilute 500 ml of cow's urine in 2.5 litres of water. Tie the seeds in small bags and soak them in the urine solution for half an hour. Dry the seeds in the shade before sowing them.
- **Using sweet flag extract** : Dissolve 1.25 kg of sweet flag rhizome powder in six litres of water. Tie the seeds in small bags and soak them in the extract for half an hour. Dry the seeds in the shade before sowing. (This is the quantity required for treating seeds to be sown in one hectare.) Using Salvadora persica Spread the leaves of Salvadora persica at the bottom of a closely- knit bamboo basket, then fill it with seed and pour about 10 to 12 litres of water over the basket. Cover the basket with the Salvadora leaves and place a weight over it. Leave the seeds undisturbed for 24 hours. The seeds are then ready to be used for sowing in the nursery. This procedure helps in early and vigorous germination. Treatment of rice seed with amrut pani/panchagavya/cow pat pit manure/jeevamrut is also effective. The efficiency needs to be evaluated.
- **Using biofertilisers** : Biofertilisers like azospirillum/azotobacter/pseudomonas (@ 1.25 kg/ha) are first mixed in one litre of cooled rice gruel. Spread the sprouted seeds on a clean floor, add the biofertiliser slurry and mix well. The mixing of seed and biofertiliser slurry can be done in a pot as well. Dry the seeds in the shade for 30 minutes before sowing. Drying the seeds for half an hour in the bright sun before sowing improves germination and seedling vigour.

SOIL SAMPLING

Soil sampling, processing and storage

Soil sampling

Principle

Soil testing is an essential component of soil resource management. Each sample collected must be a true representative of the area being sampled. Utility of the results obtained from the laboratory analysis depends on the sampling precision. Hence, collection of large number of samples is advisable so that sample of desired size can be obtained by sub-sampling. In general, sampling is done at the rate of one sample for every two hectare area. However, at-least one sample should be collected for a maximum area of five hectares. For soil survey work, samples are collected from a soil profile representative to the soil of the surrounding area.

Materials required

1. Spade or auger (screw or tube or post hole type)
2. Khurpi
3. Core sampler
4. Sampling bags
5. Plastic tray or bucket

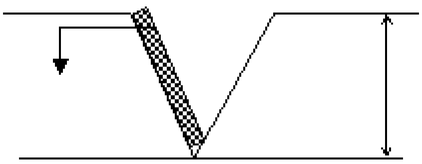
Points to be considered

1. Collect the soil sample during fallow period.
2. In the standing crop, collect samples between rows.
3. Sampling at several locations in a *zig-zag* pattern ensures homogeneity.
4. Fields, which are similar in appearance, production and past-management practices, can be grouped into a single sampling unit.
5. Collect separate samples from fields that differ in colour, slope, drainage, past management practices like liming, gypsum application, fertilization, cropping system *etc*.
6. Avoid sampling in dead furrows, wet spots, areas near main bund, trees, manure heaps and irrigation channels.
7. For shallow rooted crops, collect samples up to 15 cm depth. For deep rooted crops, collect samples up to 30 cm depth. For tree crops, collect profile samples.

8. Always collect the soil sample in presence of the farm owner who knows the farm better

Procedure

1. Divide the field into different homogenous units based on the visual observation and farmer’s experience.
2. Remove the surface litter at the sampling spot.
3. Drive the auger to a plough depth of 15 cm and draw the soil sample.
4. Collect at least 10 to 15 samples from each sampling unit and place in a bucket or tray.
5. If auger is not available, make a ‘V’ shaped cut to a depth of 15 cm in the sampling spot using spade.
6. Remove thick slices of soil from top to bottom of exposed face of the ‘V’ shaped cut and place in a clean container.



1 inch / 2.5 cm 6 inches (15 cm)

1. Mix the samples thoroughly and remove foreign materials like roots, stones, pebbles and gravels.
2. Reduce the bulk to about half to one kilogram by quartering or compartmentalization.
3. Quartering is done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters are discarded and the remaining two quarters are remixed and the process repeated until the desired sample size is obtained.
4. Compartmentalization is done by uniformly spreading the soil over a clean hard surface and dividing into smaller compartments by drawing lines along and across the length and breadth. From each compartment a pinch of soil is collected. This process is repeated till the desired quantity of sample is obtained.
5. Collect the sample in a clean cloth or polythene bag.

6. Label the bag with information like name of the farmer, location of the farm, survey number, previous crop grown, present crop, crop to be grown in the next season, date of collection, name of the sampler *etc*.

Collection of soil samples from a profile

1. After the profile has been exposed, clean one face of the pit carefully with a spade and note the succession and depth of each horizon.
2. Prick the surface with a knife or edge of the spade to show up structure, colour and compactness.
3. Collect samples starting from the bottom most horizon first by holding a large basin at the bottom limit of the horizon while the soil above is loosened by a khurpi.
4. Mix the sample and transfer to a polythene or cloth bag and label it.

Processing and storage

1. Assign the sample number and enter it in the laboratory soil sample register.
2. Dry the sample collected from the field in shade by spreading on a clean sheet of paper after breaking the large lumps, if present.
3. Spread the soil on a paper or polythene sheet on a hard surface and powder the sample by breaking the clods to its ultimate soil particle using a wooden mallet.
4. Sieve the soil material through 2 mm sieve.
5. Repeat powdering and sieving until only materials of >2 mm (no soil or clod) are left on the sieve.
6. Collect the material passing through the sieve and store in a clean glass or plastic container or polythene bag with proper labeling for laboratory analysis.
7. For the determination of organic matter it is desirable to grind a representative sub sample and sieve it through 0.2 mm sieve.
8. If the samples are meant for the analysis of micronutrients at-most care is needed in handling the sample to avoid contamination of iron, zinc and copper. Brass sieves should be avoided and it is better to use stainless steel or polythene materials for collection, processing and storage of samples.
9. Air-drying of soils must be avoided if the samples are to be analyzed for NO3-N and NH4-N as well as for bacterial count.

10. Field moisture content must be estimated in un-dried sample or to be preserved in a sealed polythene bag immediately after collection.
11. Estimate the moisture content of sample before every analysis to express the results on dry weight basis.

Guidelines for sampling depth

S.No.	Crop	Soil sampling depth	
		Inches	**cm**
1	Grasses and grasslands	2	5
2	Rice, finger millet, groundnut, pearl millet, small millets *etc*.(shallow rooted crops)	6	15
3	Cotton, sugarcane, banana, tapioca, vegetables *etc*. (deep rooted crops)	9	22
4	Perennial crops, plantations and orchard crops	Three soil samples at 12, 24 and 36 inches	Three soil samples at 30, 60 and 90 cm

WEED AND IRRIGATION MANAGEMENT

Weed management

No chemical herbicide is used in organic farming. Here weeding is done by machine or by hand. When the field is fallow, a cover crop may be planted to suppress weeds and build soil quality. Drip irrigation may be adopted whenever possible, to restrict weed growth by distribution of water to the plant line only. Another tool that sometimes may be used is a 'flame weeder,' a propane device that attaches to the back of a tractor and directs flames toward the ground. In this method land is irrigated to germinate weeds and then "flame" is used to kill weeds and weed seeds before planting.

Irrigation supplies crops and other plants with necessary water and sometimes nutrients may be applied as well. In organic farming, conservation is important in irrigation practices, as is sustainability. While you certainly can irrigate organic crops similar to conventional ones, be sure to also focus on overall water usage and other factors, such as energy usage, as you design an irrigation system for your organic farm.

Although organic doesn't inherently mean environmentally friendly, growers should try their best to use an irrigation method that helps conserve water and energy. For example, a producer could use wastewater or a solar-powered irrigation system, which can save money, time and water.

Methods

Irrigation methods for all farms — organic and conventional — obviously will differ depending on climate and the type of crops that you're planning to grow. For example, the Congressional Research Service (CRS) notes that:

"Producers who irrigate in arid areas are more likely to use irrigation throughout the growing process (full irrigation), while producers in more humid areas may use irrigation to supplement rainfall and soil moisture under drought conditions."

There are many kinds of irrigation methods in use on farms, including organic farms:

- **Drip** systems deliver water to the roots of crops via low-pressure pumps at ground level or below the soil surface.
- **Surface** methods use gravity to move water across the land downhill, without a pump.
- **Center-pivot** systems, which require a pump, are where the water flows from a series of sprinklers located on towers with wheels. This type of irrigation is common on flat, large farms, and can irrigate a 130-acre area.
- **Manual** methods, which is only practical for very small farms, have workers move the water manually to the crops.

Meanwhile, the water itself can come from the local water utility (assuming one is available), from on-site wells, from rainwater collection, or even from treated wastewater. Farmers need to protect their water source to make sure it's clean and to ensure there's enough to keep the crops healthy.

Application

Organic farms tend to be smaller on average, and so their irrigation systems should match their scope. It's hard to beat the simplicity of manual irrigation for a tiny organic farm — you can add water when and where it's needed, and let the rain take care of the rest. But once your farm gets a bit bigger, you'll almost certainly need to consider alternatives to manual labor.

Drip irrigation systems, in particular, may be well-matched to the needs of small organic farms. They require less water, and they allow the application of nutrients along with water to crops. Also, they require less energy, since the pumps used are low-power. However, drip irrigation may cost more to install — some estimates indicate they cost up to $1,200 per acre and they also may require more maintenance.

Surface irrigation can also work well for organic farms, especially with closely spaced crops that feature deep roots. Some farms use renewable energy sources, such as a solar array or wind generators, to pump the water uphill to storage tanks, and then release the water and let gravity move it down the fields.

UNIT 3

HISTORY OF COMPOSTING

This practice of sustainable gardening was first recorded on clay tablets of the Mesopotamian Akkadian Empire dated back to 2334 BC. Composting practices were also recorded in ancient Greek, Roman, Egyptian, Native American, Scottish and Chinese societies. Composting was referenced in the Bible and the Talmud, as well as mentioned in many literary works, including the writings of William Shakespeare and Sir Francis Bacon. In early United States history, George Washington, Thomas Jefferson, James Madison and George Washington Carver were all advocates for using compost as fertilizer. Composting History Over the Ages Though it is impossible to trace the exact origins of composting, in the early 1900s, British agronomist Sir Albert Howard popularized modern day sustainable gardening practices. After spending nearly thirty years in India studying and experimenting with composting practices, Sir Howard published the book An Agriculture Testament, detailing his "Indore Method" of layering compostable materials in the compost pile. By this point, manufactured chemical fertilizers had made home composting nearly obsolete, but Sir Howard's work shed a new light on the subject. In the 1960s, J.I. Rodale continued Sir Howard's work and popularized composting and other organic gardening methods in the Unites States through his many publications. Today, composting continues to gain popularity as a simple way to reuse waste. For decades, large cities all over the world have been experimenting with city-wide composting programs to reduce municipal waste. Approximately 25% of the waste that is hauled away by municipalities and disposed of in landfills or incinerators is compostable waste that would be better used to fertilize our gardens. Composting can be done in a large city-wide capacity or in small specially designed compost bins for small gardens. These days composting is not just an easy way to save money and recycle waste, it is also becoming a booming industry. The rise in popularity of organic gardening and composting has created new job opportunities in waste management and processing, and the manufacture of composting bins and tools. Following in J.I. Rodale's footsteps, each year hundreds of new publications advocate different methods of composting. With the increasing interest in all the benefits of composting, it certainly isn't just a fad that will fall out of fashion again any time soon. Printer Friendly Version This article was last updated on 03/22/22

Read more at Gardening Know How: How Old Is Composting: Learn About The Origins Of Composting

INGREDIENTS IN COMPOSTING

Compost Materials Chart

In this chart, you'll find an exhaustive list of what materials can be composted. But composting isn't only about what you put in.

It's also what you leave out, how much you use, and how you combine them together.

As a quick reminder, here is a checklist of what's needed for good decomposition in your composter:

What are the basic materials for composting?

There are four essential ingredients in composting:

- Nitrogen (Green organic matter)
- Carbon (Brown materials)
- Water
- Oxygen

Each of these elements is needed for the rotting process to function correctly. They should also be supplied in the correct proportions.

So keep in mind, successful compost is a bit of a balancing act.

Types of material used in compost

The checklist below classifies materials into two types:

- *Green*
- *Brown*

Compost Material:	Can I compost this?	Green or Brown:	Notes:

- **Green materials** are those that are **high in nitrogen** and tend to be **wetter types of ingredients**.
- **Brown matter** is **high in carbon** and generally has a **dry appearance**.
- These two types of compost materials obviously affect the moisture content, which is part of the balancing act of composting. However, oxygen supply is mostly a matter of airflow and proper aeration techniques.

Brown leaves	Yes	Brown	An excellent and abundant source of carbon. Collect them in the fall. Shred before composting for better results.
Green plants	Yes	Green	Adds plenty of bulk. A good source of nitrogen.
Twigs & branches	Yes	Brown	Harder to decompose but can add structure for aeration.
Pine needles	Yes	Brown	Could be considered “green” is fresh-cut branches. Be careful, with the quantity – pine needles are acidic.
Cornstalks/husks	Yes	Brown	Very hard to break down, so chop them up before composting.
Weeds	Yes	Green	Bury them in the center of the pile to thermally kill the seeds – add some extra nitrogen material to help them cook.
Flowers	Yes	Green	Source of nitrogen when fresh.
Grass clippings	Yes	Green	A high-nitrogen source. Mix them with browns such as dried leaves to avoid matting and improve air supply.
Straw & hay	Yes	Brown	Good source of carbon, and adds structure. Should be mixed with greens to help decomposition.
Straw bedding	careful	Brown	Straw bedding from animals can be used if they are herbivores. If the animal eats meat it can contain pathogens.
Sawdust	Yes	Brown	A good source of carbon that breaks down quickly. Avoid plywood chips – the glue is potentially toxic to microbes.
Diseased plants	No	Green	You risk spreading the disease further in your garden if your compost isn’t hot enough.
Plants with pesticides	No	Green	Avoid any chemically treated material. The chemicals could also kill off the composting microorganisms.
Spent grains / beer hops	Yes	Green	The leftover sugars are great food for composting microbes. Spread them thinly and mix them with browns to avoid

			anaerobic conditions.
Fruit & vegetable scraps	Yes	Green	Fruit and vegetables are a good source of nitrogen and moisture.
Cooked food	No	Green	Avoid cooked food waste which is cooked with fats. This is slow to decompose and can attract pests.
Bread & pasta	Yes	Green	Includes cookies, rice, etc. Bury these things in your compost to avoid attracting pests.
Tea & tea bags	Yes	Green	The metal staples on bags are too small to be worried about. Leave them in.
Coffee grounds & filters	Yes	Green	An excellent source of nitrogen. Can also discourage pests thanks to the odor.
Peanut hulls	Yes	Green	Contributes nitrogen and breaks down quite quickly. Other nut shells are long to decompose.
Eggshells	Yes	–	Contains about 95% calcium, which could be a useful amendment for plants. Grind them up before composting.
Fish	No	Green	Attracts pests and is generally full of fats, which slow down composting. Produces bad smells. Can contain bacteria which is a safety issue.
Meat scraps	No	Green	Decomposes slowly, smells bad, and can attract vermin and flies. Can contain bacteria which is a safety issue.
Bones	No	Green	Bones decompose very very slowly. Not worth putting in compost.
Dairy products	careful	–	High in fats which slow down composting and should generally be avoided. But it can be composted if buried deep in compost

Oils & fats	No	Brown	As a general rule, oil and grease contaminates compost ingredients and prevents the microorganisms from doing their job.
Wood ash	Yes	Brown	A good source of potash (potassium-nitrate). Best added in layers because it washes away easily.
Coal ash	No	Brown	Avoid coal ash which can be toxic to plants. Don’t use ash from barbecues which can be contaminated with meat fat.
Seaweed	Yes	Green	Kelp is low in nitrogen but contains potassium and many other minerals.
Paper	Yes	Brown	In general, paper and cardboard should be shredded before composting.
Newspaper	Yes	Brown	Shred before use. Most printing inks now use vegetable dyes.
Manure from herbivores	Yes	Green	A good source of nitrogen. Often mixed with bedding like straw or wood shavings, which also adds carbon.
Cat litter	No	Green	Not considered safe because manures from meat-eating animals can contain harmful bacteria or parasites.
Dog poop	No	Green	Avoid manures from meat-eating animals because of safety concerns.
Dryer lint	Yes	Brown	The carbon content can help add structure.
Vacuum dust	Yes	–	No reason not to use it.
Hair	Yes	Green	Human and animal hair can be composted.
Feathers	Yes	Green	Feathers contain a lot of nitrogen.
Soil	Yes	–	Soil is good to add to compost when you have a large amount of fresh material. It contributes useful microbes & helps inoculate the pile.

Used potting soil	Yes	–	Even if slightly depleted it contributes useful humus.

COMPOSTING METHODS

AirCompost needs to be aerated or it creates an anaerobic environment for bacteria which produces unpleasant odours and attracts verminWaterEssential to keep the compost moistVegetable MatterEssential to obtain organically rich compostWormsDigest decomposed matter and release worm castings that provide plants with the nutrients they need for growthCarbon-nitrogen mix (brown and green waste)Essential to create the right temperature for creating compost from green waste and to kill seeds and diseaseBacteria (EMO's)Will decompose the food before the worms eat itSoldier FliesNot essential but devours waste food quicker than worms or bacteriaOther Beneficial BugsCockroaches and other insects that help in the decomposition process (including maggots if putting meat in a compost pile – not recommended for most composters except the Compot.

Elements Generally Required In Most Systems In Order To Produce Compost.

1. Open Air Composting

- Organic yard debris like grass clippings, leaves, twigs, etc. can be composted utilising the open-air approach.
- They are brought, sifted to remove any unwanted items, and then shredded. Once finished, the shredded waste is stacked in neat rows outside. Naturally occurring microorganisms then devour them, releasing heat and steam through the windows.
- Regular turning of the rows is necessary to provide sufficient oxygen for the microorganisms to thrive.

Advantages of Open Air Composting

- Farmers that have a lot of green waste to mulch with animal manure can benefit greatly from open air composting.
- Chickens benefit greatly from outdoor piles for the purpose of foraging and catching food.
- If you have the time, an outdoor composting system is ideal.

The price tag is more reasonable.
Disadvantages of Open Air Composting

- Worms are attracted to open-air composting, although some may leave if the conditions are unfavourable.
- Similarly to how pH is essential, temperature is also a crucial element. If the necessary temperature is not attained, it will not disintegrate and may become a huge mess.
- Due to the mild temperatures, both snakes and rats are able to nest and reproduce in these systems. It must be turned frequently for aeration.
- Large quantities of green waste are required to produce a little amount of compost. If they are packed with the incorrect materials, they may emit an objectionable stench. The same phenomenon occurs when there is no compost turning.
- Composting in the open air necessitates a large amount of garden space and demands the dispersal of materials around the garden.

Direct Composting

- Direct Composting involves digging a pit or trench and burying food leftovers.
- It is likely the oldest and most effective way of composting, but like all other systems, it has limitations.
- The primary disadvantage is that it takes a long time to disintegrate unless everything is chopped apart.

Process

1. Create a hole around 12 inches (30 centimetres) deep and place your kitchen scraps within.
2. Mix in at least as much brown debris (shredded leaves, paper, ashes, nut shells, used potting soil) and cover the top of the hole with soil that has been removed.
3. As with any sort of composting, avoid composting meats, peanut butter, dairy, fatty meals, sick plants, carnivore faeces, charcoal fire ashes, and glossy paper.
4. In as little as a month, your subterranean stew should transform into nutrient-rich compost that can be used to feed neighbouring plants or enrich a future garden bed.

5. Make the hole in an empty area of the garden where you have no plans to plant this year.
6. Alternately, dig composting trenches between your vegetable or flower rows. The following year, plant where the compost has developed, and compost where the plants grew the year before. In big garden plots, a three-year crop rotation, compost trench, and path can be established.

Advantages of direct composting

- There is no need to turn the compost. Once the leftovers and brown material have been buried, your work is complete.
- Also, there is no need to transport the completed compost. Wherever it is buried is where it will enrich the soil.
- At this deep root level, plants benefit from receiving their dose of compost nutrients.
- Direct composting eliminates the risk of unpleasant odours and unattractive mounds.

Disadvantages of direct composting

- Animals, including the family dog, the local raccoon, and a hungry bear, may dig into your compost and destroy your garden as a result (this can be a problem with compost piles and bins too). The remedy is the same as it is for any of the larger garden pests: ensure that your beds are protected by sturdy, high, and tight fences.
- With direct composting, the compost is produced on-site. In most circumstances, it is impractical to dig it up and use it elsewhere in the garden.

3. Tumbler Composting

- Tumbler Composting is available commercially or as a do-it-yourself project in a variety of sizes and configurations ranging from single to double units.
- This is an excellent system provided you are somewhat strong and willing to turn it daily or every few days.
- Others find it difficult, especially as they advance in age. However, you can obtain motorised ones that facilitate turning.
- You often need two of these systems so that you may let one rest for a few months before emptying it. While this is occurring, you fill the second container.

- If you have a considerable amount of green and brown waste to dispose of and the space to accommodate this system, it may be an excellent option. However, similar to the bay system, a small amount of soil requires a substantial volume of garbage.
- If you're only adding green and brown garbage, a bay system would suffice, but you'll need to keep an eye out for snakes and rats nesting in the warm compost due to a lack of space.

Pros And Cons Of Tumbler Composting

- Worms are frequently added, which may be ineffective because they will die if the temperature rises.
- The correct mixture is essential, as the tumbler can become a foul-smelling slushy mess or a solid mass.
- While the first one decomposes, the second one is being filled.
- Equally unfavourable are excessive and insufficient degrees of rotation.
- Only particular foods can be introduced, and decomposition takes a lengthy period.
- It takes a huge amount of green garbage to produce a tiny amount of compost. It involves constant, laborious labour that some individuals find too difficult.
- However, it is terrific workout for some individuals.
- It is noticeable and occupies yard space, particularly if you have two.
- Inconsistent turning may lead the contents to clump into a large mass, making it extremely difficult to turn and empty.
- Unless insulated, they will only function in the summer.
- If infested with Soldier flies, it might be unpleasant for some individuals to open the door and be met with a swarm of flies. Identical to a worm farm
- The Soldier Flies may make the air stink.
- Depending on the size, this is a great option for your green garbage, but it may be too little.
- Green waste must be shredded in order to fit certain containers and to decay more rapidly.
- If you do not turn them, the acid produced by food waste can corrode the bottom of metal containers. A frequent occurrence when people fail to turn them off
- They have been known to emit foul odours depending on the contents.

- Similar to an open-air system, you would need to monitor the heat produced inside.
- Small containers can be purchased instead of large containers, so conserving room. Double containers can be obtained so that you can alternate between filling and resting one.
- After a few months of resting, it produces wonderful compost.
- You cannot dispose of ALL kitchen waste with these systems. Only fruit, vegetables, and paper or cardboard
- If you do none of these things and simply put your garbage in and allow it to sit and degrade, it will function, but it will be difficult and time-consuming to finally turn and empty.
- Similar to the open-air method, you need two to three bins, depending on the amount of waste, for them to function effectively.

Worm Farm Composting

- For many, Worm Farm Composting is the most popular and favoured method of composting due to its capacity to cultivate worms, produce compost and compost tea, and keep rodents out of the compost.
- Worms create castings that are rich in nutrients but contain less nitrogen than other composting methods.
- Worm farms can be used even if there is no garden available.
- Copper, which is poisonous to your worms, leaches from metal containers.
- Using plastic containers to collect the juice necessitates the addition of a drain or a method for rotating the containers to collect the worm tea.
- They must be maintained out of the sun, frost, and rain, and in a location that is neither too hot nor too cold.
- Worms are temperamental creatures that will attempt to leave their containers if they are unhappy with their environment.
- It is recommended to utilise local worms in your region.

Pros And Cons Of Worm Farm Composting

- It is necessary to introduce worms and give bedding to preserve the worms.
- If conditions are not optimal, worms perish from overheating or freezing.
- Produces exquisite juice, which must be collected lest worms drown.

- They do generate lovely worm tea and compost, however.
- No onions, meat, oil, dairy products, eggs, or citrus may be added.
- Preferably, the worms should not be overfed.
- Decomposition requires time; worms only consume degraded food.
- For faster breakdown, it is beneficial to cut the food into small pieces, which requires a little extra effort.
- As there are no heated zones, weed seeds and tubers are not killed.
- Soldier Fly larvae can enter your worm farm and either kill the worms or crowd them out, leaving you with no worms. During the winter, when soldiers hibernate (depending on the climate), there is nothing to breakdown their excrement if it is too cold.
- When trays are full, it can be difficult to rotate and empty them.
- Worms will perish if not fed, as they are unable to roam around a garden in search of food.
- If you go for the holidays, you must arrange for someone to feed your pets.
- It is visible and occupies a minimal amount of space in your garden.
- Suitable for a garage in a modest townhouse without a backyard.
- Worm farming is a rewarding and efficient approach for producing worms and compost, according to many.

5. Emo Composting

- EMO Composting, also known as Effective Microorganisms, is a system typically used for indoor composting, but it can be utilised by anyone who prefers this way of composting or who is in an apartment.
- Bokashi is the most popular product that uses EMOs, although other indoor systems can also use it, and some systems also use a carbon filter in the lid to filter odours.
- Typically, you need two of them so that one can rest while the other is filled.
- You can collect juice to utilise in your garden.
- But you cannot use the Bokashi System for everything in your kitchen.
- Numerous online retailers offering the Bokashi System sell EMO.
- If you so choose, you can employ EMOs in other systems to enhance the composting process.

Pros and Cons of EMO Composting

- It requires Efficient Microorganisms (EMOs for fermentation / breakdown)
- This necessitates collection, but is beneficial for your plants.
- Oil, water, milk, juice, and bones should not be added, although the business has stated that they may be included.
- Once it is full, it must sit until all of the material has decomposed. Therefore…
- While the first one decomposes, you must fill the second one. This may be an issue in a unit, however it depends on the available space.
- When waste is initially buried, it is acidic and cannot be placed near plants since it could harm their roots.
- It takes seven to ten days for the garbage in the garden to neutralise. This is not an issue if the waste is buried in an acceptable location.
- You must keep the lid covered during decomposition to avoid attracting insects.
- If it is improperly closed, it can present a problem with insects inside the home.
- Bacteria alone are used to decompose garbage, thus the process is not incredibly quick.
- It occupies space in your kitchen, shed, or balcony. It requires a new hole to be dug every time it is emptied, which isn't a problem provided you have enough room.

Combination Composting

- Combination Composting, also known as Compot Composting, combines open-air composting, direct composting, vermicomposting, and EMO composting.
- All components of composting are utilised, and the method is suitable for the majority of residential situations.
- For certain individuals, it too presents obstacles. For me, though, the obstacles are fewer and the rewards are greater.
- All of your kitchen waste can be composted, not just portion.
- Consequently, you have over fifty percent less rubbish to place in your council bin each week.
- It is quicker and less labor-intensive than most other composters.
- And it enriches the soil with all of your household garbage.

Pros and Cons of Compot Composting

- Throw away all kitchen trash, including meat, dairy, citrus, eggs, onions, oil, coffee, and tea bags.
- It will compost all biodegradable materials.
- Perfect for animal waste — puppy doos etc. – gone in 20 minutes (not in your veggie garden)
- Decomposes incredibly rapidly – with the aid of the Black Soldier Fly
- There will be worms. You should not add worms unless your soil is extremely poor.
- Your worms won't perish. They take care of themselves, so you may enrich your garden without exerting any effort. You do not need to feed your worms while you are on vacation.
- By planting a few around your garden, it will provide nourishment to all of the different areas.

7. Commercial Composting

- Commercial composting differs from home composting and utilises distinct ingredients.
- Compost is produced in long rows utilising materials such as sawdust, pine bark, sand, ferrous sulphate, and sometimes some ammonium sulphate.
- It is typically bagged after six weeks and is turned every three to four days.
- The nutritious value of inexpensive commercial compost is minimal.
- There are, however, little independent commercial compost companies that produce a product of higher quality than the huge commercial compost companies. However, they are more pricey.
- The adage "you get what you pay for" holds true with commercial compost.
- The less expensive commercial compost is an excellent filler for raised garden beds or for backfilling a Compot in sandy or clay soil.
- Or it can be used with composted soil to fill raised garden beds or possibly a potted plant.
- If you are using commercial compost to grow plants, you should use a high-quality propagation mix.

Pros and Cons of Commercial Composting

- Different manufacturers employ different ingredients, thus some may be good while others are not and are frequently not sufficiently decomposed before use.
- If you require big quantities, commercial compost is ideal for filling a new garden bed or a raised garden bed because it is often inexpensive and consistent between brands.
- It varies by brand, so you must experiment with various brands to discover one you like, as it may not be quality compost.
- Depending on the quality of the ingredients and the manufacturer, the price can vary.
- Typically, small independent producers generate more expensive, superior compost.
- In the end, nothing beats generating your own compost. You are aware of what goes in and what comes out. No additional chemicals or fertiliser. Consequently, if you cultivate your own vegetables, you are aware of what goes into the soil. It is difficult to tell exactly what is in your food if you purchase it commercially unless you get certified organic compost.

Mechanical Composting

- Mechanical Composting is an effective method of composting that employs electricity to generate the necessary heat and rotation of the contents to produce semi-composted trash in less than 24 hours.
- This system is ideal for restaurants, hotels, motels, hospitals, schools, and kindergartens, as well as any other major institution that generates large amounts of garbage from several individuals.
- It is a manageable in-house system as opposed to sending waste to municipal dumps. However, you must further compost the trash, thus you need someone to collect the remaining contents for further composting in a garden bed or bay composting system.
- There are also small systems that may be suitable for private residences, but they can be rather costly and will, of course, incur continuing electrical costs. Like all composters, they have advantages and disadvantages, but they generate semi-composted soil rapidly.

Advantages of composting

Affordable and waste-minimizing

Composting not only provides a cheap, abundant input for the garden, but also reduces household or garden waste and is a way of efficiently managing disposal of unwanted material in the home.

Enriches the soil with nutrients and healthy bacteria

It provides nutrients which may not be available in the original soil. Compost as a nutrient source is highly versatile and can be used for growing crops, maintaining garden perennials or planting of annuals. Also, it supplies a range of healthy bacteria to the soil which help to improve the soil environment by reducing the risk of disease from other unwanted bacteria or fungus.

Supplies the soil with essential humus

Once mixed into soil, compost gradually converts into humus. This is broken down leaf matter and is incredibly useful for growing of plants and crops as it holds up to ninety per cent of its own weight in water therefore helping to keep soil moist. As well as holding moisture, humus is able to keep soil aerated through texture, and acts as a buffer in acidic or alkaline soils by regulating pH.

A better balance of Nitrogen, Phosphorus, and Potassium

Natural compost has a balance of N, P and K along with microorganisms which means that plants will be supplied with a rich mix of the nutrients they actually need. Synthetic fertilizers on the other hand, though nutrient-dense, often have excessive nitrogen levels to save on costs which is either wasteful or harmful to the development of plants.

Absolute control of materials being composted

Composting at home allows materials to be selected carefully, whilst store-bought compost may contain undesirable contents as a result of low-grade input materials of unknown origin. Though not always detrimental to plant and crop health, materials such as sewage sludge often contain high concentrations of harmful bacteria and heavy metals which may remain active in the final compost product.

Improve soil texture

In clay soils, good compost well-mixed into the soil can increase permeability which is important for most plants and crops grown in the garden. For sandy soils, it can help to provide extra nutrients and improve the nutrient-holding capacity of the soil by reducing the quantity of nutrients washed away through watering and rain.

Improves workability of the soil

Good compost improves the workability of garden soil and makes planting and maintenance easier once mixed in as needed. If prepared properly, home-made compost can be of much higher quality and suitability to local environments than commercial equivalents.

Advantages of vegetable composting

Vegetable composting involves separating green and vegetable materials from odoriferous food items such as meat and eggs to be composted. One of the main advantages, particularly to house-keeping is separation of organic and inorganic material in the kitchen.

It helps to prevent unwanted odors

Separating out waste food from waste packaging and other recyclable materials means that the decomposing food can be stored in a smaller receptacle elsewhere, for example outside or close to a back door. The smaller container holding the waste food can be transferred directly to the composter once full or once smells start to arise.

Also, there are indoor composters available commercially which can be used to compost small quantities of weekly vegetable food waste. These units are specially designed to compost indoors by controlling unwanted smells and by preventing the introduction of unwanted pests or disease.

Helps to recycle nutrients

As well as using up unwanted food scraps and providing a useful repository for vegetable waste, vegetable composting helps to close the nutrient loop from vegetables grown locally to return them back to the soil rather than losing them to landfill.

Time efficiency and less energy

If building or managing a composter is deemed too time-consuming, vegetable waste can simply be chopped up, tipped into a trench roughly one-foot deep and covered with soil. If done several months before the growing season, plants or crops can be seeded directly above the vegetable waste which will have decomposed into a source of humus, nutrients and moisture.

Advantages of garden composting

As with kitchen composting, using waste garden material reduces the need to transport waste to dump sites, and can potentially save on costs. By composting garden waste, money and labor is saved both on the cost of disposing garden waste and on the purchasing and carrying of soil additives such as manure. Garden composting is also much less likely to create bad odors or attract large pests, as the contents are less nutritious than vegetables or fruits and therefore less appealing.

Disadvantages of composting

Composting cane be time consuming, the time needed to allow waste material to break down into a useable garden materials is one of the major disadvantages of composting. The time taken varies depending on local climate, the materials used and the presence or absence of organisms able to break the material down before its use.

Increases the risk of unwanted infestations

Many different unwanted organisms can use the non-decomposed matter as a source of food, and may be attracted to the area which can create problems. Such problems, which include rats and other pests can however be managed through the use of appropriate repellents, baits or composter design.

Composting is energy intensive and restricted in some areas

It requires a great amount of energy from gardeners to build and manage compost completely, and not all municipalities allow it due to the potential for attracting unwanted vermin. If looking to compost, it is worthwhile finding out which local rules apply, and choosing a composting method accordingly. If the use of a composter is not allowed on the grounds of environmental safety, it may be possible to use the method for burying vegetable waste in a trench and covering with soil as a means of composting without the risk of pests.

How to speed up the composting process:

1. Sort out materials in order of speed of decomposition. Food items should be kept aside from garden waste. Garden waste generally has a much higher cellulose content which is harder to breakdown; therefore keeping this separate from food waste will allow usable compost to be available from the food composter in a much shorter space of time. Materials can also be cut up to reduce their surface area which helps to reduce composting times.

2. Ensure that whatever item you are using to make the compost is constructed and positioned appropriately. The organisms which break down food material require oxygen, water and heat as well as energy from the food; therefore making sure the composter provides these inputs ensures a faster rate of decomposition.

3. Oxygen supply can be aided through the incorporation of holes or gaps into the composter design. If the composter is made from brick, these should be positioned

with small gaps in between to provide a flow of air, whilst wooden composters can have holes drilled into the sides or parts constructed from pallets and netting to provide natural gaps.

4. Temperature and water can also be controlled depending on local climate. If in a hot, dry climate the composter should be positioned out of direct sunlight to retain moisture as much as possible, to avoid bad odors and to minimize the risk of attracting pests. Water can also be added sporadically to ensure that the composter contents are sufficiently moist.

Compost needs warmth to decompose quickly. In a cooler climate, position the composter somewhere with exposure to sunlight at some point during the day to increase microbial activity.

However, given that the bacteria breaking down the matter create their own heat, composter temperature is less important than the moisture level. For garden composters, water will need to be added on a reasonably regular basis, and can also have some NPK fertilizer added to speed up the composting process.

Isolation of Rhizobium:

Rhizobium is a symbiotic N_2 fixer found to occur as bacteroids in the root nodules of leguminous plants. They can be easily isolated and cultured in vitro. Rhizobia are Gram-negative rods which are motile with bi-polar, sub-polar and peritrichous flagella.

Principle:

Rhizobium grows well on Yeast Extract Mannitol Agar (YEMA). Congo red added to the medium differentiates rhizobia stand out as white, translucent, glistening elevated, small colonies with entire margin, in contrast to the red stained colonies of Agrobacterium.

Requirements:

1. Root nodules (pink) of Phaseolus.

2. **Congo red, Yeast Extract, Mannitol Agar (pH 6.8 – 7.0):**

Congo red (1% aqueous)

2.5 ml (1.0 g in 100 ml)

Distilled water 1000.0 ml

3. Inoculation loop/needle.

4. Bunsen burner/laminar clean air flow hood.

5. Slides and glass rod.

6. Petri plates and tubes with YEMACR.

7. Sterile distilled water.

10. 95% alcohol and 0.1% $HgCl_2$.

Procedure:

1. Loosen the soil around an actively growing Phaseolus plant about 14-16 cm away and uproot it slowly.

2. Wash the root system under a slow stream of running tap water, taking care to see that the nodules are intact.

3. Select pink nodules, remove them by keeping a bit of root on either side.

Wash and keep the nodules in 95% ethanol for a minute, wash and transfer them to 0.1% $HgCl_2$.

5. Remove after five minutes and wash the nodules about four to five times with sterile distilled water.

6. Place the nodule on a sterile slide in a drop of sterile distilled water and crush it either with a sterile glass rod or a flat tipped forceps (plucker).

7. Remove a loopful of this cloudy suspension and streak inoculate on YEMACR plates and label.

8. Incubate in dark at 28°-30°C for 2-3 days.

9. Mucoid colonies which do not take up congo red appear on the agar medium.

10. Subculture them on YEMACR slants and store for authentication and further use.

IDENTIFICATION OF RHIZOBIUM

1. A bacteria called *Rhizobium* is found in soil and aids in the nitrogen fixation process in leguminous plants.
2. It grows nodules and affixes to the leguminous plant's roots.
3. These nodules capture air nitrogen and transform it into ammonia, which the plant can use to grow and develop.
4. A typical nodulation experiment can be used to distinguish between different *Rhizobium* species.
5. This requires the development of a host plant that has been injected with the *Rhizobium* species.

6. They resemble elongated rod-shaped cells with dimensions of 0.5–0.9 m in width and 1.2–3 m in length when viewed under a microscope.

MASS CULTIVATION OF RHIZOBIUM

Bacteria to be inoculated in soil as biofertilizer need to be multiplied on artificial media to harvest on a large scale so that it can be supplied to farmers.

Rhizobium

Species of *Rhizobium* are kept in different specialization groups. Inoculum of different strains are prepared separately and cultivated on large scale, as required. Strains of *Rhizobium* sp. are grown in Yeast Extract Mannitol (YEM) broth in a small or large container as needed. Chemical composition of YEM broth is as below :

Yeast extract	1g
Mannitol	10g
K_2HPO_4	0.5 g
Mg SO^4 $7H_2O$	0.2 g

NaCl	0.1 g
Distilled Water	1000 ml
pH	6.5 - 7.0

Methods of Cultivation

Following are the steps of mass cultivation of *Rhizobium.* *(a)* sterilize the growth medium and inoculate with broth of mother culture prepared in advance, *(b)* incubate for 3-4 days at 30 - 32°C, *(c)* test the cultures for its purity and transfer to a large fermenter, wait for 4-9 days for bacterial growth (for good bacterial growth make the device for its aeration), *(d)* allow to grow the bacteria either in a large fermenter containing broth or in small flasks as per demand, *(e)* check the quality of broth, *(f)* blend the broth with sterile carrier *e.g.* peat, lignite, farmyard manure and charcoal powder, *(g)* pack the culture in polyethylene bags and keep at 25°C, *(h)* check the quality of carrier culture, *(i)* store at 4°C in a controlled-temperature room, and *(j)* supply to farmers.

During the blending of broth a variety of carriers are used, for example, peat, lignite, farmyard manure, charcoal powder, etc. In India powdered farmyard manure and charcoal powder are good carrier and an alternative to peat and lignite. Good quality of carrier culture is that which contains sufficient amount of rhizobial cells *i.e.* 1000×10^6 to 4000×10^6 rhizobia/g carrier. Seed inoculation with aqueous suspension of carrier culture during sowing has revealed the luxuriant nodulation and good yield of crops.

Methods of seed inoculation with rhizobial culture

The steps of seed inoculation with rhizobial culture are given in Fig. 12.1. Dissolve 10 per cent sugar or *gur* (jaggery) in water by boiling it for some time. Leave the content to cool down. Gum arabic solution (10%) may also be added to the solution. This serves as sticker for *Rhizobium* cells to seeds. Mix this carrier based culture of *Rhizobium* to form the inoculum slurry. For one hectare, 400 g charcoal based culture would be sufficient for mixing the seeds. Transfer the inoculum slurry on seeds and mix properly. The number of rhizobial cells/ seed should be between 10^5 to 10^6. Spread the seeds in shade for drying on cement floor or plastic sheets.

While using rhizobial cultures, certain precautions are taken into account. For example, use of culture before expiry date, use of small amount of pesticides when required, immediate sowing of seeds after mixing, etc. Seeds must be stored at 4°C when not used immediately to protect the rhizobial cells.

Pelleting

When soil has the adverse conditions such as dryness, acidity, excess fertilizers and pesticides, etc., the rhizobial cells are protected by adopting special method of inoculation. One of these methods is pelleting *i.e.* preparation of pelleted seeds. This method involves the procedure as described earlier. High amount of gum arabic (40%) or carboxymethylcellulose (20%) is added to the inoculum slurry before mixing with seeds. Finally, pelleting agent is mixed when inoclated seeds are moist (before seed drying) to get the seeds evenly coated.

The commonly used pelleting agents are calcium carbonate, rock phoshate, charcoal powder, gypsum and betonite.

ISOLATION AND CULTIVATION OF AZOSPIRILLUM

Azospirillum is a type of bacteria that is known for its plant growth-promoting and nitrogen-fixing abilities. It forms symbiotic relationships with plant roots, helping plants to acquire nutrients and promoting their growth. Isolation, characterization, and mass cultivation of Azospirillum are essential steps for utilizing this beneficial bacterium in agriculture.

Here's an overview of these steps:

1. **Isolation**: The process of isolating Azospirillum involves collecting soil or plant root samples from environments where these bacteria are likely to be present. The goal is to obtain a pure culture of Azospirillum strains. The isolation process typically includes the following steps:
    - **Sample Collection**: Soil samples are collected from the rhizosphere (root zone) of plants known to have a beneficial relationship with Azospirillum.

- **Dilution and Plating**: Serial dilutions of the soil samples are prepared, and then small volumes are plated onto selective agar media. These media encourage the growth of Azospirillum while inhibiting the growth of other microorganisms.
- **Isolation of Colonies**: Individual bacterial colonies that show characteristics consistent with Azospirillum are isolated and subcultured to obtain pure cultures.

2. **Characterization**: Characterization involves studying the isolated Azospirillum strains to understand their properties, capabilities, and potential for promoting plant growth. This step includes:
    - **Morphological Analysis**: Studying the bacteria's size, shape, and cell structures under a microscope.
    - **Biochemical Tests**: Performing tests to identify specific metabolic and biochemical traits of the bacteria.
    - **Molecular Analysis**: Using techniques like DNA sequencing to identify the genetic makeup of the strains and confirm their identity as Azospirillum.
    - **Nitrogen-Fixing Capability**: Testing the ability of the strains to fix atmospheric nitrogen into a form that plants can use.
3. **Mass Cultivation**: Once the desired Azospirillum strains are isolated and characterized, they can be mass-cultivated for use in agriculture. Mass cultivation involves growing large quantities of the bacteria under controlled conditions. This can be achieved through various methods:
    - **Liquid Culture**: Azospirillum can be grown in liquid media using bioreactors or fermentation tanks. These cultures provide a high cell density and are suitable for producing liquid inoculants.
    - **Solid Substrate Fermentation**: Growing Azospirillum on solid substrates, such as rice husks or vermiculite, can yield bacterial formulations that can be easily applied to soil.

- **Carrier-Based Formulations**: Azospirillum can be coated onto carriers like clay particles or peat, creating formulations that protect the bacteria during storage and application.

The mass-cultivated Azospirillum can be used as a biofertilizer to enhance plant growth and reduce the need for synthetic fertilizers. These bacteria establish a symbiotic relationship with plant roots, promoting nutrient uptake and stimulating plant growth hormones.

The successful isolation, characterization, and mass cultivation of Azospirillum contribute to sustainable agricultural practices by harnessing the beneficial interactions between these bacteria and plants.

UNIT 5

INTEGRATED PEST AND DISEASE MANAGEMENT UNDER ORGANIC FARMING

Pest and disease management in organic agriculture is a complex process and requires integration of all management components including use of resistant varieties, biological diversity on farm, balanced nutrition, steady supply of nutrients and use of preventive and curative steps.

Most pest management practices require long term continuous planning and implementation of activities that aim at preventing and controlling pests and diseases and include both preventive and curative strategies.

Preventive management focuses on keeping existing pest populations and diseases low. Control, on the other hand, focuses on killing pests and diseases. The general approach in organic agriculture is to deal with the causes of a problem rather than treating the symptoms, an aspect that also applies to pests and diseases.

Continuous monitoring, at least once a week of soil, water, pests, natural enemies, weather factors etc. is essential. The health of a plant is determined by its environment, which includes physical factors (such as soil, rain, sunshine hours, wind etc.) and biological factors (such as pests, diseases, weeds, diversity, naturally occurring organisms etc.).

All these factors play an important role in the balance, which exists between herbivorous insects and their natural enemies. Organic pest management strategies largely rely on understanding the intricate interaction of the ecosystem, which play a critical role in pest management.

Understanding and conserving the natural enemies/ defenders is important. In orchards, there can be various types of insects out of which some may be beneficial and some are harmful. Fanners need to understand the difference between the two and try to keep on monitoring the population of friendly insects. Sweep nets, visual counts etc. can be adopted to arrive at the number of pests (P) and defenders (D). The natural enemies can be divided into 3 categories- 1. Parasitoids 2. Predators and 3. Pathogens.

The general rule to be adopted for management decisions is relying on the P:D ratio of 2:1. This means 1 predator is competent to take care of 2 pests. However, some of the parasitoids and predators will be able to control more than 2 pests. Whenever the P:D ratio is less than 2:1 then there is no need for any control measures. In case if it goes beyond 2:1 (i.e. 3.1 and above) then resort to inundative release of parasitoids and predators depending upon the type of pest.

In addition to inundative release of parasitoids and predators the usage of microbial biopesticides can be resorted to. Use of botanicals and organically acceptable chemical formulations be adopted only as last resort.

Preventive Measures for Controlling Disease in Organic Plants:

Thorough understanding about plant health and occurrence of pests and diseases helps growers to choose effective prophylactic measures. As there can be many factors that influence the development of a pest and disease, it is most important to provide necessary interventions at the most sensitive time. This can be accomplished through correct timing of management practices, a suitable combination of different methods, or the choice of a selective method.

Some important preventive crop protection measures are as follow:

(a) Selection of adapted and resistant varieties.

(b) Selection of healthy and disease free seed and planting material.

(c) Selection of optimum planting time and spacing.

(d) Integration of diversity through rotations, intercrops, alley cropping, multi- tier cropping etc.

(e) Balanced nutrient management and addressing secondary or micronutrient deficiency.

(f) Maintenance of soil health and biological activity through timely incorporation of organic manures.

(g) Timely weed management.

(h) Effective water management, preferably through efficient irrigation systems.

(i) Conservation and promotion of natural enemies.

(j) Use of proper sanitation measures and timely removal of infected plant parts from the ground to prevent the disease from spreading, eliminating residues of infected plants after harvesting.

Role of Diversity in Containing Pests for Organic Plants:

Studies have indicated that enhanced diversity in a particular field or plantation helps in containing pests. Diversity can be enhanced by planting border plants, planting on bunds, intercrops, rotation, alley cropping, multitier cropping etc. Several types of plants like nitrogen fixing plants, plants of pesticidal value, insectary plants which specifically attract useful insects because of their pollen nectar, can be planted.

It has been observed that in mono-cropping the host plants are concentrated in time and species whereas intercrops or border crops increase the diversity in the field and act as barriers for colonization and movement of insect pests. Also many flowering plants planted in the orchard act as attractants for many natural enemies. In conclusion, enhanced diversity creates natural habitat conditions which results in increase, in natural enemy populations ultimately resulting in lower insect pest level.

Planting Material Treatment for Organic Plants:

Seeds and planting material such as cuttings etc. can be treated to protect against pests and diseases in the soil that can attack seeds, roots or young seedlings (soil-borne diseases).

There are four main methods for seed treatment in organic farming:

1. Physical – Heat sterilization by soaking seed in hot water (typically 50- 60°C),
2. Botanical – By coating seeds with a layer of plant extract, such as turmeric powder, crushed garlic or clove-cinnamon extract,
3. Biological – By coating seeds with a layer of antagonistic microorganisms such as Trichoderma or Pseudomonas fluorescens,
4. Organically acceptable chemicals – By coating/treating seeds with vinegar, copper salts or baking soda and mineral oil etc.

Some of the most widely practiced organic seed treatment options are as follows:

1. Beejamrit:

Made from cow dung, cow urine and lime is an excellent seed treatment formulation and is being used by large numbers of organic farmers in almost all crops. Beejamrit treatment provides protection against seed rot, seedling rot and some other soil borne diseases. Beejamrit treatment improves seed germination.

2. Cow Urine:

Dilute one part of cow urine with 5 parts water, soak the seeds for 15 min and then dry in sun. The treatment prevents soil borne diseases and increases germination.

3. Cow Milk:

Dilute one part cow milk with 5 parts water, soak the seeds for 15-20 min, sun dry and sow, this treatment helps in control of leaf spot diseases and prevents yellowing of leaves.

4. Horse Manure/Compost Tea:

Horse manure/compost tea is ideal for seedbed treatment in nurseries.

5. Wood Ash:

Mix 10 gm finely powdered wood ash in 500 ml water and treat the seeds. Dry in sun and sow immediately. The treatment helps in reduction of seedling rot.

6. Horsetail (Equisetum Arvense) Decoction:

Boil 500 gm plant parts in 5 lit water and boil till it becomes half. Filter and store. The extract can be used for seed treatment for protection against soil borne fungal diseases such as seedling rot.

7. Panchagavya Treatment:

3% solution of Panchagavya can be used to soak the seeds or dip the seedlings before planting. Soaking for 20 minutes is sufficient. Rhizomes of turmeric, ginger and sets of sugarcane can be soaked for 30 minutes before planting.

8. Turmeric Powder:

250 gm powder in 1 lit of water for 10 kg seed. Treatment provides protection against fungal rot and wilt diseases.

9. Asafoetida:

250 gm in one lit of water for 10 kg seed. Treatment provides protection against fungal rot and wilt diseases. The treatment also repels insects and ants.

10. Garlic Extract:

Crush 250 gm garlic cloves in 1 lit of mineral oil. Keep overnight and collect filtrate. 20 kg seed can be treated with this extract.

11. Garlic-Clove-Cinnamon Extract:

Crush 250 gm of garlic, 100 gm of clove buds and 100 gm cinnamon powder in 1 lit of mineral oil. Keep overnight and squeeze out the extract. 20 kg seed can be treated with this extract.

12. Steam Distilled Plant Oils:

Steam distilled oils of thyme, cinnamon, clove and garlic are effective against wide range of seed and soil borne fungal and bacterial diseases. 1-2% of such oils mixed with mineral oil or any other vegetable oil can be used for seed treatment.

13. Sodium Hypochlorite:

Hard seed coat seeds can be surface sterilized by using 5% solution of sodium hypochlorite for 5 minutes followed by several washings of clean water.

14. Vinegar:

Mix 1 tbsp of vinegar in 4 cups of water. Place the seeds in a small cloth bag and dip the seed bag into vinegar-water solution. Dry dipped seeds on old newspapers before sowing. Make sure that seeds are completely dry before storing.

15. Copper Salts:

Seed treatment with copper sulphate and lime or copper oxychloride is generally advised as last resort where other methods have failed.

16. Elemental Sulphur:

200-mesh fine powder of elemental sulphur at 20 gm per kg of seed is also effective against many seed and soil borne diseases. Lime sulphur can also be used in place of elemental sulphur.

Biological Seed Treatment Methods for Organic Plants:

Microbial inoculants in the form of bio-fertilizers and bio-pesticides are being used widely not only for growth promotion and nutrient mobilization, but also for protection of seeds against soil borne plant pathogens. These inoculants are applied both as seed and soil treatment.

For seed treatment 5 gm of inoculant is adequate for treating one kg of seed. In case of multiple inoculations 5 gm of each inoculant is used per kg of seed. Treatment is done by making slurry of the inoculant and sticker (like sugar, jaggary or gum Arabic) in water and then mixing it with seeds. Treated seeds are dried in shade and sown within 4-6 hrs of treatment.

i. Biofertilizers such as Rhizobium, Azotobacter and PSB:

Act as nutrient mobilizers and growth promoters. Very high microbial population around seeds creates a barrier for pathogens to reach seeds. Azotobacter releases some fungistatic complex, which helps in reduction of soil borne pathogen attack.

ii. Trichoderma Viride:

The fungal inoculants are being used as biological control agents against plant pathogenic fungi and are effective as seed dressing in the control of seed and soil-borne diseases including Rhizoctonia solani, Macrophomina phaseolina and Fusarium species. On application to seed it colonizes on the seed surface and kills not only the pathogens present on the cuticle, but also provides protection against soil-borne pathogens.

iii. Trichoderma Harzianum:

It is also used as bio-fungicide and is suitable for application as foliar application, seed treatment and soil treatment for suppression of various diseases caused by fungal pathogens including Botrytis, Fusarium and Penicillium sp. and also nematodes.

iv. Paecilomyces Lilacinus:

It is used as effective control agent against root knot nematodes as seed and soil treatment. It can be used alone or in combination with Trichoderma viride.

v. Pseudomonas Fluorescens:

Effective strains of P. fluorescens possess excellent bio-control properties and on application as seed or soil treatment protect the roots of plants against pathogenic fungi such as Fusarium and Pythium. P. fluorescens has also been found to be effective against some phytophagous nematodes.

vi. Bacillus Subtilis:

Some strains of Bacillus subtilis are effective biofilm producers around roots of treated plant thereby protecting their roots from various soil borne fungal pathogens. Bacillus subtilis inoculants have been specifically found very effective in nurseries and in protected cultivation.

Weed Management for Controlling Organic Plants:

Weed management under organic management is one of the most challenging tasks and requires long term planning and adoption of various cultural methods.

Besides the cultural and agronomic options, weed management is generally addressed through following practical solutions:

1. Manual weed removal.
2. Mechanical scraping or cutting through hand or motor operated weeders, bullock operated scrapers or tractor mounted weeders and smotherers.
3. Mulching – keeping the soils covered with organic/biological mulch is the best strategy not only for weed suppression but also for soil fertility management. In vegetables covering the vacant spaces by crop residue, dried leaves and degradable waste, immediately after transplanting is the most effective strategy.
4. Intercropping with legumes and cover crops also prevents weed growth.

5. Use of plastic mulch is highly effective, but being cost intensive is resorted to only in cash crops.

6. Flaming of weeds between the rows of fruit plants is a viable option and is very effective in new as well as old orchards with woody plant stand.

7. Use of organically acceptable chemicals such as vinegar and salt for suppressing the weed growth.

Curative Pest Control Measures for Organic Plants:

If preventive crop protection practices fail to sufficiently prevent economic losses then, it may be necessary to take curative action. Curative action means controlling the pest or disease once it has already infested the crop.

Several options exist in organic agriculture:

1. Mechanical control with traps, sticky plates or hand picking.
2. Biological control with natural predators or antagonistic microbes.
3. Natural pesticides based on herbal preparations or other natural products.
4. Organically acceptable chemical alternatives such as copper sulphate, lime and elemental sulphur

Mechanical Control Measures for Organic Plants:

1. Removal of Affected Plants or Parts:

The virus affected diseased plants should be removed from the field; it prevents the transmission of disease to other plants.

2. Collection & Destruction of Egg Masses and Larvae:

Keep surveillance of the crop for pest monitoring and during survey collect the egg masses and larvae from the field and destroy them. This practice helps in minimizing the pest load.

3. Light Traps:

Among the most widely used constructed traps are kerosene lamp traps or light traps. Ultraviolet lamps are much more effective than ordinary electric bulbs. These traps should be used at appropriate time, depending upon the life cycle of the insects.

The best time is immediately after the emergence of moths, before they lay the eggs. In these traps the light source is kept over a shallow wide bowl of water added with few spoonful of oil or kerosene. Moths that attract towards light fall in this bowl and will not be able to fly. From there they are collected and destroyed.

4. Pheromone Traps:

Sex pheromones are synthetic chemicals that are basically used to attract and trap insect pests so as to reduce the insect population. Since sex pheromones are not sprayed directly on to the crop, there is no pollution problem.

5. Use of Sticky, Coloured Plates and Other Physical Traps:

Different species of insects are attracted by different colours. The results indicated that yellow plastic plates coated with grease or any sticky substance and insecticide were effective in controlling leaf miner. This method avoids environmental pollution since the insecticide is not sprayed directly onto the crop. Different colours may attract different insects. Appropriate colours need to be identified for the purpose.

6. Physical Barriers:

The flat snail (Bradybaena similaris) is widely distributed in Taiwan, Mainland China, Japan and India. Recently, a method has been developed for controlling the snail by the use of disposable plastic soda bottles made into traps. These prevent the snails from climbing up onto the grapevine. The traps are made by cutting off both ends of the bottle and splitting one side of the body longitudinally to allow it to be sleeved around the stem of the grapevine.

The bottles are then stapled firmly around the stem at a height of 1 m above the ground. Since the bottles are tightly fixed around the grape stem, the snails cannot pass through the neck to infest the vines. Unable to descend, all the snails are trapped in the bottle and soon die of starvation. These traps give a control rate of more than 94.8%. This is a very cheap and effective method of controlling flat snail, and there is no threat to the environment. It can thus be widely recommended to grape farmers.

Bagging Fruits:

Bagging prevents insect pests, especially fruit flies damaging the fruits. The bag provides physical protection from mechanical injuries (scars and scratches) and prevents egg laying activities of female flies, latex burns and fungal spots on the fruits.

Although bagging is not widely practiced due to involved costs and difficulties in bagging so many fruits, but it is widely practiced in banana world over and is also economical. Wherever possible it can be used and gives reliable estimate of projected harvest.

How to make a bag?

1. Cut old newspapers measuring 15 x 22 cm or 12.5 x 27.5 cm for mango and for fruits of similar size.
2. Double the layers, as single layer break apart easily.
3. Fold and sew or staple the sides and bottom of the sheets to make a rectangular bag.
4. Fruit bags can also be made of plastic film or fine net mesh.

5. Ready-made fruit nets/sleeves are also available in the market.

How to bag a fruit?

1. Blow in the bag to inflate it.
2. Remove some of the fruits, leaving 1 on each cluster.
3. Insert one fruit per bag then close the bag using coconut midrib or firmly tie top end of bag with string or wire or staple it.
4. Push the bottom of the bag upwards to prevent fruit from touching the bag.
5. Use a ladder to reach as many fruits as possible. Secure the ladder firmly on the ground and for bigger and higher fruit trees, secure or tie the ladder firmly on big branches to ensure safety of workers.

Remember:

1. Bagging works well with melon, bitter gourd, mango, guava, star fruit, and banana.
2. Start bagging bitter gourd when the fruit is 2-3 cm in length. Tie the bag with a string around the stalk. The bag is formed like a cylinder and must be longer than the anticipated size of the fruit when it matures.
3. Start bagging the mango fruit 55-60 days from flower bloom or when the fruits are about the size of a chicken egg.
4. When using plastic bags, open the bottom or cut a few small holes to allow moisture to dry up. Moisture trapped in the plastic bags damages and/or promotes fungal and bacterial growth that cause diseased fruits. Plastic also overheats the fruit.
5. Bags made of dried plant leaves are good alternatives to plastic.
6. Remove the bags during harvest and dispose them properly.

Biological Alternatives for Controlling Pests in Organic Plants:

Nature has its own device to balance the ecosystem. Spiders, insect predators, parasitoids and insect pathogens are present in nature and are playing major role in maintaining the pest population in undisturbed ecosystems. The potentiality of such system can be harvested for maintaining the pest population below economic injury level in our agricultural fields. Natural enemies are highly specific and safe to non-target species. Once established they survive in nature till the pest is prevalent and are self-perpetuating in nature.

Use of Pest Predators and Parasites:

Mass production of predators, parasites and pathogens and their augmentation in the infested or infected field, effectively controls the pest population below economic injury level.

With the help of inundative release of Trichogramma sp. @40,000 to 50,000 per hectare, Chelonus blackburni @ 15,000 to 20,000 per hectare, Apanteles spp. @ 15000-20000 per ha and Chrysoperla sp. @ 5,000 per ha, 2-3 times a year can effectively check the spread of large number of insect pests and helps keep their population below economical threshold limit.

Use of Biopesticides:

Biopesticides or pesticides of microbial origin are emerging as sustainable non-chemical alternatives in pest management. Trichoderma viride or T. harzianum or Pseudomonas fluorescens formulation @ 4 gm/kg seed either alone or in combination can manage most of the seed borne and soil borne diseases.

There are other formulations viz. Beauveria bassiana, Metarhizium anisopliae, Nomitraea rileyi, Verticillium sp., which are available in the market and can manage their specific host pest. Discovery of isolates like Bacillus thuringiensis, B. tenebrionis and B. thuringiensis san-diego acting against Coleopterans as well other species has extended the scope of bacterial insecticides.

BIOPESTICIDES AND THEIR MULTIPLICATION

Introduction

Pest problem is one of the major constraints for achieving higher production in agriculture crops. India loses about 30% of its crops due to pests and diseases each year. The damage due to these is estimated to be Rs.60,000 crores annually. The use of pesticides in crop protection has certainly contributed for minimising yield losses. The pesticides, which are needed to be applied carefully, only when the threshold limits of the pest population is exceeded. However, quite often the indiscriminate and unscientific use of pesticides has led to many problems, such as pests developing resistance, resurgence of once minor pest into a major problem besides environmental and food safety hazards.

The problem of insect-pest is acute in case of all the crops and especially so in case of commercial crops. The use of insecticides and pesticides have increased manifolds during the past 3 - 4 decades with the introduction of intensive cropping. The average consumption of pesticides in India is about 570 gms per ha. as compared to developed countries like Japan, Thailand and Germany where the consumption rate is 11 kg, 17 kg and 3 kg per ha, respectively. Though the average quantum of pesticides usage in India is low, the damage caused due to their indiscriminate usage and poor quality maintenance is alarming. Interms of value, much of the pesticide application is accounted for by a few crops. For example, cotton, paddy and vegetable crops account for 80% of the value of pesticides applied in India.

Pesticides or chemicals are meant to control harmful pests such as insects, nematodes, diseases, weeds etc. However, excessive use of pesticides not only leave residues in soil, water and air but also have adverse effects on the non target organisms such as pollinators, parasitoids, predators and wild animals. This has adversely affected the ecological balance resulting in pest resurgence, development of resistance in the pest species and environmental pollution. Development of pest resurgence and resistance has resulted in high cost of production and low income especially to cotton farmers in AP, Maharashtra.

In view of the several disadvantages associated with the unscientific use of pesticides in agriculture, there is an urgent need for minimising the use of chemical pesticides in the management of insect pests. Growing public concern over potential health hazards of synthetic pesticides and also steep increase in cost of cultivation/low profit making by farmers has led to the exploration of eco-friendly pest management tactics such as Integrated Pest Management (IPM). IPM aims at suppressing the pest species by combining more than one method of pest control in a harmonious way with least emphasis on the use of insecticides. In simple terms "IPM is the right combination of cultural, biological and chemical measures which provides the most effective, environmentally sound and socially acceptable methods of managing diseases, pests and weeds". The major components of IPM are prevention, observation and intervention. The IPM seems to be the only answer to counter some of the major pests of crops, which have become unmanageable in recent years. The success of IPM largely depends upon conservation of naturally occuring bio control agents.

Importance of Bio-pesticides

In nature every ecosystem exists in a balance. Growth and multiplication of each organism depends on the food-chain, its predetors, parasites, etc. In biological control system, these interrelations are exploited. The natural enemy of a pest, disease or weed is selected, its biology is studied for mass multiplication and utilize the same to check the target pest. They are also specific in their action and perish once their feed (i.e. the pest) is exhausted. Thus they are based on natural principles, do not leave any residue, safe and economical.

Among the alternatives, biological control of pests is one of the important means for checking pest problems in almost all agro-ecological situations.

Bio pesticides are living organisms which can intervene the life cycle of insect pests in such a way that the crop damage is minimized. The agents employed as biopesticides, include parasites, predetors and disease causing fungi, bacteria and viruses, which are the natural enemies of pests. Further, they complement and supplement other methods of pest control. Utilisation of naturally occurring parasites, predators and pathogens for pest control is a classical biological control. On the other hand, these bio agents can be conserved, preserved and multiplied under Laboratory condition for field release. Once these bio-agents are introduced in the field to build their population considerably, they are capable of bringing down the targeted pest' population below economic threshold level (ETL). However, the crux lies in their mass production and application at the appropriate time.

Major advantages of bio pesticides

Bio-pesticides are preferred over chemical pesticides for the following reasons:

- no harmful residues;
- target specific and safe to beneficial organisms like pollinators, predetors, parasites etc.;
- growth of natural enemies of pests is not affected, thus reducing the pesticide application;
- environmental friendly;
- cost effective;
- important component of IPM as 1st line and 2nd line of defence, chemicals being the last resort.

Status of bio pesticide use in India

Last decade has witnessed a tremendous breakthrough in this aspect, especially on standardization of production techniques of Trichoderma, Gliocladium, Paecilomyces, Pseudomonas, Trichogramma, NPV and Bacillus to use them against many insect pests and diseases.

There are a number of instances where bio control agents have been successfully employed in

India. Some examples of these are given below :

- Growth of lantana weed was controlled by using the bug **Telonemia scrupulosa**
- Sugarcane **pyrilla** has been successfully controlled in a number of States by the introduction of its natural enemy **Epiricania melanoleuca and Tetrastictus pyrillae**.
- **Trichogramma**, which feeds on the eggs of sugarcane borers, has been used against the borers in the states of Tamil Nadu, Rajasthan, UP, Bihar and Haryana.
- Similarly Trichogramma, Bracon, Chelonus and Chrysopa spp. are being used for the control of cotton bollworms. Trichogramma has also been used against rice stem borer and leaf folder.
- The sugarcane scale insect has been controlled with the help of predatory **coccinellid** beetles in UP, West Bengal, Gujarat and Karnataka.

The popularity of biopesticides has increased in recent years, as extensive and systematic research has greatly enhanced their effectiveness. Also, techniques for the mass production, storage, transport and application of biopesticides have been improved in recent years.

Scope for Commercial Production of Biopesticides

Though there are about 140 biopesticide production units existing in the country as on today, they are able to meet the demand of only less than 1% of cropped area. There exists a wide gap, which can only be bridged by setting up of more and more units for production of biopesticides. This requires large scale investment and private participation.

Some of the local small scale industries have already started production and marketing of Trichoderma viride (against few fungal diseases) and Trichogramma (against sugarcane early shoot borer). There is a scope to enhance production and use of biological control agents in the days to come as the demand is on the increase every year.

PRODUCTION TECHNOLOGIES

A. Trichogramma egg parasite

1. Introduction

Trichogramma spp. belongs to the category of egg parasitoid of biological agents. Trichogramma spp., the most widely used bio-control agent in the world and is effective against bollworms of cotton, stem borers of sugarcane, fruit borers of fruits and vegetables. It attacks the pest at the egg stage itself and hence damage done by larvae is avoided. It offers a lower cost but more effective plant protection option in comparison to insecticides. Two species i.e., T. chilonis and T. japonicum are predominantly used in India.

Trichogramma are dark coloured tiny wasps and the female wasp lays 20-40 eggs into the host's eggs. The entire cycle is completed within 8-12 days. The tiny adult wasps search for the host (pest) eggs in the field and lay their eggs into the eggs of the pests. The parasitised host's eggs turn uniformly black in 3-4 days. The Trichogramma eggs on hatching, feed the embronic contents of host's egg, completes its development and adult comes out of the host egg by chewing a circular hole. A single Trichogramma, while multiplying itself, can thus destroy over 100 eggs of the pest.

2. Major equipment needed

Equipments like semi-automatic corcera rearing cages, trays, iron racks, hot air oven, air conditioner, UV chamber, incubator, moth breeding tins, grinder, mating chambers, parasitization jars, refrigerator, wire mesh, netlon etc. are required for mass rearing of corcera and Trichogramma production.

3. Steps involved in production

i) Identification of host

The Trichogramma of multiplication starts with identification of a suitable host species, with the following characteristics :

- easily available.
- easy to culture with the locally available material.
- should yield maximum host egg/larvae/pupae per unit cost.

In India **Corcera cephalonica**, a stored grain pest has been used for mass multiplication of targetted species.

ii) Rearing of host insect

The host rearing containers are made of materials which are non-toxic, cheap and optimum sized to permit mating and host searching and amenable to easy cleaning. Most commonly used cages are wooden cages, which are now replaced with semi automatic corcyra rearing cages. The nuclear culture, i.e. eggs of Corcyra cephalonica are introduced in rearing cages. In the model use of semiautomatic rearing cages of 30 no. is considered.

iii) Preparation of feed material

Corcyra feed may be prepared from bold white sorghum grains without any insecticide residues. This can be tested by taking a sample of 100 g from each bag. The crushed sample is fed to 20 number of 1st/2nd instar Corcyra larvae for 2-3 days. Based on the mortality of the larvae, suitability of grains may be decided. The requisite quantum of sorghum is milled to make 3-4 pieces of each grain. Sorghum grains are heat sterilised in oven at 1000C for 30 minutes and the grains are sprayed with 0.1% formalin. This treatment helps in preventing the growth of moulds as well as to increase the grain moisture to the optimum (15-16%), which was lost due to heat sterilisation. Then grains are air dried.

iv) Corcyra charging

In each rearing cage, 7.5 kg of sorghum grains are filled and charged with 0.5cc eggs (1cc = 20,000 eggs) of mother culture. Yeast, groundnut kernel and streptomycin is added to enhance egg laying capacity of the adult moths and for enriching the diet.

v) Collection of moths

After about 40 days of charging, moths start emerging and the emergence continues for two months. 10 to 75 moths emerge daily with the peak emergence being between 65th and 75th day.

Collect the moths daily and transfer to the specially designed oviposition cages for egg laying. Roughly 2000-3000 pairs of moth can be placed in one chamber. Moth emergence reduces after 100 days of initial infestation and cages are released for cleaning.

vi) Collection of eggs

Eggs are collected by means of manual suction and are placed in tubes and counted with measuring cylinder. Approximately one cc of eggs of Corcyra counts about 20,000 at the fresh harvest. After that due to shrinkage of eggs the count may be increased. The present model assumes 20,000 eggs per one cc for calculation purpose. The final output of Corcyra eggs from one cage has been assumed at 7.5 cc.

4. Production of Trichocards

The demand for Trichocards will start from the onset of kharif season and extends to rabi season. The summer season vegetables offer an extra demand.

i) Egg preparation

The eggs of Corcyra thus collected are cleaned to make it free from insect scales etc. They are sieved thrice and then poured on a plain paper. By slowly tapping eggs come downward stick on to gummed card. Thus, the cleaned eggs are spread on the gummed cards (15 cm x 10 cm) with the help of screen. These eggs of Corcyra are exposed to UV rays of 15 watt UV tube for 45 minutes to prevent hatching. While UV exposure, egg card should be kept about 12-15 cm away from tube.

ii) Introduction of Trichogramma

After the sterilisation the egg cards are placed in plastic bottles and are introduced with nucleus culture of Trichogramma species of egg or pupal stage. The ratio of host egg and parasite adult should be maintained at 1:5.

iii) What is a tricho card ?

The parasitisation of Trichogramma spp., in laboratory condition on one cc eggs of Corcyra cephalonica, which are uniformly spread and pasted on a card measuring 15 cm x 10 cm is called as Tricho card. The card has 12 demarcations (stamps). About 12,000 Trichogramma adults emerge out from this card in 7-8 days after parasitisation. To delay the emergence of Trichogramma, these cards can be stored in refrigerator at 5-100C for 10-15 days. On removing the cards to room temperature, the parasitoids emerge normally. Trichocards have a shelf life of 2-3 days. However, these can be stored in a refrigerator for a period of 1 month without any spoilage.

5. Dosage

For controlling sugarcane early shoot borer : Start releasing 6,000 parasites per week per acre area, for a period of 5 weeks, starting from 4th week of planting i.e., as soon as the adult male moths of early shoot borer are noticed in the field. Totally 30,000 parasites are to be released per acre. More parasites may also be released depending upon the crop and pest density.

In cotton- The Trichocards are released in the field at 45 days after sowing @ 5 cards / ha (one lakh eggs). In total three release are necessary.

6. How to use 'Tricho card'

The cards are to be used before the emergence of the adult parasite. Cut or tear each Tricho card into small pieces and distribute them all over the field. The pieces may be stapled to sugarcane leaf at 7-8 m distance. Care is to be taken to release the parasites either in morning or evening i.e., during cool hours, in windward direction and there should not be any pesticide spray. Before releasing the parasite, the infected shoots are to be cut to ground level and buried inside the soil so as to avoid secondary infestation.

7. Advantages of using Tricho cards

- Less cost, more effective.
- field application (releases) is very simple as compared to other methods.
- Records show higher yield in sugarcane (about 4-5 tonnes), as secondary infestation is avoided while using Tricho cards.
- Cost of pest control is very nominal.
- Added to all these, environmental pollution is avoided.

8. Precautions

The following precautions are required to be taken while using Trichocards :

- Trichocards should be packed in such a way that the parasitised surface is on the inner side.
- Emergence date should be specified on cards for the guidance of the users.
- Trichocards should be stapled on the inner-side of the leaf to avoid direct sunlight.
- Card should be stapled in morning hours and just before emergence to avoid predation.
- Farmers should refrain from using pesticides in the field where Trichogramma are released. If need arises selective / safer pesticides can be used and it is to be ensured that pesticides are used 15 days before or after release of Trichogramma

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B. Chrysopid predetors

1. Importance

Chrysopid predators are important for the management of bollworms and aphids in cotton and tobacco and several sucking pests in fruit crops. They are capable of bringing down the population of the pest drastically. Chrysoperla (Chrysoperla carnea) is a potential chrysopid, which is also amenable to mass multiplication.

Chrysoperla are generally green in colour, varying in length from 1.0-1.3 cm. The pre-oviposition period lasts 3 to 7 days. Adults start laying eggs from 5th day onwards and peak egg-laying period is between 9 and 23 days after emergence. The male longevity is 30-35 days. Adult female lay eggs of 600-800 eggs/female on an average. The eggs are stalked and green in colour. The eggs are laid singly or in clusters. Egg stage lasts 3-4 days. The larva has 3 instars and after 8-10 days it will form cocoons. Adult emerges in 5-7 days from cocoons.

The green lacewing is being mass released in the field for the control of aphids, white flies, mealy bugs and eggs and young larvae of lepidepteron pests. The Chrysoperla predetors may be used on cotton, groundnut, pulses, vegetables, ornamentals and several other crops. They also feed on the eggs and freshly hatched larvae of Helicoverpa armigera and such other caterpillar pests.

It is being mass produced primarily on the eggs of rice grain moth, Corcyra cephalonica in India. For mass production of chrysoperla, an efficient rearing technique is required.

2. Mass Production

Chrysoperla predators are mass multiplied in laboratory at 27 ± 10C and 70% RH on the eggs of Corcyra cephalonica, a laboratory host. Three days old 120 chrysopid eggs are mixed with 0.75 ml Corcyra eggs (the embryo of Corcyra eggs are inactivated by keeping them at 2 feet distance from 30 watt ultraviolet tube light for 45 minutes) in a plastic container. On hatching, the larvae feed on the contents of eggs. The second and subsequent instars are reared individually in cells of louvers on the eggs of C. cephalonica. It is assumed that for rearing 100 larvae (1cc) C. cephalonica eggs are required. Host eggs are provided twice during the course of larval rearing. First feeding of 1.75 ml for 100 larvae and second feeding of 2 ml for 100 larvae with a gap of 3 to 4 days is provided. Cocoons formed in the cells are collected after 24 hours. The cocoons are placed in oviposition cage for adult emergence (Photograph-1). In each oviposition box roughly 20 pairs can be accommodated and inside portion of the container is covered with black paper on which adults lay eggs. The adults in the oviposition boxes are provided with castor pollen, protinex mixture (equal volume of protinex, fructose, honey and powdered yeast dissolved in small quantity of water), 50% honey and drinking water in cotton swab. Adults lay eggs on the under surface of the top lid which is removed by sliding a clean lid. After 24 hours of hardening the eggs are gently brushed with a brush to dislodge on to a paper eggs are collected and either reused for mass multiplication or sent to farmers for field release. Only first instar larvae are released on to the recommended crop plants.

3. Major equipment required

Facilities like rearing room (6 x 6 m), slotted angle iron racks, work tables, plastic louvers 60 x 22 cms with 2.5 cm cubical cells, acrylic sheets to cover the louvers, glass vials, adult oviposition cages (45 x 30 x 30 cms), plastic louvers, plastic containers, scissors and brushes, cotton wool, tissue paper, sponge, fructose, protinex, honey, yeast, castor pollen etc. are required for the mass rearing of chrysopids.

4. Dosage

At least 1000 eggs or larvae may be used per acre.

C. Ladybird beetle (Cryptolaemus montrouzieri)




1. Importance

Mealybugs are serious pests on fruits, vegetables, ornamentals and plantation crops. Besides causing direct loss to the plants they also reduce market value of infested fruits. The extent of damage may go upto 70 percent in severe infestation. Lady bird beetle, Cryptolaemus montrouzieri introduced from Australia is a potential bio control agent and is being utilized on many crops in Southern India.

Mealybugs or scale insects constitute the natural food of certain ladybird beetles. The adult beetles as well as their larvae (grubs) seek the pests and feed voraciously on all stages. They often wipe out the entire pest colonies. The lady bird beetles are being used for suppression of mealy bugs in citrus, coffee, grapes, guava, ornamental and a variety of other crops.

2. Equipment needed

Equipments like wooden boxes/cages, iron rack, buckets etc. are needed for mass multiplication of ladybird beetles.

3. Production Technology

The production involves the following steps:

- After 15 days of infestation of pumpkins with mealy bugs (Planococcus citri), they are exposed to a set of 100 beetles for 24 hrs. After exposing the pumpkin is kept back in a cage. The beetles during the period of exposure feed on mealybugs as well as deposit their egg singly or in groups of 4-12. The young grubs feed on eggs and small mealybugs but as they grow they become voracious and feed on all stages of mealybugs. For facilitating the pupation of grubs, dried guava leaves or pieces of papers are kept at the base of each of the eggs. The first beetle from the cages start emerging on 30th day of exposure to beetle adults. The beetles are collected daily and kept in separate cages for about 10-15 days to facilitate completion of mating and pre-oviposition. The beetles are also fed on diet containing agar powder (1gm), sugar (20gm), honey (40cc) and water (100cc).
- The adult beetle diet is prepared by boiling sugar in 70cc of water, adding 1gm agar, diluting 40cc honey in 30cc of water and adding to the sugar and agar mixture when it comes to boiling point. The hot liquid diet is kept on small white plastic cards in the form of droplets which get solidified on cooling. Such cards containing diet can be fed not only to C. montroozieri but also to many other species of cocinellids. From

each cage about 175 beetles are obtained. The emergence of the beetles is completed within 10 days.

The Beetles can also be reared on corcyra cephalanica eggs but empty ovisacs of Planococcus citri are to be kept for inducing egg laying by the beetles.

4. **Field release and application**

Before releasing in the field in the endemic areas, moderate to severely infested plants are marked. The plant trunks are ringed one foot away with a band of 5% diazinan granules 24 hrs before the release of the beetles; this stops the patrolling of ants on the trunk atleast 3 days. On citrus 10 beetles per infested plants are released but on other crops the releases are calculated based on infestation and crop canopy.

- Release of 10-15 adults / tree depending up on canopy and infestation once in a season
- 600 to 1000 beetles may be released per acre

5. Precautions

The important precautions are given below:

- All due precautions should be taken to avoid scarcity of food for the grubs to avoid cannibalism by grubs.
- All the pumpkins showing sign of rotting should be properly incinerated. -

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D. Production of Ha NPV and SI NPV

1. Introduction

Baculovirus group have a very narrow host range and generally infests the larvae of crop pests. The research aimed at insect pest control is, therefore, confined to nuclear polyhedrosis viruses (NPVs) and granular viruses (GVs).

NPV is a nucleic acid (double standard, circular DNA) enclosed in protein matrix, hence it is called polyhedral occlusion body (POB). NPV infects the nucleus of the cell and multiplies within the nucleus.

In India, extensive research has been conducted on the use of NPVs for tackling two major pests namely Spodoptera litura and Helicoverpa armigera.

Nuclear Polyhedrosis viruses like Ha NPV, SINPV are increasingly being used as alternatives to chemicals. These viruses have distinct advantages over other methods of pest control. NPVs are virulent pathogens of insect characterised by the polyhedral occlusion bodies (POB). These viruses are highly specific and do not affect beneficial insects like parasitoids and predetors and are safe to fish, birds, animals and man. Considering the usefulness of NPV's there has been a growing demand amongst the farmers for these bioagents.

2. Major equipment required

The major equipments like centrifuge, laminar flow, magnetic shaker, microscopes, autoclave, coolers, refrigerators, incubator, distillation units etc. are required in addition to glassware, plastic trays, basins, iron racks for mass production of Ha NPV and SI NPV.

3. Spodoptera litura (Tobacco Caterpillar)

Spodoptera litura commonly known as tobacco caterpillar, is a polyphageous pest. It is a serious pest of tobacco nurseries and also a sporadic pest of cauliflower, cabbage, castor, cotton, groundnut, potato and lucerne. It causes serious crop losses.

4. SI NPV

The virus is specific and infects only Tobacco Caterpillar. NPV can be successfully multiplied on tobacco caterpillar and the viral extraction can be applied in the field to control the caterpillar. For continuous production of SI NPV, it is necessary to rear Tobacco Caterpillar larvae continuously in a lab condition.

5. Gram pod borer (Helicoverpa armigera)

It is widely distributed in India and infests/damages a variety of cultivated and wild plants throughout its distribution range. It is a serious pest on commercial crop like cotton; pulses like redgram and bengalgram; vegetables like tomato, bhendi and dolichos bean; oilseeds like sunflower, soybean and safflower and cereals like sorghum and maize.

6. Ha NPV

Ha NPV is a highly infective microbial biopesticide which can be used to control Gram borer. It is derived from naturally diseased or under laboratory conditions artificially infected larvae of gram borer.

7. Mass production of Ha NPV and SI NPV

The mass production of Ha NPV and Si NPV involves 3 steps

- Rearing of adult Gram pod borer and Tobacco caterpillar for mass production of eggs.
- Rearing of larvae of the above species either on the host plants like chickpea and castor under semi natural condition or on the synthetic diet in the laboratory conditions. In the model only the later is considered for large scale commercial production of NPV.
- Inoculation of Ha NPV and Si NPV into the larvae of Gram pod borer and Tobacco caterpillar respectively for mass multiplication of viruses and extraction of polyhedral occlusion bodies(POBs) from the diseased larvae, which are used as biopesticide on the crop plants.

7.2 Details of mass production

Diet preparation

The larvae ofGram pod borer and Tobacco caterpillar can be multiplied by using chick pea based semi-synthetic diet. The composition of the diet for rearing larvae is as follows:-

	Item	**Quantity**
'A' fraction:	Chickpea (Kabuli chenna) flour	105.00 gm
	Methyl para-hydroxt benzoate	2.00 gm
	Sorbic acid	1.00 gm
	Streptomycin sulphate	0.25 gm
	10% formaldehyde solution	2.00 ml
'B' fraction:	Agar-agar	12.75 gm
'C' fraction:	Ascorbic acid	3.25 gm

	Yeast tablets	25 tablets
	Multivitaplex	2 capsules
	Vitamin E	2 capsules
	Distilled water	780.00 ml

390 ml of water is mixed with fraction 'A' of the diet in the blender which is run for two minutes. Fraction 'A' and 'C' are mixed and the blender is run again for 1 minute. Fraction 'B' is boiled in the remaining 390 ml water, added to the mixture of A and B and the blender is run for a minute. Formaldehyde solution is added at the end and the blender is again run for a minute.

Mass production of eggs
Tobacco caterpillar

The culture of Tobacco caterpillar is initiated by collecting eggs from the fields of castor, cauliflower, lucerne, tobacco etc. These field collected eggs are reared in isolation to eliminate the emerging parasitoids and diseases, if any.

The culture can also be established by collecting the gravid females with the help of light traps. Once the pure culture is established the mass production is commenced under laboratory conditions after the first generation established.

Pairs of newly emerged moths of Tobacco caterpillar are placed in well ventilated plastic containers. The inner wall of the containers is lined with paper to enable the adults to lay eggs. The bottom of the container is lined with sponge covered over by blotting paper. The moths are provided with 50% honey solution and water on two cottons swabs placed in small plastic cups. The eggs which are generally laid in batches on the paper are cut out. Freshly laid egg masses are sterilised by dipping in 10% formalin for 30 minutes, washed in running water for 30 minutes, dried on blotting paper and kept for hatching in sterilised glass vials.

The freshly laid eggs can also be surface sterilised in 0.05 percent solution of sodium hypo chlorite for 5 minutes. These eggs are washed several times in running tap water to remove the traces of sodium hypo chlorite. The traces of sodium hypo chlorite could be neutralized by dipping the eggs in 10% sodium thiosulphase solution and again the eggs are washed thoroughly under running tap water. The surface sterilised eggs are kept in plastic tubes (7.5 x 25 cm) on moist tissue paper for continuing the stock culture. After 3 days, the newly hatched larvae are transferred to bouquets of castor leaves and kept in a plastic container with stand for pupation. The pupae are collected 3 days after all the larvae enter the sand. The pupae are sexed and kept on a lid over a wet sponge in adult emergence cage. After 10 days, freshly emerged males and females are collected from their respective emergence cages.

Gram pod borer (Helicoverpa armigera)

The culture of Gram borer is initiated either collecting the adults with the help of light traps. It could be by collection of larvae on a large scale from its host crops in endemic areas. Nucleus culture can also be obtained from the established laboratories. The material thus obtained is reared in the laboratory in aseptic conditions and the healthy progeny is selected and established.

The production starts with the availability of 250 pairs of adults every day, which will yield 10,500 eggs daily. The adults are kept @ 100 pairs in each oviposition cage with a cloth enclosing the frame. A circular plastic mesh (on which cotton swabs soaked in water and honey solution are placed in small containers) rests on a support above the base of the frame. The cloth cover is open at both ends with a 20 cm vertical slit in the centre which can be closed with a zip or cloth clips. The cloth cover enclosing the frame is tied with rubber bands at both ends. It is placed on tray with a sponge at the bottom soaked in water. The temperature inside the cage is maintained at 260 C and humidity at 60 - 90%.

The eggs are laid all over the inner surface of the cloth cover. The egg cloth is removed daily. This cloth is surface sterilised in 10% formalin for 10 minutes, the eggs could also be surface sterilised using 0.2% sodium hypchlorite solution for 5-7 minutes and treated with 10% sodium thiosulphate solution to neutralise the effect of sodium hypo chlorite, rinsed in distilled water. The eggs are later placed on paper towell under laminar flow for drying. The dried cloth pieces containing eggs are kept in 2 litre flasks containing moist cotton. Flasks are plugged with cotton wrapped in muslin cloth and the bottom of the flask is wrapped with aluminium foil.

Rearing of larvae on semi-synthetic diet

Tobacco caterpillar

Stage - I (rearing of early instar larvae): The rearing unit is prepared by placing a sponge piece on a glass sheet. The sponge is covered with a single layer of soft tissue paper. A small plastic container containing 200 surface sterilised eggs of Tobacco caterpillar is placed in the centre over the tissue paper. A petri dish containing about 200 ml of diet is placed inverted over the tissue paper. The eggs hatch within 25 hr and neonate larvae crawl and spread out on the diet.

Stage - II (rearing of late instar larvae): Late instar larvae are reared in a modified plastic boxes. One window each on the four sides of the box is cut and covered with a fine plastic mesh to provide sufficient ventilation and to prevent moisture accumulation inside the box. A thick layer of sterilised sand is spread at the bottom of the box. A small piece of tissue paper is kept at the centre over the sand.

The diet in the petri dish (containing 200 larvae) is divided into five equal pieces. One piece of diet bearing 40 larvae is kept in plastic box over the tissue paper so that the sand does not soil the diet. In this way, 5 boxes are charged with larvae from 1 petri dish. A plastic grill is fitted into the box in such a manner so that it forms a crest higher than the brim of the box. Thick cake of diet (about 500 gm) in a petri dish is divided into two equal pieces. One such piece is kept on the top of the crest and the lid of the box is then fixed so that the diet and grill crest are opposed to each other just beneath the lid. After consuming the small quantity of diet on tissue paper the larvae crawl and perch on the grill and feed from the ceiling of the box. The boxes are stacked and left intact for 3 days. During this time the diet is almost completely consumed. Now another piece of fresh diet (about 250 gm) is kept on the crest in each box and the boxes are closed and stacked again. During the last 3/4 days of larval stage the food consumption is maximum and so is the fecal matter accumulation on the sand layer. After 20 days from hatching the larvae move into the sand and start pupating. In a period of 25 days, all the larvae, pupate and the chitinisation of pupae is also completed. The boxes are now ready for the pupal harvest. The pupae are collected, cleaned, sterilised and placed in adult emergence cages. The freshly emerged moths are then placed in oviposition cages.

Gram borer

The larvae of gram borer can also be reared on a chickpea based semisynthetic diet as detailed under point 7.2.1.

The diet is poured as per the requirement either on the nylon mesh for rearing 5-7 day old larvae or in tray cells for rearing the older larvae or poured into sterilised petri plates and allowed to solidify. The diet could be stored in the refrigerators for upto 2 weeks. For preparing large quantities of diet, the quantity of diet ingredients to be used should be calculated accordingly and industrial type waring blenders could be used.

The larvae are removed from the top of the aluminium foil wrapped flasks with a brush and then transferred to the diet. 220 larvae are transferred to diet impregnated on nylon mesh and placed in plastic containers or sterilised glass vials. 100 such containers are maintained daily for 5-7 days. Multi-cellular trays with semi-synthetic diet is advantageous for rearing a large number of larvae.

Starting with 10,500 eggs, the total number of larvae available is 10,000 considering an estimated 5% mortality in initial 5 days of emerging and 10% mortality upto first 5 - 7 days. The total number of larvae available for virus production is 8000 (80%). The rest of 20% will be utilized for maintenance of host culture continuously.

The diet requirements at various stages of production of larva are:

- for the young larvae upto 5-7 days will be 2 gms / larva.
- for 5-7 day old larvae for Ha NPV production will be 4gms/larva
- for five to seven day old larvae for continuation of host culture will be 6 gms/larvae.
- for rearing the field collected larvae for augmenting the nucleus stock will be about 1 kg

In host culture units, larvae start pupating when they are 18-19 days old and the pupation will be over within 2-3 days. The harvested pupae are surface sterilised using 0.2% sodium hypo chlorite solution followed by washing with 10% sodium thiosulphate solution to neutralize sodium hypo chloride and then washed thoroughly with distilled, sterilised water. After washing, the eggs are dried by rolling over blotting paper. The male and female pupae are separated out and placed over moist sponge in adult emergence cages.

The egg, larval, pupal and adult stages of gram borer last 3-4, 18-29, 7-8 and 7-9 days respectively. The oviposition period of the females is about 5 days.

Production of Helicoverpa armigera NPV (Ha NPV) and Spodoptera litura NPV (SI NPV).

For Ha NPV and SINPV production, the synthetic diet prepared is poured at 4gm/cell in the multi-cavity trays and the diet surface is uniformly sprayed with virus prepared in distilled sterilised water at 18 x 106 POBs / ml. Eighty percent of the total 5-7 day old larvae are utilised for Ha NPV and SINPV production.

The trays are incubated at 260 C for 7 days. In case of virus infected larval trays, the diseased larvae dies after attaining its maximum size of 6th instar, where the dead caterpillar will have 2-6 billion poly occlusion bodies (POB) which is in terms of larval equivalent (LE). 1 LE of H.armiegera NPV = 6 x 109 POBs; 1 LE of S. litura = 2 x 109 POBs. The dead larvae have to be harvested, macerated in distilled/sterilised water and filtered through muslin cloth to get the crude suspension of the virus. The extraction is centrifuged to further clarify the solution.

8. Other Important Aspects

1. General precautions to be followed while maintaining host cultures

- In production units, keep the host culture in a separate room and the virus production and storage facility should be located in a different facility.
- In the NPV production units, inspite of best care, 100% larvae are not infected, the larvae which do not turn inactive after 4 - 5 days and keep consuming the normal diet should be culled out regularly from the NPV production unit.
- Utmost care should be taken to prevent the break in the chain of the production system. This could be achieved only if highly dedicated and disciplined workers are engaged for such production units.
- Strict hygiene should be maintained in different facilities. The equipments used should be either heat sterilised or sterilised using steam or chemicals. The work place should be thoroughly disinfected with sodium hypo chlorite solution.
- The host culture should be initiated from a batch of healthy adults.
- Microbial infection could be avoided if good insect husbandry practices are followed. If infection is detected, the culture or infected part should be destroyed immediately. Besides hygienic conditions, optimum temperature (24o C- 26o C) and humidy (65 - 70%) should also be maintained.
- The texture and quality of the natural/semisynthetic diet should be good.
- entry to host culture unit after visiting virus production unit should be avoided.

2 Mode of action

NPV acts as a stomach poison only to the target host (pest) and hence beneficial insects are not affected. The infected larvae become pale and glossy and tissue get disintegrated and liquified. Most of the body tissues and organs (except gut) get infected by polyhedral occlusion bodies (POBs), which contains the virions. The liquid which oozes out of the infected larvae (which hang upside down) contains millions of POBs. Each POB measuring about one micron in diameter and possessing a characteristic movement can be identified under the microscope.

3 Field application and dosage

Ha NPV is used for controlling H.armigera attacking cotton, redgram, bengalgram, tomato, okra, sunflower, groundnut, chillies, maize, sorgram etc., whereas, SI NPV is used for controlling tobacco caterpillar attacking tobacco, groundnut, soyabean, sunflower, cotton, cabbage, beetroot, cauliflower etc.

4 Directions for use of NPV

- The recommended dosage is 200 ml of NPV/acre or 500 ml/ha containing 100 and 250 larval equivalent (LE) of NPV respectively as active infective material (one LE = 6 x 109 POBs).
- 100 ml of NPV could be diluted in 200-400 litres of water when high volume sprayer is used and in 50-70 litres of water in case of power sprayers.
- Preferable to spray using high volume knap-sack sprayer. Virus should be sprayed during evening hours. Spray should be initiated as soon as some newly hatched larvae are observed or three to five days after a trap catch of 5 moths per pheromone trap. Subsequent sprays should be made at 7-10 days intervals depending upon the pest population.

5 Compatibility with other insecticides

The viral pathogens seems to be less sensitive to chemical pesticides. When the combination of pathogen and pesticide is used, sometimes synergistic action is noticed. But is recent years mixing of NPV with insecticides is not advisable due to cross resistance problem.

E. Technology for mass production of Trichoderma fungi

1. Introduction

Crop losses due to soil borne plant pathogens worldwide are Pythium spp., Furarium oxysporum, sclerotium rolfsii, Rhizoctonia solani and Phytophthora spp. These fungi pathogens generally cause wilt disease in many crops. Trichoderma, a fungi, which grow saprophytically in soils have proved as an effective biocontrol agent of wilt diseases.

Trichoderma spp. are commonly found in almost any soil and other natural habitats consisting of organic matter such as decaying bark, plant material, etc. They grow trophically towards hyphae of other pathogenic fungi, coil them and degrade their cell walls. This process is called "mycoparasitism", which limits the growth and activity of plant pathogenic fungi. In addition, they produce toxic metabolites which protect the seeds from soil borne pathogenic fungi, by forming a protective coating on them.

Trichoderma spp. are saprophytic fungi that grow best in neutral and acid soils and thrive well in moist conditions.

The important species available for mass production are Trichoderma viride and Trichoderma harzianum

Equipments required: Equipments like fermentor, rotary mixer, auto packer, rotary shaker, laminar flow, water distillation unit, refrigerator, haemo cytometer etc. are required for the production of Trichoderma fungi.

2. Major steps in production process

Inoculation | Fermenter run | Harvesting | Blending | Drying and Packing

3. Outlines for production of Trichoderma

- The pure mother culture of Trichoderma fungi is being maintained in Agri. Universities, IARI, some ICAR institutions (like PDBC, Bangalore) etc. The mother culture can be purchased from the identified sources. They have to be further sub-cultured and maintained purely for mass production by adopting standard techniques under the supervision of trained microbiologist /

pathologist.

- The culture has to be mass multiplied in two levels namely (i) at primary level using shakers in flasks and (ii) secondary stage multiplication in fermenters. The important factor in this is the preparation of growing medium in which the culture is mass multiplied. For Trichoderma Fungi, the growing media used in the model is molasis and protein material.
- After the growing media is formulated and sterilised in fermenter, it is inoculated using the culture multiplied in the flasks.
- The molasis based culture media is continuously aerated by passing sterile air from compressors. After about 3-4 days fermentation period, the culture will be ready for packing in a carrier material.
- While the inoculated culture is gathering ready in the fermenters, the carrier material is sterilised in autoclaves and kept ready for mixing the culture. Talk powder is reported to be the commonly used carrier material for Trichoderma Fungi.
- The cultured (fungi) and sterilised carriers are mixed mechanically in a blender and the material is packed using semi automatic packing and sealing machine.

4. Dosage

Talc based formulations of the fungal antagonists are applied at the rate of 4gm per kg of seed for controlling soilborne plant diseases. Mix the powder with sufficient quantity of water to make slurry for treating seed before sowing.

5. Advantages of Trichoderma applicatiom

- Ecofriendly
- Can be used along with organic manure
- Trichoderma spp. are also known to suppress plant parasitic nematodes (roo-knot nematodes).
- Lower cost and longer efficacy than fungicides
- Does not lead to development of resistance in plant pathogens
- No physotoxic effects
- Minimises losses and cost of production and increases yield & profit.

- Promoter plant growth

6. Application

Soil application

Trichoderma spp. suppress the activity of soil borne fungal pathogens, especially Rhizoctania solani and Pythium spp. and protect transplanted seedlings by colonizing their roots.

Seed treatment

Seed treatment is an alternative approach to introduce Trichoderma spp. into the soil. This method requires smaller amounts of biological material than soil treatment. Unlike chemical fungicides, Trichoderma spp. provide long term protection without any adverse side effects.

F. Sex pheromone traps of Helicoverpa armigera and Spodoptera litura

1. Introduction

Sex pheromones are single or complex blend of different chemicals released by one insect to attract the opposite sex of the same species. In general, females (especially the moths) emit sex attractants to attract males for mating. Sex pheromones are artificially synthesized in the laboratories and supplied as sex pheromone lures. Such pheromones are placed in the field to attract trap and kill the males, thus matting is not allowed. Hence, sex pheromone traps can be considered as a key component in Integrated Pest Management (IPM).

Ready-to-use Sex pheromone lures and traps are available for Helicoverpa armigera (attacking crops like cotton, redgram, tomato, okra, sunflower, chillies, maize, sorghum etc.) and spodoptera litura (attacking crops like tobacco, groundnut, sunflower, cotton, cabbage, beetroot, cauliflower, etc.)

2. Advantages of pheromone lures

- No harmful effects to beneficial insects, non-target organism or an environment.
- Helps in monitoring & early detection of pests (at moth stage only)

- Helps in scheduling pest control measures
- Reduction in usage of insecticides
- Much simpler

3. Equipment needed

Only micropippets are required in addition to rubber septas, traps and pouches.

4. Production of Pheromone Traps

Sex pheromones are insect specific, produced artificially in laboratories and they are generally imported. In India, it is available from National Chemical Laboratory (NCL), Pune. Chemicals obtained from laboratory is diluted to the required dosage and filled into plastic lures with the help of micro pippets and closed with rubber septa. Lures are individually sachet packed and should be stored under refrigerated conditions when not in use.

5. Field application

Lures containing sex pheromones are placed into insect trap and erected in the field at a recommended spacing. The lure will release the sex pheromane at a constant rate over a period of 2-4 weeks. Male months are attracted and while attempting for matting, fall into a container having pesticide. Thus the female moths in the field are deprived of successful mates and fail to reproduce or lay viable eggs.

6. Dosage

Timely use of sex pheromone helps in early detection and prompt action against pests. In general, 2-3 traps / acre are recommended for 'monitoring' or more for 'mass-trapping'. These are arranged such that the trap is 1-2 feet above the crop canopy. On the field each lure is effective for atleast 15 days. Change the lures once in two weeks.

PRODUCTION OF BIO AND HERBAL PESTICIDES AT HOUSEHOLD/ FARM LEVEL

Producing bio and herbal pesticides at the household or farm level can be an effective and environmentally friendly way to manage pests while reducing reliance on synthetic chemical pesticides. Here's a general overview of how you can produce and use bio and herbal pesticides:

Biopesticides: Biopesticides are naturally derived products that use living organisms or their byproducts to control pests. They include beneficial insects, microbial pesticides, and plant-derived substances.

1. **Microbial Biopesticides**: These are based on beneficial microorganisms that can kill or inhibit pests. Bacillus thuringiensis (Bt) is a well-known microbial biopesticide used to control various insect larvae. To produce microbial biopesticides:
    - Isolate and culture the beneficial microorganism.
    - Multiply the culture in a suitable growth medium.
    - Concentrate and formulate the microbial solution.
    - Apply the solution to target plants.
2. **Plant-Derived Biopesticides**: These are derived from natural plant extracts and oils with pesticidal properties. Neem oil and pyrethrum are examples of plant-derived biopesticides. To produce plant-derived biopesticides:
    - Collect and dry plant parts with pesticidal properties.
    - Extract the active compounds using appropriate methods (e.g., cold pressing, steam distillation).
    - Dilute the extract and use it as a spray.

Herbal Pesticides: Herbal pesticides are made from various plant parts with pesticidal properties. These can be used to repel, deter, or kill pests.

1. **Plant Extracts**: Different plant parts (leaves, stems, roots) can be used to make extracts that repel or deter pests. Garlic, chili peppers, and onions are examples of plants used for this purpose. To make herbal pesticide extracts:
    - Crush or grind the plant parts.
    - Mix them with water and leave the mixture to steep.
    - Strain the mixture and use the liquid as a spray.

2. **Plant-Based Formulations**: Herbal pesticides can also be formulated using natural additives. Soap, oil, or other natural ingredients can help enhance the effectiveness of the pesticide.

Steps for Production:

1. **Identify Pests and Plants**: Identify the pests you want to target and the plants or plant extracts known to repel or control those pests.
2. **Materials and Equipment**: Gather the necessary materials and equipment for extraction and formulation. This may include containers, grinding tools, strainers, and spray equipment.
3. **Extraction/Preparation**: Depending on the type of bio or herbal pesticide, extract the active compounds from plants or culture the beneficial microorganisms.
4. **Formulation**: Mix the extracted solution with other ingredients if needed (e.g., soap for better adhesion). Test the formulation on a small area before large-scale application.
5. **Application**: Dilute the pesticide if required and apply it to the plants using spray equipment. Apply during early mornings or evenings to avoid harming beneficial insects.
6. **Storage**: Store any unused portions of the pesticide according to instructions. Some formulations may have a limited shelf life.

Remember that while bio and herbal pesticides are generally safer than synthetic chemicals, they can still have an impact on non-target organisms. Therefore, always use these pesticides judiciously, following recommended dosages and application methods. It's also a good practice to rotate different types of pesticides to prevent the development of pest resistance.

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