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FACULTY OF AGRICULTURE SCIENCE AND ALLIED INDUSTRIES

Organic methods of weed management:-

Weeds can be considered a significant problem because they tend to decrease crop yields by increasing competition for water, sunlight, and nutrients while serving as host plants for pests and diseases. Since the invention of herbicides, farmers have used these chemicals to eradicate weeds from their fields. Today, some farmers have a renewed interest in organic methods of managing weeds since the widespread use of agrochemicals has resulted in purported environmental and health problems. It has also been found that in some cases herbicide use can cause some weed species to dominate fields because the weeds develop resistance to herbicides. In addition, some herbicides are capable of destroying weeds that are harmless to crops, resulting in a potential decrease in biodiversity on farms. It is important to understand that under an organic system of weed control, weeds will never be eliminated but only managed.

Organic weed management is a holistic system involving an entirely different approach to managing a farming system. The organic farmer is not interested in eliminating all weeds but wants to keep the weeds at a threshold that is both economical and manageable. A farmer who manages weeds organically must be intimately familiar with the type of weeds and their growth habits to determine which control methods to employ.

Optimizing the biological terrain of the soil for the crop will create an unfavorable environment for many weeds, effectively reducing weed numbers and vigor. This concept forms the core of effective weed control in an organic production system. Contrast to this the weed-control strategies of conventional farming, with heavy use of salt fertilizers, herbicides, monoculture and imbalanced cation saturations. Indeed, that environment could accurately be described as one of cultural weed enhancement. The conventional field environment presents heavy pressure to select for herbicide-resistant weeds that thrive under these conditions. Each year, these highly adapted weeds find the same favorable conditions and reproduce abundantly. It is really no wonder that most herbicides are only effective for a few years before a newer, stronger (and more expensive) chemical is needed to control weeds sufficiently. It is important to know your enemy. All weed species have their weaknesses and their strengths, usually occurring at distinct stages of their life cycles or resulting from specific growth patterns. Different weeds present problems at different times of year, or with different crops. Some weed control strategies, such as disking a field infested with quack grass, may even increase the prevalence of certain species of weeds under specific conditions. Grassy weeds often require different control measures than do broad-leafed weeds. Correctly identifying the species of weeds that are causing major problems in your fields is critical to choosing and timing effective control measures

Organic Methods of Weed Management:-

1. Thermal weed control Thermal weed control involves the use of flaming equipment to create direct contact between the flame and the plant. This technique works by rupturing plant cells when the sap rapidly expands in the cells. Sometimes thermal control involves the outright burning down of the weeds. Flaming can be used either before crop emergence to give the crop a competitive advantage or after the crop has emerged. However, flaming at this point in the crop production cycle may damage the crop. Although the initial equipment cost may be high, flaming for weed control may prove cheaper than hand weeding.

2. Soil solarization: During summer and fall, organic farmers sometimes sterilize their soil through solarization. During this process, a clear plastic film is placed over an area after it has been tilled. Solarization works when the heat created under the plastic film, which is tightly sealed at the edges, becomes intense enough to kill weed seeds.

3. Mulch: Mulching or covering the soil surface can prevent weed seed germination by blocking light transmission preventing seed germination. Allelopathic chemicals in the mulch also can physically suppress seedling emergence. There are many forms of mulches available. Listed are three common ones:

i. Living mulch: Living mulch is usually a plant species that grows densely and low to the ground, such as clover. Living mulches can be planted before or after a crop is established. It is important to kill, till in, or otherwise manage the living mulch so that it does not compete with the actual crop.

ii. Organic mulches: Such materials as straw, bark, and composted material can provide effective weed control. Producing the material on the farm is recommended since the cost of purchased mulches can be prohibitive, depending on the amount needed to suppress weed emergence. An effective but labor-intensive system uses newspaper and straw. Two layers of newspaper are placed on the ground, followed by a layer of hay. It is important to make sure the hay does not contain any weed seeds.

iii. Inorganic mulches: Materials such as black polyethylene have been used for weed control in a range of crops in organic production systems.

Mechanical weed management

Managing weeds mechanically is both time consuming and labor-intensive but it is also one of the most effective methods for managing weeds. The choice of implementation, timing, and frequency will depend on the structure and form of the crop and the type and number of weeds. Cultivation involves killing emerging weeds or burying freshly shed weed seeds below the depth from which they will germinate. It is important to remember that any ecological approach to weed management begins and ends in the soil seed bank. The soil seed bank is the reserve of weed seeds present in the soil. Observing the composition of the seed bank can help a farmer make practical weed management decisions.

Stale seedbed

The stale or false seedbed technique of flushing out weed seeds from the soil works by depleting the seed bank. After the soil is cultivated two to three weeks before sowing, emerging weeds are killed by flaming or light cultivation. By helping to reduce the seed bank, this technique reduces subsequent emergences of weeds.

Crop rotation

Crop rotation has been at the heart of the organic weed management system since medieval times and has persisted well into the 20th century due to its proven effects on weed populations. The goal of a crop rotation is to create an unstable environment that discourages weeds from becoming established in the field. Deciding on the sequence of crops, a farmer must take into account the type of soil he or she is working with, the climate, and the crop. Diverse crop rotations are essential to build a healthy, sustainable organic system and break pest and weed cycles. In general, it is best to alternate legumes with grasses, spring-planted crops with fall-planted crops, row crops with close-planted crops, heavy feeders with light feeders. Careful use of cover crops during times when the ground would be bare adds valuable nutrients (especially nitrogen), adds organic matter, improves soil microbial diversity, and prevents erosion. Maintain a long-term balance of diverse crops on a

farm, taking into account any necessary soil conservation practices, livestock requirements, time constraints and market profitability.

Crop establishment and competition

Make sure crops emerge first to give them a head start in their competition with weeds. Transplanting helps increase a crop's competitive ability since the plants are larger and easier to establish. Sow crops close together by reducing the row spacing. Since the crop will take up more space, it shades the weeds, reducing the weeds' ability to compete. Another technique involves increasing the seeding rate of a crop. This increases the competitive ability of the crop by increasing the odds that the crop will survive in greater numbers than the weeds. The most effective way to control weed growth is to have highly competitive crops. A vigorously growing crop is less likely to be adversely affected by weed pressure. It is imperative to create conditions where the intended crop can establish dominance quickly. Using high-quality, vigorous seed, well adjusted planting equipment, adapted varieties, optimal soil fertility, good soil drainage and tilth, and proper soil preparation will usually result in rapid, vigorous crop growth.

Sanitation

Using clean seed will prevent the introduction of new weed problems and will avoid planting a generous crop of weeds with your desired crop. Mowing weeds around the edges of fields or after harvest prevents weeds from going to seed. Handroguing weeds in problem areas, and thoroughly composting manure can reduce the spread of weed seeds and difficult weed species. Thorough cleaning of any machinery that has been used in weedy fields is a good idea, as is establishing hedgerows to limit wind-blown seeds. Common sense, yes — and it works! Cultural practices won't prevent all weed growth, and some mechanical follow- up will usually be necessary, but cultural practices can improve soil conditions, permitting more effective mechanical control, they can adjust weed species to ones that are easier to control, and, most importantly, cultural weed-control practices can produce high-quality, vigorous, high-yielding organic crops.

It is important to maintain proper sanitation on the farm to reduce the introduction and spread of weed seeds. There are several ways to keep weeds and weed seeds from entering the farm. First, any animal manure that will be used on the farm should be composted because weed seeds can pass through an animal's digestive system unharmed, it is important to compost the manure. Composting results in temperatures that become high enough to kill many weed seeds. Second, purchase certified seed that is guaranteed to be free of weed seeds. If you are a farmer interested in saving your own seed, be diligent about collecting clean seed so you do not contaminate your collections. Also make sure to remove weeds before they set seed. Once a weed is allowed to set seed, the number of weed seeds in the seed bank is increased. Last, keep tillage and other equipment clean when moving between fields to reduce the spread of weed seeds.

Allelopathy

Allelopathy is an alternative and organic approach to weed control that uses chemicals that are excreted from a plant to cause either direct or indirect harm to weeds by negatively affecting their germination, growth, or development. Nearby weeds can be affected by allelopathic chemicals entering the rhizophere from the roots or the aerial parts of the crop plant. Crop residues from cover crops, such as fall rye, or other organic mulches can also be used to suppress weeds through such allelopathic interactions. This "allelopathy" is one of nature's most effective techniques of establishing plant dominance. Allelopathic crops include barley, rye, annual ryegrass, buckwheat, oats, sorghum, sudan-sorghum hybrids, alfalfa, wheat, red clover and sunflower. Selecting allelopathic crops can be useful in particularly weedy fields with reducing overall weed pressure.

Soil Fertility & Condition

In an organic system, it is important to rely on the biological activity of the soil as the main source of fertility and favorable soil physical structure. An active and diverse soil microbial population is the key to growing healthy, high-yielding organic crops. Successful organic fertility management should primarily feed the soil microbial life in a long-term manner, rather than simply feeding the plants. Soil organic matter is a tremendous source of plant nutrients and water holding capacity. Soil tests can be useful, but only if the results are interpreted appropriately for an organic system. Careful attention to the balance of key nutrients can often reduce weed problems and enhance crop plant growth. One common mistake made by many organic farmers is the improper application of manure or improperly finished compost. This can throw off the balance of certain soil nutrients and microbial life and can often increase weed growth. Some soil fertility amendments, such as gypsum, can increase the looseness and tilth of the soil. This improves success for mechanical-cultivation operations, but it also seems to reduce the pressure from certain weed species that are favored by hard, tight soils.

Variety Selection

Careful selection of crop varieties is essential to limit weeds and pathogen problems and satisfy market Lely weeder. Needs, It is important to consider planting disease-resistant varieties if certain pathogens are prevalent in the area. Any crop variety that is able to quickly shade the soil between the rows and is able to grow more rapidly than the weeds will have an advantage. Deep shading crops, which intercept most of the sunlight that strikes the field and keeps the ground dark, will prevent the growth of many weed species. Alfalfa, clover and grasses are particularly good shading crops because any weeds that grow in them will usually be cut when hay is harvested, thereby preventing weed seed production.

Mycoherbicides

Herbicides especially soil applied have harmful effects on both human and animal health. In this context, fungal pathogens control specific weeds and continue to survive on the weeds year after year unlike herbicides that are to be applied every year. Fungal pathogens as a bio-agent in controlling weeds are more popular than bacterial, viral or nematodes because, most of the plant pathogens are fungi, which are destructive and widely prevalent, and they can be safely used in organic farming. Phytopathogens normally initiate diseases in specific weeds and produce phytotoxins killing the weeds within 3-5 weeks.

Characteristics of mycoherbicides

a. They should be culturable in artificial media
b. They should produce abundant spores
c. They should be stable in storage
d. Should be genetically stable
e. Effective under field condition
f. Tolerant to variation in temperature
g. These herbicides should be compatible with other chemicals/culturable practices

Diseases and insect pest management, biological agents and pheromones, bio-pesticides:-

Pest and disease management consists of a range of activities that support each other. Most management practices are long-term activities that aim at preventing pests and diseases from affecting a crop. Management focuses on keeping existing pest populations and diseases low. Control on the other and is a short-term activity and focuses on killing pest and disease. The general approach in organic agriculture to deal with the causes of a problem rather than treating the symptoms also applies to pest and diseases. Therefore, management is of a much higher priority than control. This document describes preventive practices, as well as control practices using biological, mechanical control and natural pesticides.

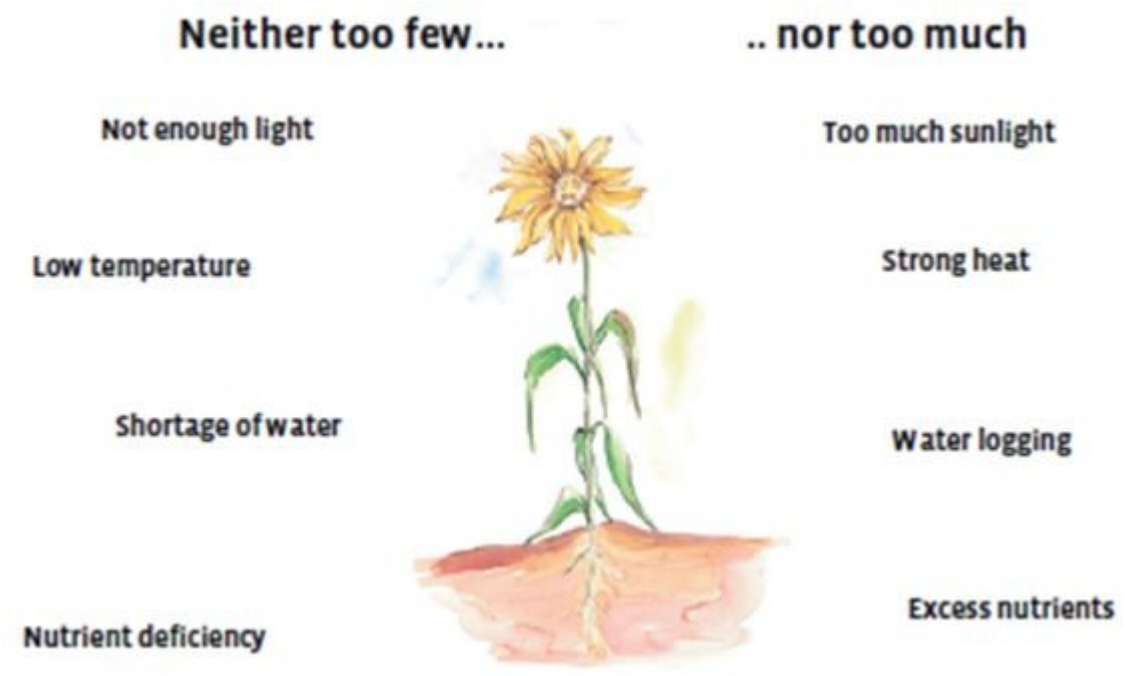
Favorable conditions to keep a plant healthy

- A healthy plant is less vulnerable to pest and disease infestation.
- A major aim for the organic farmer is to create conditions which keep a plant healthy.

The principles of pest and disease management in organic agriculture

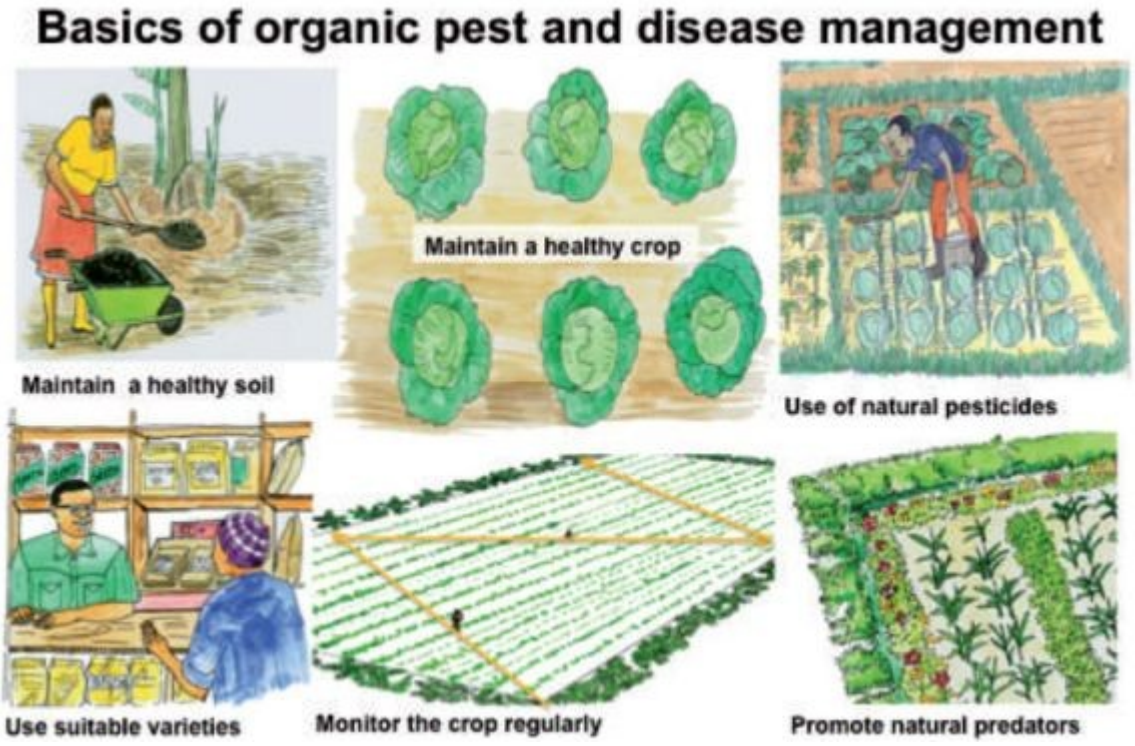
- The interaction between living organisms and their environment is crucial for a plant's health.
- A plant's health is more at risk in monocultures and on-farm diversification provide a balanced interaction between different plants and pests and predators.
- This is why a well-managed ecosystem can be a successful way of reducing the level of pest or disease population.
- Certain crop varieties have more effective mechanisms than others due to their adaptive nature to the environment and therefore have a lower infection risk.

Figure 1. Factors influencing plant health



- The health condition of a plant depends to a large extent on the fertility of the soil.
- When nutrition and pH is well balanced, the plant becomes stronger and is therefore less vulnerable to infection.
- Climatic conditions, such as suitable temperatures and sufficient water supply, are further factors which are crucial for a healthy plant.
- If one of these conditions is not suitable, the plant can become stressed.
- Stress weakens the defence mechanisms of plants and makes them easy targets for pests and diseases.
- One of the most important points for an organic farmer is therefore to grow diverse and healthy plants.
  - This avoids many pest and disease problems.

Figure 2. Basics of organic pest and disease management



Prevention practices and monitoring

Prevention practices

- Knowledge about plant health and pest and disease ecology helps the farmer to choose effective preventive crop protection measures.
- As many factors influence the development of pest and disease, it's crucial to step in at the most sensitive points.
- This can be accomplished through the right timing of management practices, a suitable combination of different methods, or the choice of a selective method.

- Below are some important preventive crop protection measures

1. Selection of adapted and resistant varieties

- Choose varieties which are well adapted to the local environmental conditions (temperature, nutrient supply, pests and disease pressure), as it allows them to grow healthy and makes them stronger against infections of pests and diseases.

2. Selection of clean seed and planting material

- Use safe seeds which have been inspected for pathogens and weeds at all stages of production.
- Use planting material from safe sources.

3. Use of suitable cropping systems

- Mixed cropping systems
  - These can limit pest and disease pressure as the pest has less host plants to feed on and more beneficial insect life in a diverse system

- Crop rotation
  - This reduces the chances of soil borne diseases and increases soil fertility.
- Green manuring and cover crops
  - This increases the biological activity in the soil and can enhance the presence of beneficial organisms (but also of pests - therefore a careful selection of the proper species is needed).

4. Use of balanced nutrient management

- Moderate fertilization
  - Steady growth makes a plant less vulnerable to infection.
  - Too much fertilization may result in salt damage to roots, opening the way for secondary infections

- Balanced potassium supply contributes to the prevention of fungi and bacterial infections.

5. Input of organic matter

- Increases micro-organism density and activity in the soil, thus decreasing population densities of pathogenic and soil borne fungi.
- Stabilises soil structure and thus improves aeration and infiltration of water.
- Supplies substances which strengthen the plant's own protection mechanisms.

6. Application of suitable soil cultivation methods

- Facilitates the decomposition of infected plant parts.
- Regulates weeds which serve as hosts for pests and diseases.

- Protects the micro-organisms which regulate soil borne diseases.

7. Use of good water management

- No water logging: causes stress to the plant, which encourages pathogens infections.
- Avoid water on the foliage, as water borne disease spread with droplets and fungal disease germinate in water.

8. Conservation and promotion of natural enemies

- Provide an ideal habitat for natural enemies to grow and reproduce.
- Avoid using products which harm natural enemies.

9. Selection of optimum planting time and spacing

- Most pests or diseases attack the plant only in a certain life stage.
  - Therefore it's crucial that this vulnerable life stage doesn't correspond with the period of high pest density and thus that the optimal planting time is chosen.
- Sufficient distance between the plants reduces the spread of a disease.
- Good aeration of the plants allows leaves to dry off faster, which hinders pathogen development and infection.

10. Use of proper sanitation measures

- Remove infected plant parts (leaves, fruits) from the ground to prevent the disease from spreading.
- Eliminate residues of infected plants after harvesting.

Monitoring

- Regular monitoring of pests, diseases and weeds is the basis for effective management.
- To be able to manage pests, diseases and weeds, information is needed on the specific pests, diseases and weeds present in the region, village or crop fields and the associated damage they cause.

1. Typical signs of pest attacks on crop plants

- Most crop pests belong to the insects, mites and nematodes.
- However, in Africa, mammals (like elephants, monkeys or voles), and birds (like sparrows, starlings and crows) can also damage crops.
- Insect damage can be categorized by biting and chewing (e.g. caterpillars, weevils), piercing and sucking (e.g. *aphids, psyllids*) and boring (e.g. borer, leaf miner) species.
  - Some are slow moving (e.g. caterpillars), fast moving (e.g. fruit flies), hidden (e.g. stem borer), or easy to observe (e.g. caterpillars, weevils).
- Pest damage is often species-specific.
  - Leaves with holes or missing parts is an indication of caterpillar or weevil damage; curled leaves is an indication of aphids; damaged or rotten fruits are often caused by larvae of fruit flies; withering

plants can also be caused by larvae of noctuids or the stem borer; and branches or trunks with holes may be an attack by lignivorous insects.

- Mites are very small and cannot be seen with the naked eye.
  - However, some mite species (spider mites) weave a typical tissue on attacked plant parts and can, therefore, easily be detected.
  - If mites are present on plants, leaves and fruits become yellowish.
- Nematodes are also very small and therefore, they are not easy to observe with the naked eye.
  - They mostly attack plant roots; plants become yellow, wither and die.

.2 Typical signs of disease attacks on crop plants

Most crop diseases are caused by fungi, bacteria or viruses.

- Fungi cause the great majority, estimated at two-thirds, of infectious plant diseases.
  - They include all white and true rusts, smuts, needle casts, leaf curls, mildew, sooty moulds and anthracnose.
  - They are responsible for most leaf, fruit, and flower spots, cankers, blights, wilts, scabs, and root, stem, fruit, wood rots among many others.
  - Parts of plants or the total crop plant can wither and die.
- Bacteria cause any of the four following main problems.
  - Some bacteria produce enzymes that breakdown the cell walls of plants anywhere in the plant.
  - This causes parts of the plant to start rotting (known as 'rot').
  - Some bacteria produce toxins that are generally damaging to plant tissues, usually causing early death of the plant.
  - Others produce large amounts of very sticky sugars; as they travel through the plant, they block the narrow channels preventing water getting from the plant roots up to the shoots and leaves, again causing rapid death of the plant.
  - Finally, other bacteria produce proteins that mimic plant hormones.
  - These lead to overgrowth of plant tissue and form tumours.
- Viruses mostly cause systemic diseases.
  - Generally, leaves show chlorosis or change in colour of leaves and other green parts.
  - Light green or yellow patches of various shades, shapes and sizes appear in affected leaves.
  - These patches may form characteristic mosaic patterns, resulting in general reduction in growth and vigour of the plant.

- Careful and continuous monitoring of pest and disease levels during critical times of growth of a crop is the key to successful management.
  - This can be done through regular scouting of the field by the farmer.
  - It helps the farmer to intervene early enough before the pest and/or disease cause significant damage.

- Scouting avoids unnecessary use of natural plant extracts.
  - Limited use of these substances (e.g. *pyrethrum*, derris and tobacco) and oils is important as they also have negative effects on beneficial insects.
  - If the application of these substances is not regulated, many pest predators and parasitoids may be killed as well.
  - Over application of these substances may also lead to pests developing resistance.
  - Therefore, scouting should be planned and done in an organised way.
  - It is important to get a random sample that will be representative of the overall situation in the crop garden.

- Therefore, the scout (farmer) needs to observe and record any of the findings for better decision making.

- The most common pattern in pest and disease scouting programs involves walking along a predetermined zigzag or M-shaped route through a field.
- This pattern is commonly used because it is easy to teach, convenient to use, and ensures that all regions of the field are visited.
- To monitor insect pests, different traps can also be used.
- The simple idea is to know more about the presence of the insect pests in the field especially the fast moving (mobile) insect pests (e.g. fruit flies, lepidopteran pests).

- Fruit flies can be captured using bait traps.
- For example, PE-bottles with small holes can be half-filled with water, some cattle urine, fruit flesh or a small dead fish and a drop of detergent or soapy water.
- These bottles are then hung in trees and checked every three days.

- Yellow plastic cards coated with adhesive are also good for trapping aphids and leafhopper.
- Yellow orange plastic boards are appropriate for white flies, while blue cards are appropriate for thrips monitoring.

- Light traps are especially needed where noctuids (e.g. moths, cutworms, African armyworm, and cotton bollworm) are a problem.
- Within crops attacked by cutworms, visual checks of caterpillars have to be done by dawn.

- Organic management and control of diseases is based strongly on strengthening the plant with the aim of enhancing its self-defence and thereby preventing the outbreak of the disease.
  - One typical expression of induced resistance is the thickening of cell walls of the plant, which interferes with pathogen entering the cell.
  - Another is the dying of the infested cell walls, which causes the pathogen to die also, and thus reduce its spread.
- There are several resistance-inducing substances that can be prepared by the farmers themselves.
  - Some are plant extracts made from efeu (*Hedera helix*), rhubarb (*Rheum rhabarbarum*), or giant knotweed (*Reynoutria sachalinensis*).
- Compost teas and herbal teas are tools that can be made on the farm to enhance crop health and fertility, and to inoculate the leaves and roots with soluble nutrients, beneficial microorganisms, and beneficial metabolites (products that aid in the growth and development of plants).
- Compost extract is a fertilizer, but it also can induce plant resistance.
  - For its preparation, mature compost is mixed with water at a ratio of 1:5 to 1:8 (vol/vol: one liter of compost for every 5 to 8 liter of water) and well stirred before it is left to ferment for three to seven days.
  - One spoonful of molasses can be added per liter of liquid, because this enhance the development of the microorganisms.
  - The fermentation site should be shaded and safe from the rain.
  - After the fermentation period and before the application, the extract is well stirred, then filtered and diluted at a ratio of 1:5 to 1:10.
- Plant extracts can be obtained from stinging nettle, horsetail, comfrey, clover, seaweed and others, alone or mixed with marine by-products such as fish waste or fishmeal.
  - Dilution of 1:10 or 1:5 is used as foliar spray or soil drench.
- As a general rule it is recommended to apply compost extracts or teas every seven to ten days to prevent diseases from developing and as a way to enhance soil microorganisms.

Curative methods:-

1. Promoting and managing natural enemies

- The natural enemies of pests are other organisms (fungi, bacteria, viruses, insect predators, and insect parasitoids) which kill pest.
  - Therefore, the organic farmer should try to conserve natural enemies already present in the crop environment and enhance their impact.
  - This can be achieved with specific methods.
  - Minimize the application of natural pesticides (chemical pesticides anyway are not per-mitted in organic farming).
  - Allow some pests to live in the field which will serve as food or host for natural enemies.
  - Establish a diverse cropping system (e.g. mixed cropping).
  - Include host plants providing food or shelter for natural enemies (e.g. flowers which adult beneficial insects feed on)

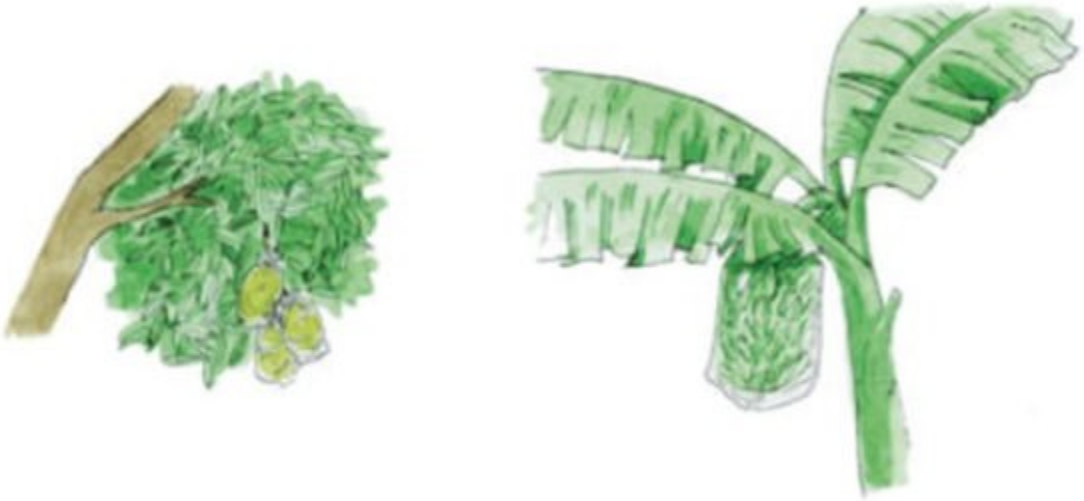
There are many possibilities to enhance floral diversity within and along the boundaries of crop fields.

- Hedges
  - Use indigenous shrubs known to attract pest predators and parasitoids by offering nectar, pollen, alternative hosts and/or preys.
  - Most flowering shrub species have this property.
  - However, care should be taken to not use plant species known to be alternative hosts of pests or diseases.
- Beetle banks
  - Strips of grass in the neighbourhood of crop fields harbour different natural pest enemy groups like carabids, staphylinid beetles and spiders.
  - In order to lower the risk of weeds and plants known as host plants of crop pests and diseases, one to three native grass species can be sown in strips of 1 to 3 m.
- Flower strips
  - Use indigenous flowering plant species known to attract predators and parasitoids by offering nectar, pollen, alternative hosts and/orpreys.
  - Most flowering plant species have this property.
  - However, care should be taken not to use alternative hosts of pests or diseases.
  - Three to five native flowering plant species can be sown in well-prepared seed beds, arranged in strips of 1 to 3 m on the boundary of the crop field.
  - After flowering, seeds can be collected to renew the strip or create new ones.
- Companion plants
  - Natural pest enemies can also be attracted by companion plants within a crop.
  - These companion plant species can be the same as used in the flower strips.
  - A few (1 or 2 per 10 $m^{2)}$ flowering companion plants within a crop serve as a 'service station' for natural pest enemies.

Mechanical Control:-

- Mass-trapping of pests is an additional control measure.
- They often can easily be built with cheap material.
  - Light traps can be used to catch moths such as armyworms, cutworms, stem borers and other night flying insects.
    - Light traps are more efficient when placed soon after the adult moths start to emerge but before they start laying eggs.
    - However, light traps have the disadvantage of attracting a wide range of insect species.
    - Most of the attracted insects are not pests.
    - In addition, many insects that are attracted to the area around the light traps (sometimes from considerable distances) do not actually fly into the trap.
    - Instead, they remain nearby, actually increasing the total number of insects in the immediate area.
  - Colour and water traps can be used to monitor adult thrips.
    - In some cases thrips can even be reduced by mass trapping with coloured (blue, yellow or white) sticky traps or water traps in the nursery or field.
    - The colour spectrum of the boards is important for the efficacy of the sticky traps. Bright colours attract more thrips than darker ones.
    - Sticky traps with cylindrical surfaces are more efficient that flat surfaces.
    - They are best placed within a meter of crop level. Traps should not be placed near the borders of fields or near shelter belts.
  - Water traps should be at least 6 cm deep with a surface area of 250 to 500 cm^2 , and preferably round, with the water level about 2 cm below the rim.
    - A few drops of detergent added to the water ensure that thrips sink and do not drift to the edges and escape.
    - Replace or add water regularly.
  - Yellow sticky traps can be used to control whiteflies, aphids and leaf mining flies.
    - Yellow plastic gallon containers mounted upside down on sticks coated with transparent car grease or used motor oil, is one such trap.
    - These should be placed in and around the field at about 10 cm above the foliage.
    - Clean and re-oil when traps are covered with flies. Yellow sticky boards have a similar effect.
    - To use, place two to five yellow sticky cards per 500 m^2 field area.
    - Replace traps at least once a week. To make your own sticky trap, spread petroleum jelly or used motor oil on yellow painted plywood (size 30 cm x 30 cm).
    - Place traps near the plants but faraway enough to prevent the leaves from sticking to the board.
    - Note that the yellow colour attracts many insects.
    - Note that the yellow colour attracts many insect species, including beneficial insects, so use yellow traps only when necessary.
  - Fruit bagging prevents fruit flies from laying eggs on the fruits.
    - In addition, the bag provides physical protection from mechanical injuries (scars and scratches).
    - Although laborious, it is cheap, safe and gives a more reliable estimate of the projected harvest.
    - Bagging works well with melon, bitter gourd, mango, guava, star fruit, avocadoes and banana (plastic bags used).

Figure 7. Fruit bagging



Mango fruits in paper bags

Banana bunch in polythene bags

Recommendations to farmers regarding fruit bagging

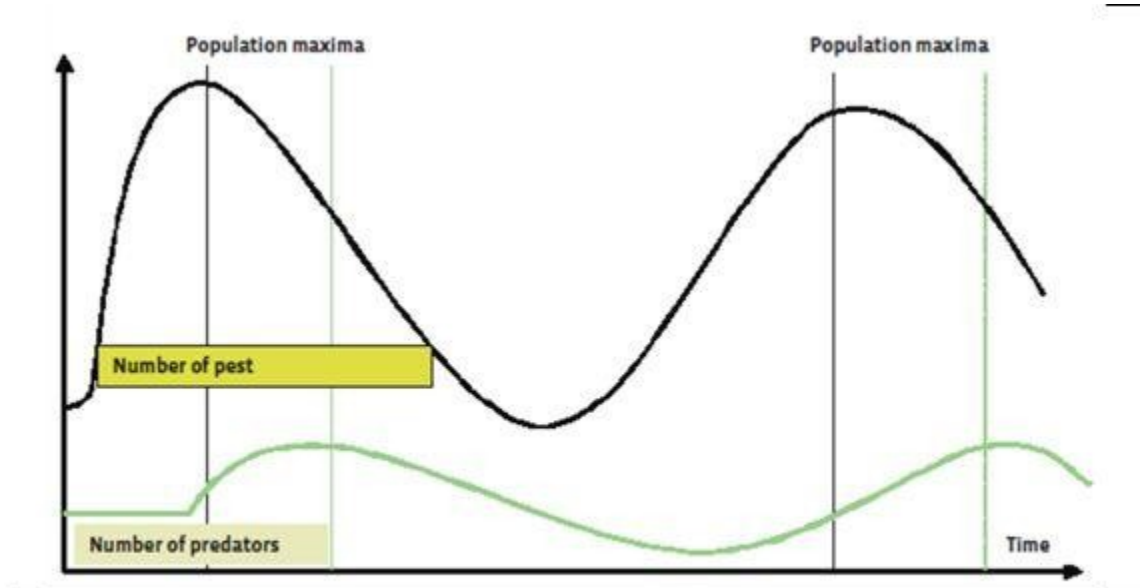
- Cut old newspapers to fruit size and double the layers, as single layers break apart easily.
- Fold and sew or staple the sides and bottom of the sheets to make a rectangular bag.
- Blow in the bag to inflate it.
- Insert one fruit per bag then close the bag and firmly tie the top end of the bag with sisal string, wire and banana fibre or coconut midrib.
- Push the bottom of the bag upwards to prevent fruit from touching the bag.
  - For example, start bagging the mango fruit 55 to 60 days from flower bloom or when the fruits are about the size of a chicken egg.
  - When using plastic bags (e.g. with bananas), 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 causes diseased fruits.
  - Plastic also overheats the fruit.
  - Bags made of dried plant leaves are good alternatives to plastic.

Biological control:-

1. Population dynamics

- Biological control is the use of natural enemies to manage populations of pests (such as ladybird beetles, predatory gallmidges, hoverfly larvae against aphids and psyllids) and diseases.
  - This implies that we are dealing with living systems, which are complex and vary from place to place and from time to time.

Figure 8. Population dynamics of pests and predators



Population dynamics of pests and predators: the y-axis shows the size of the pest and predator populations, the x-axis their development in time.

2. Releasing of natural enemies

- If populations of natural enemies present in the field are too small to sufficiently control pests, they can be reared in a laboratory or rearing unit.
  - The reared natural enemies are released in the crop to boost field populations and keep pest populations down.
- There are two approaches to biological control through the release of natural enemies.
- Preventive release of the natural enemies at the beginning of each season.
  - This is used when the natural enemies could not persist from one cropping season to another due to unfavourable climate or the absence of the pest.
  - Populations of the natural enemy then establish and grow during the season.
  - Releasing natural enemies when pest populations start to cause damage to crops.
  - Pathogens are usually used in that way, because they cannot persist and spread in the crop environment without the presence of a host ('pest').
  - They are also often inexpensive to produce.

3. Different types of natural enemies

- Natural enemies that kill or suppress pests or diseases are often fungi or bacteria.
  - They are called antagonists or referred to as microbial insecticides or bio-pesticides.
- There are many commonly used antagonistic microbes.
  - Bacteria such as *Bacillus thuringiensis* (Bt).
  - Bt has been available as a commercial mi-crobial insecticide since the 1960s.
  - Different types of Bt are available for the control of caterpillars and beetles in vegetables and other agricultural crops, and for mosquito and black fly control.
  - The best-known biocontrol agent used in field crops is the bacteria *Bacillus thuringiensis var. kurstaki* and *Bacillus thuringiensis. var. aizawai* against diverse lepidopteran pests, and the *Bacillus thuringiensis var israeliensis* against mosquitoes.

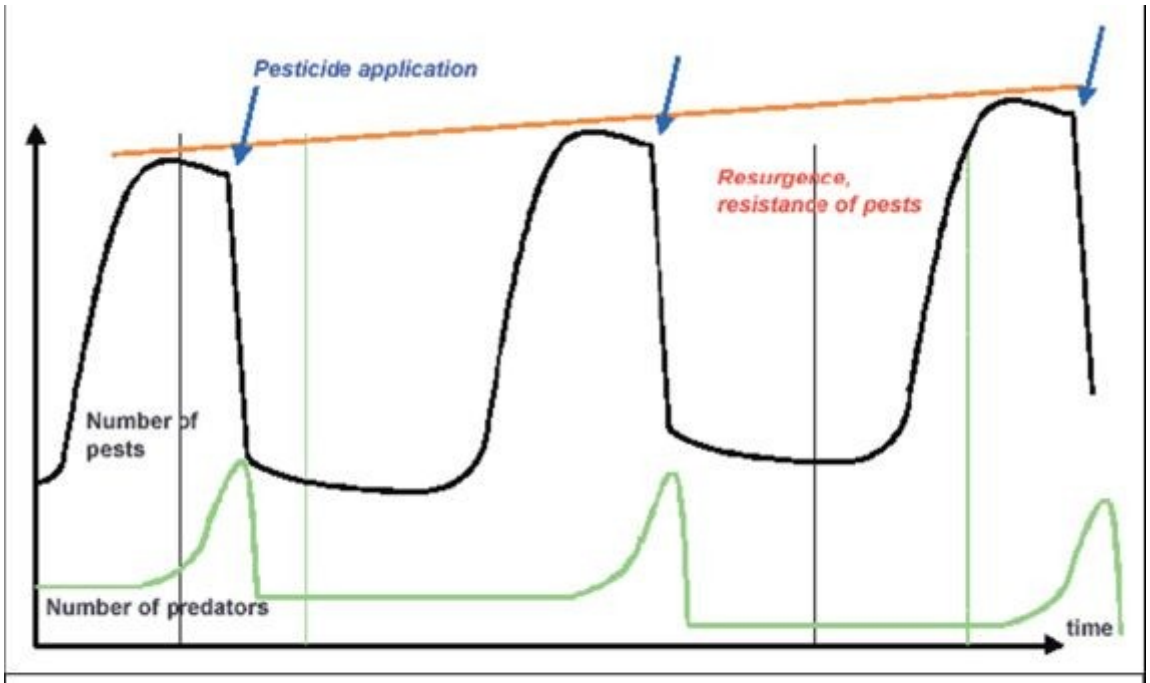
- *Bacillus thuringiensis var kurstaki* is produced in local factories in different African countries (e.g. South Africa, Kenya and Mozambique) and can be used against different pests (African armyworm, African bollworm, bean armyworm, beet armyworm, cabbage webworm, cabbage moth, cabbage looper, cotton leafworm, diamondback moth, giant looper, green looper, spiny bollworm, spotted bollworm, pod borers, and tomato looper).
  - Viruses such as NPV (*nuclearpolyhedrosis virus*), effective for control of several cater-pillar pest species. Every insect species, however, requires a specific NPV-species.
- An example is the armyworm *Spodoptera exigu*a, which is a major problem in shallot production in Indonesia.
- Since experiments showed that SeNPV (NPV specific for *S. exigua*) provided better control than insecticides, farmers have adopted this control method.
- Many farmers in West-Sumatra are now producing NPV on-farm.
  - Fungi that kill insects, such as *Beauveria bassiana*.
- Different strains of this fungus are commercially available.
- For example the strain Bb 147 is used for control of corn borers (*Ostrinia nubilalis* and *O. furnacaiis*) in maize, strain GHA is used against whitefly, thrips, aphids and mealybugs in vegetables and ornamentals.
- Several species of fungi can occur naturally in ecosystems.
- For example, aphids can be killed by a green or white coloured fungus during humid weather.
  - Fungi that work against plant-pathogens.
- Some examples include *Trichoderma sp*., widely used in Asia for prevention of soil-borne diseases such as damping-off and root rots in vegetables.
- Some Trichogramma species against the African bollworm are bred in some laboratories in Africa against *lepidopteran* pests and *aphids*.
- A successful introduction of the neotropical parasitoid *Apoanagyrus lopezi* against the cassava mealybug (*Phenacoccus manihoti*) caused a satisfactory reduction of *P. manihoti* in most farmers' fields in Africa.
- This is one of the success stories of classical biocontrol.
  - Entomopathogenic nematodes against different weevil species (e.g. *Steinernema carpocapsae, Heterorhabditis bacteriophora*) and to control soil insects like cutworms (*Agrotis spp*.) in vegetables.

Figure 10. Biocontrol of plant diseases by non-pathogenic fungi

Natural pesticides

- Some plants contain components that are toxic to insects.
  - When extracted from the plants and applied on infested crops, these components are called botanical pesticides or botanicals.
  - The use of plant extracts to control pests is not new. Rotenone (*Derris sp*.), nicotine (tobacco), and pyrethrins (*Chrysanthemum sp.*) have been used widely both in small-scale subsistence farming as well as in commercial agriculture.
- Most botanical pesticides are contact, respiratory, or stomach poisons.
  - Therefore, they are not very selective, but target a broad range of insects.
  - This means that even beneficial organisms can be affected.
  - Yet the toxicity of botanical pesticides is usually not very high and their negative effects on beneficial organisms can be significantly reduced by selective application.
  - Furthermore, botanical pesticides are generally highly biodegradable, so that they become inactive within hours or a few days.
  - This reduces again the negative impact on beneficial organisms and they are relatively environmentally safe compared to chemical pesticides.

Figure 11. The impact of chemical pesticides on natural enemies



The impact of chemical pesticides on natural enemies: the y-axis shows the size of the pest and predator populations, the x-axis their development in time.

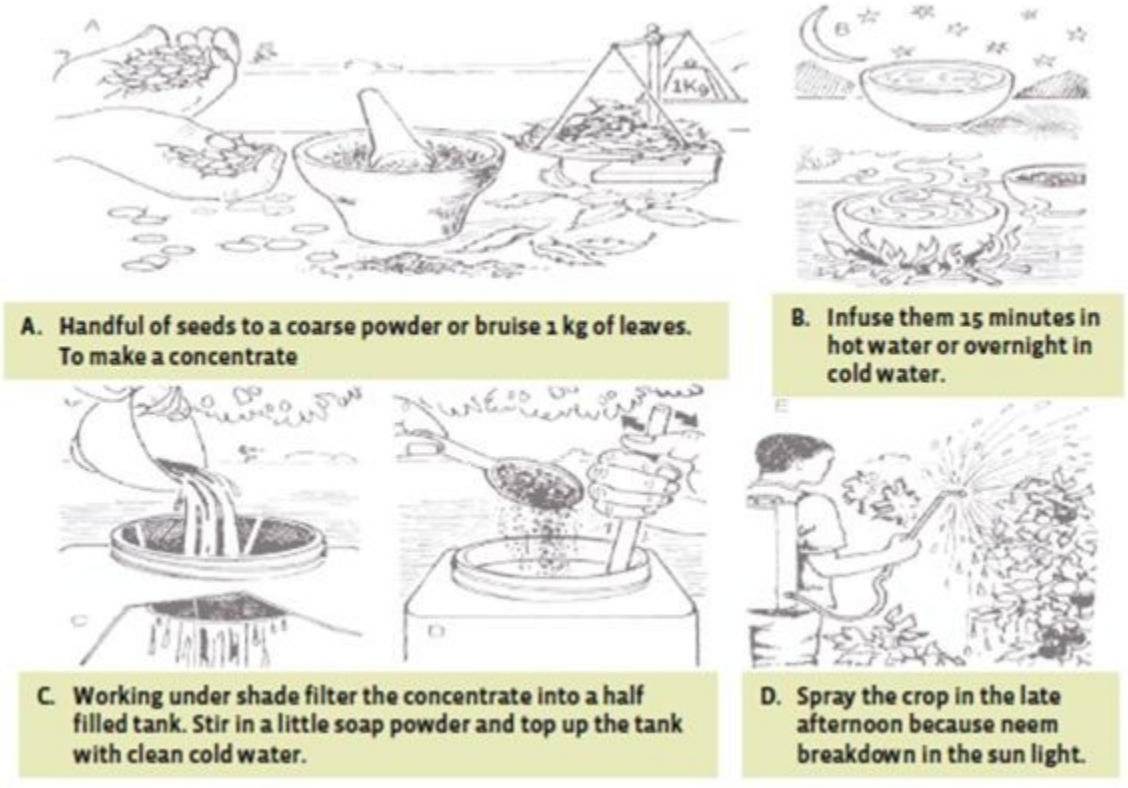
1. Neem

- The preparation and use of botanicals requires some know-how, but not much material and infrastructures.
  - It's a common practice under many traditional agricultural systems.
- There are many commonly used botanicals.

- Neem

- Neem derived from the neem tree (*Azadiracta indica*) of arid tropical regions, contains sev-eral insecticidal compounds.
- The main active ingredient is azadiractin, which both deters and kills many species of caterpillars, thrips and whitefly.
- Both seeds and leaves can be used to prepare the neem solution.
- Neem seeds contain a higher amount of neem oil, but leaves are available all year.
- A neem solution looses its effectiveness within about eight hours after preparation, and when exposed to direct sunlight.
- It is most effective to apply neem in the evening, directly after preparation, under humid conditions or when the plants and insects are damp.
- There exist different recipes for the preparation of a neem solution.
- Recommendations for farmers for the preparation of neem pesticides.
- In Ghana, Africa, neem seed kernel extract was tested on cabbage in farmer trainings and had a very good repelling effect on diamondback moth (*Plutella xylostella*).
- Pound 30 g neem kernels (that is the seed of which the seed coat has been removed) and mix it in 1 litre of water.
- Leave overnight.
- The next morning, filter the solution through a fine cloth and use it immediately for spraying.
- It should not be further diluted.
- Neem cake (ground neem seed or neem kernel powder) has also a considerable potential as a fertilizer and at the same time it will hinder nematode attacks of the crop roots (e.g. tomato).
- Put neem cake in the planting pit (200 g per m^2) and mix it with substrate.
- The neem cake will repel and even kill nematodes and other root pests.
- Insecticidal agents (*azadirachtin*) will be translocated to above-ground parts of the plant and help to get rid of pests there.

Figure 12. Preparation of a Neem solution



2. Pyrethrum

- Pyrethrum is a daisy-like *Chrysanthemum*.
  - In the tropics, pyrethrum is grown in mountain areas because it needs cool temperatures to develop its flowers.
  - Pyrethrins are insecticidal chemicals extracted from the dried pyrethrum flower.
  - The flower heads are processed into a powder to make a dust.
  - This dust can be used directly or infused into water to make a spray.
  - Pyrethrins cause immediate paralysis to most insects.
  - Low doses do not kill but have a 'knock down' effect.
  - Stronger doses kill.
  - Pyrethrins break down very quickly in sunlight so they should be stored in darkness.
  - Both highly alkaline and highly acid conditions speed up degradation so pyrethrins should not be mixed with lime or soap solutions.
  - Liquid formulations are stable in storage but powders may lose up to 20 percent of their effectiveness in one year.
  - Recommendations for farmers for the preparation of Pyrethrum pesticides.
    - Pyrethrum powder is made with dried ground flowers.
    - Use pure or mix with a carrier such as talc, lime or diatomaceous earth and sprinkle over infested plants.
    - To make liquid pyrethrum extract (mix 20 g pyrethrum powder with 10 litres water), add soap to make the substance more effective.
    - Strain and apply immediately as a spray. For best effects this should be applied in the evening.
    - Pyrethrum can also be extracted by alcohol.

3. Chilli-pepper

- Chillies and capsicum pepper have both repellent and insecticidal effects.
- Recommendations for the farmers for the preparation of chilli pesticides.
  - To make the chilli extract grind 200 g of chillies into a fine dust.
  - Boil it in 4 litres water.
  - Add another 4 litres of water and a few drops of liquid soap.
  - This mixture can be sprayed against aphids, ants, small caterpillars and snails.

4. Garlic

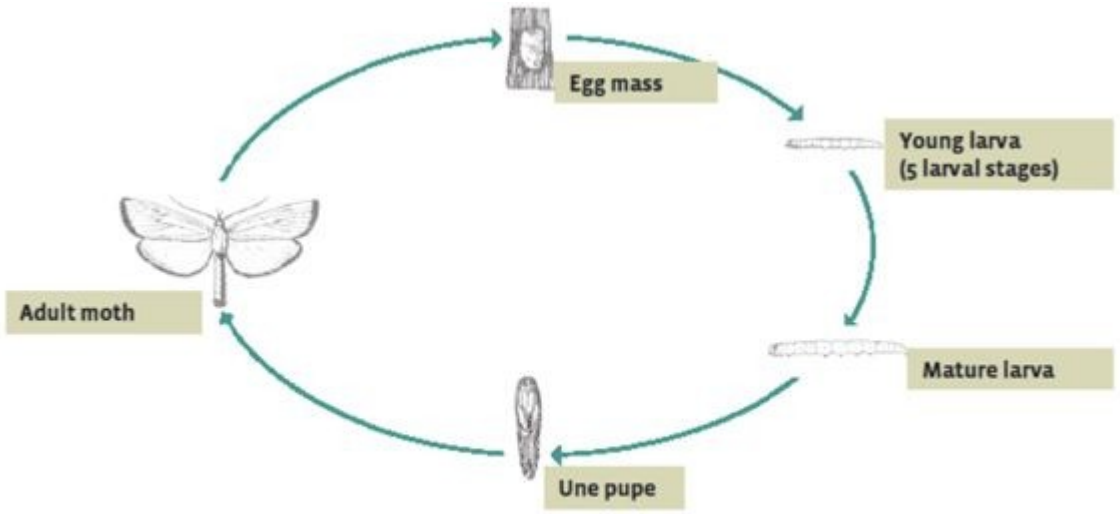
- Garlic has antifeedant (insect stop feeding), insecticidal, nematicidal and repellent properties.
  - Garlic is reportedly effective against a wide range of insects at different stages in their life cycle (egg, larvae, adult).
  - This includes ants, aphids, armyworms, diamondback moth, whitefly, wireworm and termites.
  - Garlic is non-selective, has a broad-spectrum effect and can kill beneficial insects as well.
  - Therefore, it should be used with caution.
  - Recommendations for farmers for the preparation of garlic pesticides.
    - Grind or chop 100 grams garlic into 0.5 litre water.
    - Allow mixture to stand for 24 hours.
    - Add 0.5 litre of water and stir in liquid soap.
    - Dilute at 1:20 with water and spray in the evening.

- To improve efficacy, chilli extract can be added.

5. Other extracts of plants

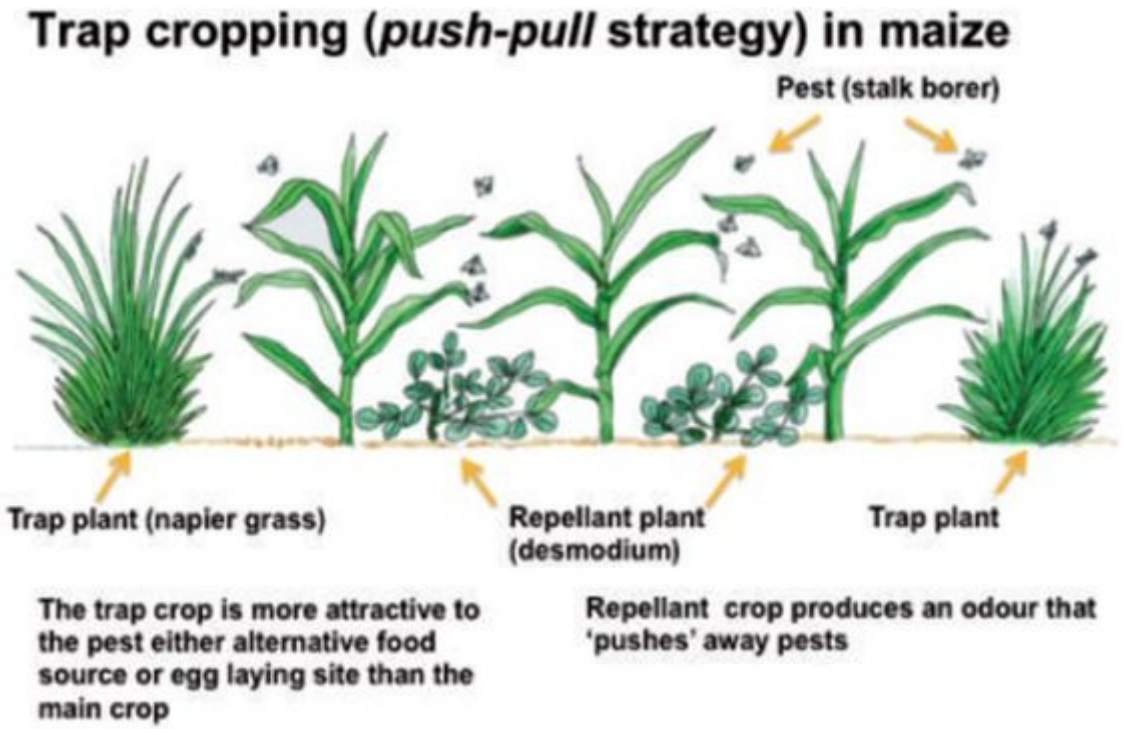
- There are many other extracts of plants known to have insecticidal effects like tobacco (*Nicotiana tabacum*), yellow root (*Xanthorhiza simplicissima*), fish bean (*Tephrosia vogelii*), violet tree (*Securidaca longepedunculata*), and nasturtium (*Nasturtium trapaeolum*) which are traditionally used to control pests in Africa.
- Anise, chillies, chives, garlic, coriander, nasturtium, spearmint and marigold are plants known to have a repellent effect on different pest insects (aphids, moths, root flies, etc.) and can be grown as intercrop or at the border of crop fields.
  - Marigold is especially known to deter root nematodes, while neem cake is known to deter mice.

Figure 13. The life cycle of the rice yellow stem borer



Life cycle of rice yellow stem borer (Scirpophaga incertulas): egg mass – young larva – mature larva – pupa – adult. (Source : IRRI, 1986)

Figure 14. Trap cropping - Trap intercropping



Precautions to farmers regarding use of plant extracts

- Despite being 'natural' and widely used in agricultural systems, some botanicals may be dangerous for humans and they can be very toxic to natural enemies.
  - Nicotine for example, derived from the tobacco plant, is one of the most toxic organic poisons for humans and other warm-blooded animals.
  - Pyrethrins are not poisonous for humans and warm-blooded animals.
  - However, human allergic reactions are common.
  - It can cause a rash, and breathing the dust can cause headaches and sickness.
- Before a new botanical pesticide is applied in a large scale, its effect on the ecosystem should be tested in a small field experiment.
  - Do not just use botanical pesticides as a default option!
  - First understand the ecosystem and how botanicals influence it!
- Do not have direct skin contact with the crude extract during the process of preparation and application.
- Contact with plant extracts should be avoided in the eyes.
- Make sure that you place the plant extract out of reach of children during storage.
- Wear protective clothing (eyes, mouth, nose and skin) while applying the extract.
- Wash your hands after handling the plant extract.
- Besides extractions of plants, there are some other natural pesticides, which are allowed in organic farming.
  - Although some of these products have limited selectivity and are not fully biodegradable, there are situations, when their use is justified.
  - However, in most cases, the desired effect is best reached in combination with preventive crop protection methods.
  - Below are some examples.
    - Soft soap solutions against aphids and other sucking insects.

- Light mineral oil against various insect pests (harms natural enemies!).
- Sulphur against spider mites (harms natural enemies!).
- The acaricidal effect of sulphur is best at temperatures above 12° C.
- However, sulphur has the potential to cause plant injury in dry hot weather (above 32° C).
- It's also incompatible with other pesticides.
- Sulphur should not be used together or after treatments with oil to avoid phytotoxicity
- Plant ashes
- Wood ashes from fire places can be efficient against ants, leaf miners, stem borers, termites and potato moths.
- Ash should be dusted directly on pest colonies and infested plant parts.
- The ash will dehydrate the soft bodied pests.
- Wood ashes are often used when storing grains to deter storage pests such as weevils.
- In addition, ashes are used against soil borne diseases.

Other practices for disease control

1. Sulphur

- Sulphur is mostly used against plant diseases like powdery mildew, downy mildew and other diseases.
  - The key to its efficacy is that it prevents spore germination.
  - For this reason, it must be applied prior to disease development for effective results.
  - Sulphur can be applied as a dust or in liquid form.
  - It is not compatible with other pesticides.
  - Lime-sulphur is formed when lime is added to sulphur to help it penetrate plant tissue.
  - It is more effective than elemental sulphur at lower concentrations.
  - However, the odour of rotten eggs usually discourages its use over extensive fields.

2. Bordeaux mixture

- Bordeaux mixture (Copper sulphate and lime) has been successfully used for over 150 years, on fruits, vegetables and ornamentals.
  - Unlike sulphur, Bordeaux mixture is both fungicidal and bactericidal.
  - It can be effectively used against diseases such as leaf spots caused by bacteria or fungi, powdery mildew, downy mildew and various anthracnose pathogens.
  - The ability of Bordeaux mixture to persist through rains and to adhere to plants is one reason it has been so effective.
  - Bordeaux mixture contains copper sulphate, which is acidic, and neutralized by lime (calcium hydroxide), which is alkaline.
  - Recommendations to farmers for the preparation of Bordeaux mixture.
- Bordeaux mixture comes in several formulations.
- One of the most popular, effective and least phytotoxic formulations for general use is the following formulation.
- Mix 90 grams of blue copper sulphate with 4.5 litres of water (in a nonmetallic container).
- In another non-metallic container, mix 125 grams of slaked lime with 4.5 litres of water.
- Stir both, mix both solutions, and stir again.
- This formulation was developed in recognition of the fact that copper, like sulphur, is phytotoxic and that the level of toxicity is related to the age of plant tissue being treated.

- Application of Bordeaux during hot weather (above 85° F or 30° C) may cause yellowing and leaf drop.
- Additionally, leaf burn can occur if it rains soon after a Bordeaux application.
- Care should be taken when applying this fungicide to young, tender leaves of fruit trees.
- Do not apply Bordeaux mixture to corn or sorghum, which are described as copper-sensitive plants.
- There are other, very common and cheap copper formulations available: copper hydroxide and copper oxychloride.
- They are accepted in organic farming provided that the number of applications is strictly followed and a proper soil amendment is observed to prevent copper accumulation in the soil.

3. Acidic clays

- Acidic clays have a fungicidal effect due to aluminium oxide or aluminium sulphate as active agents.
- They are used as an alternative to copper products but, are often less efficient.

4. Milk

- Milk has also been used against blights, mildew, mosaic viruses and other fungal and viral diseases.
- Spraying every 10 days with a mixture of 1 litre of milk to 10 to 15 litres of water is effective.

5. Baking soda

- Baking soda has been used to control mildew and rust diseases on plants.
- Spray with a mixture of 100 g of baking or washing soda with 50 g of soft soap.
- Dilute with 2 litres of water. Spray only once and leave as long gaps as possible (several months).
- Do not use during hot weather and test the mixture on a few leaves because of possible phytotoxic effects.

Other plants

- Many plant extracts are known to have fungicidal effects.
- Onion and garlic are effective against many diseases such as mildew and fungal and bacterial diseases.
- Mexican and African marigold act as a crop strengthener to help potatoes, beans, tomatoes and peas resist fungal diseases such as mildew.
- The leaves o f papaya (*Carica papaya*) and sweet basil have a general fungicidal effect.
- Many other plant species are known to have fungicidal effects.
- Traditional knowledge might be of help to amend the range of plant extracts in each region

a. Integrated disease management:-

For mitigating the loses due to diseases, several methods such as fungicides, organ mercurial, chemotherapy, thermotherapy, cultural methods and host resistance are employed. However, no single method is effective in controlling a disease. Therefore, integrated disease management (IDM) became imperative for effective disease control. Integrated disease management in organic farming combines the use of various measures. The usefulness of certain measures depends on the specific crop-pathogen combination. In many crops, preventative measures can control diseases without the

need of plant protection products. However, for certain disease problems, preventative measures are not sufficient. For example, organic apple production strongly depends on the multiple uses of plant protection products.

All the cultural methods discussed under IPM hold well for IDM also. Broad based tentative IDM components are being adopted for disease control. However, all these components are not feasible for any specific ecosystem or any specific disease. For many other diseases the role of host resistance, cultural methods and chemical methods are integrated. Solar heat therapy (drying the seed in hot sun after harvest and again before sowing) is a common practice in our agriculture. Among mechanical methods for prevention and against spread of diseases uproot and burn is the age old and the best method so far. It is better to prevent and control vectors against spread of diseases.
Disease affected plants are to be uprooted and burnt and alternate and collateral host-crops, grasses, stubbles etc. destroyed. Disease can affect any part of a plant. Disease may be fungal, bacterial and viral. Viral diseases are more serious than fungal and bacterial.

Disease management in organic cropping systems combines various components which can be divided into strategic preventative measures, tactical preventative measures and control measures. For each crop-pathogen relationship and cropping system such components will contribute to different extent to disease management (Termorshuizen, 2002). The development of integrated disease management systems depends on thorough knowledge of the cropping systems as well as of the pathogen and can only be achieved by interdisciplinary research.

PATHOGEN CHARACTERISTICS AND DISEASE MANAGEMENT:-

Host-specificity and mobility are the two main characteristics of pathogens determining the choice of disease management measures (Wijnands et al., 2000). Strictly host-specific pathogens which are not mobile can be controlled by using cropping systems with low frequencies of the susceptible crop. Examples are cyst nematodes of potato or sugar beet. Pathogens which are not host-specific and not mobile can be controlled by the choice and sequence of crops grown in the rotation supported by preventative measures increasing soil suppressiveness and plant health. Examples are the soil borne pathogens *Sclerotinia sclerotiorum* and *Rhizoctonia solani*. Host-specific pathogens with high mobility such as *Phytophthora infestans* in potato cannot be controlled by crop rotation.
Preventative measures are sanitation in a cropping area and the choice of crop structure and planting date in combination with resistant varieties. In many situations also control measures such as applications of plant protection products may be needed to achieve sufficient yield. Also pathogens which are not host-specific but highly mobile cannot be controlled by crop rotation. Disease prevention depends on strengthening the crop, escaping the disease by choosing proper seeding dates and creating an open crop structure. Disease control by using crop protection products may be needed in many cases. Example for a mobile pathogen with a broad host range is *Botrytis cinerea* causing grey mould in various crops such as beans, peas, strawberries, grapes and many other crops.
How differently various measures contribute to disease management in different crop-pathogen relationships will be illustrated by the comparison of two systems. In wheat, various *Fusarium* spp. can cause *Fusarium* Head Blight (FHB) leading to a decrease of yield and, more important, the production of mycotoxins in the grain. *Fusarium* sp have a broad host range and also can survive saprophytically. Mobility of spores of most *Fusarium* sp is low. In apple, *Venturia inaequalis* can cause apple scab on leaves and fruit resulting in reduced yields and quality of fruit.
The pathogen is strictly host-specific and can survive only on apple tissues. The mobility of spores is low.

STRATEGIC PREVENTATIVE MEASURES:-

Many measures for preventative disease control have a long-term strategic character. Various aspects of the farm management and the long-term cropping system as well as of the location

including the farm neighborhood have impact on diseases of crops and thus should generally be considered in integrated disease management.

Avoidance of pathogen sources in neighborhood of field and crop rotation in neighbouring field: Since most
Fusarium spores travel only a few centimeters, sources in the crop neighborhood will not cause epidemics.
Ascospores of *V. inaequalis* produced in neighbouring orchards may reach the crop. Abandoned orchards and orchards with high apple scab pressure should not be found in the neighbourhood of an apple orchard.
Soil structure, soil suppressiveness, biological soil disinfection, and catch crops: These measures are important for managing soil borne diseases but will have no direct effect on the above-ground development of *Fusarium* spp. and *V. inaequalis*.

Crop rotation: Main inoculum source of FHB are crop residues of preceding diseased crops. The best documented example is the high risk of FHB when wheat is grown after maize. Maize stubble are often colonized by the same *Fusarium* sp affecting wheat and such *Fusarium* sp can survive and multiply on maize stubble for several years.
Avoiding growth of maize in rotation with wheat will substantially reduce risks of FHB epidemics. Rotation schemes with cereals grown after cereals should generally be avoided. In the perennial apple production crop rotation is no issue.

Tillage: Primary inoculum of FHB is crop residues left on the soil after tillage. Using reduced tillage systems will increase FHB risks since much more residues will be present on the soil surface. In apple orchards, tillage is not an option.

TACTICAL PREVENTATIVE MEASURES:-

Tactical preventative measures deal with the planning and realization of a certain crop. Typical measures are the choice of variety, seed quality, seeding time and crop structure.

Resistant varieties: In wheat, resistance breeding made considerable progress and partly resistant cultivars are used in practice. In apple, partly resistant varieties are available. However, the pathogen has the potential to adapt.
Furthermore, changing varieties in a perennial crop needs high investments.

Removal of crop residues from field: *Fusarium* sp threatening wheat crops are surviving primarily in stubble of cereals including maize. Removing this potential inoculum sources is not feasible, although physical removal especially of maize stubble may have a significant impact on disease development. In apple, removal of fallen leaves as the principle inoculum source of apple scab in spring is an interesting option. Removal of leaves by using specially designed vacuum cleaners has been demonstrated. However, mechanization is difficult, cost intensive and application depends much on orchard circumstances.

Biological crop residue treatments: Microbial decomposition of crop residues is a natural process which can be supported by adding stimulating nutrients or selected micro-organisms. Also earthworms can be protected and stimulated to consume plant residues on the soil surface. In arable crops, stimulation of resident microbial populations on residues may be achieved by creating a suitable microclimate, e.g. by using mulches.

Healthy seeds and planting material: Seeds of wheat can be infected by *Fusarium* spp. producing healthy seeds is important to guarantee the establishment of a vigorous crop. For the development of

FHB epidemics after flowering, the major inoculum sources are infested crop residues and thus field-borne. Reducing the seed-borne fraction of the disease inoculum may only have very limited effect against FHB. Using clean planting material of apple will not result in any disease prevention since *V. inaequalis* overwinters on the orchard floor and easily can enter disease– free young trees.

Sowing time: For infections of wheat ears by *Fusarium* sp, the crucial factor are the climatic conditions during the short window of flowering. Choosing early or late sowing times is not an option for disease prevention since weather during flowering cannot be predicted. Also for apple, no effect of planting time on apple scab can be expected.
Crop structure: Crop structure affects microclimatic conditions within the canopy and determines the distance pathogen spores have to spread to reach susceptible host tissue. A dense wheat crop will favour pathogen sporulation on the soil, but may block spore flights of *Fusarium* sp. Depending mainly on splash dispersal during rainfalls, vertical leaf positions may also block spore flights.

DISEASE CONTROL MEASURES
Disease control measures are used to control a certain disease of a crop. Physical, chemical or biological control measures may be used. Physical treatments. *Fusarium* spp. on seeds can be controlled by warm water treatments. However, the effect on
FHB will be limited. Natural compounds and bio-control agents as plant protection products. The control of FHB does not depend on plant protection products since preventative measures such as rotation, and tillage can be used. In apple, preventative

Biological based technologies are most effective when integrated with physical and chemical approaches in the process towards sustainable ecological based plant diseases management. The **important measures are:**
Use of antagonists is equivalent to natural enemies used in control of insects. Seeds treated with antagonists can be used as feed and food.
Use of non-pathogenic materials like *F. oxysporum* (Fusariclean) and F. fluorescens (biocoat) for fusarium wilt in vegetables and flower crops.
2, 4-diacetyl fluoroglucinol for all diseases of wheat.
Biosave 10 and biosave 11 (based on strains of *Pseudomonas syringal* against storage rot of vegetables and fruits.
Use of root-knot nematode.
Use of molecular tools to assure pathogen free planting materials.

b. Integrated pest management
Integrated pest management (IPM), which by definition is a pest management system that, in the context of associated environment and population dynamics, utilizes all the appropriate techniques to minimize the pest population at levels below those causing economic injury. Though several parasitoids, predators and pathogens of pests, antagonistic microorganisms were known to be effective for several decades, they were not commercially exploited because of quick knock down effect and easy availability of chemical pesticides instead of **bio-pesticides and IPM.** Steadily, there has been growing appreciation about the role of cultural and biological methods in pest control.

Cultural and biological methods are the two major components in integrated plant protection.

Cultural methods
Agronomic adjustments, necessary for higher yield, are at the same time are directed at prevention, mass multiplication and spread of pests by modifying the crop microclimate.

Sanitation: It includes removal or destruction of breeding refuges and over wintering of pests. Seed material, farm yard manure etc carrying insect eggs or its stages of development should be carefully screened before their use.
Destruction of alternate hosts minimizes pest population build up.

Tillage and inter-cultivation: Ploughing and inter-cultivation brings about unfavourable conditions for multiplication of pests as well as diseases and weeds. Quiescent stages (pupae) of harmful organisms will be exposed to dehydration or to predation by birds and other stages may be mechanically damaged or buried deep in the soil.

Cultivar selection: cultivars with high yield potential and quality without resistance to pests and diseases are the main causes of frequent epidemics and mass multiplication of pests and diseases. A large number of cultivars resistance/tolerance to pest and diseases has been developed to suit different agro-ecosystems. Selection of such cultivars can bring down the losses considerably.

Time of sowing: As weather influences developmental rhythm of plansts as well as growth and survival of pests and diseases, serious setback occurs when the weather conditions are such as to bring about coincidence of susceptible growth stages with highest incidence of pests and diseases. Therefore, adjustment in sowing dates is often resorted to as an agronomic strategy to minimize the crop losses. Maize sown late suffers little borer damage, as by then the egg parasite *Trichogramma* is able to keep down the population of the pest. Rice may suffer less from borer attack if planted early (early June). Early maturing cotton cultivars have become popular in Punjab and Haryana as they escape pink bollworm.

Plant population: Plant population per unit area influence crop microclimate. Dense plant canopy leads to high humidity build up congenial for pest and disease multiplication. Keeping the total plant population constant, inter and intra row plant population can be adjusted to minimize the humidity build up within the plant canopy.

Manures and fertilizers: Excessive nitrogen increases susceptibility of crop to sucking and leaf eating pests.
Higher rates of nitrogen application than the recommended rate to hybrids without corresponding increase in phosphorus and potassium is the main factor for heavy pest and disease incidence. Balanced application of NPK helps the crop to tolerate pests and diseases considerably.

Water management: Irrigation can reduce the soil inhabiting pests by suffocation or exposing them to soil surface to be preyed upon by birds. Irrigating potato crop at tuber formation can minimize potato scab. Anthracnose of beans, early blight and charcoal rot of potato can be checked by furrow irrigation than sprinkler irrigation.

Habitat diversification: Many pests prefer feeding on a particular plant or others. This preference may be exploited to reduce the pest load on crop. Crop rotation, intercropping, traps cropping and strip cropping can bring down the pest load considerably.

Behavioral methods:-

Bio-pesticides: Natural occurrence of diseases caused by micro-organisms is common in both insects and weeds and is a major natural mortality factor in most situations. Use of micro-organisms for pest control involves their culture in artificial media and later introduction of larger amounts of inoculums in to the field at appropriate time. Many fungi and bacteria can be handled in this way but insect viruses have the limitation that they have to be raised in living insects. As the bio-control agents (microbial pathogens) are applied on the targeted pests in much the same way as chemical pesticides, they are often termed as bio-pesticides or natural pesticides.

Bacillus thuringensis, a bacterial pathogen infesting a wide range of insect pests, is the most common microbial insecticide in use today. It is used against caterpillars that attack a wide range of crop. Unlike most other chemical insecticides, it can be used on edible products up to the time of harvest. It is selective in action and does not harm parasites, predators or pests. The bacteria come in several commericla formulations such as Dipel, Delfin, Halt, Spicturin, Biolep, BioAsp etc. Another bacterium *B popilaleis* also commonly available against white grub *Popillae japonica* and *Hototricha* sp. amongst insect pathogenic fungi, commercial preparations of *Verticillium lecanii* are available for the control of aphids, thrips and white fly under glass house conditions.

Trap cropping

Trap cropping is the planting of a trap crop to protect the main cash crop from a certain pest or several pests (See Appendix I). The trap crop can be from the same or different family group, than that of the main crop, as long as it is more attractive to the pest. There are two types of planting the trap crops; perimeter trap cropping and row intercropping. Perimeter trap cropping (border trap cropping) is the planting of trap crop completely surrounding the main cash crop. It prevents a pest attack that comes from all sides of the field. It works best on pests that are found near the borderline of the farm. Row intercropping is the planting of the trap crop in alternating rows within the main crop.

Advantages of trap cropping

1. Lessens the use of pesticide
2. Lowers the pesticide cost
3. Preserves the indigenous natural enemies
4. Improves the crop's quality
5. Helps conserve the soil and the environment