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This developPPP project aims to strengthen the production of cardamom (Kerala), Cumin and Dill seed (Rajasthan) turmeric (Tamil Nadu and Karnataka), Celery (Punjab and Haryana) by increasing the capacities of spice farmers and making the production practices economically, socially and environmentally more sustainable.

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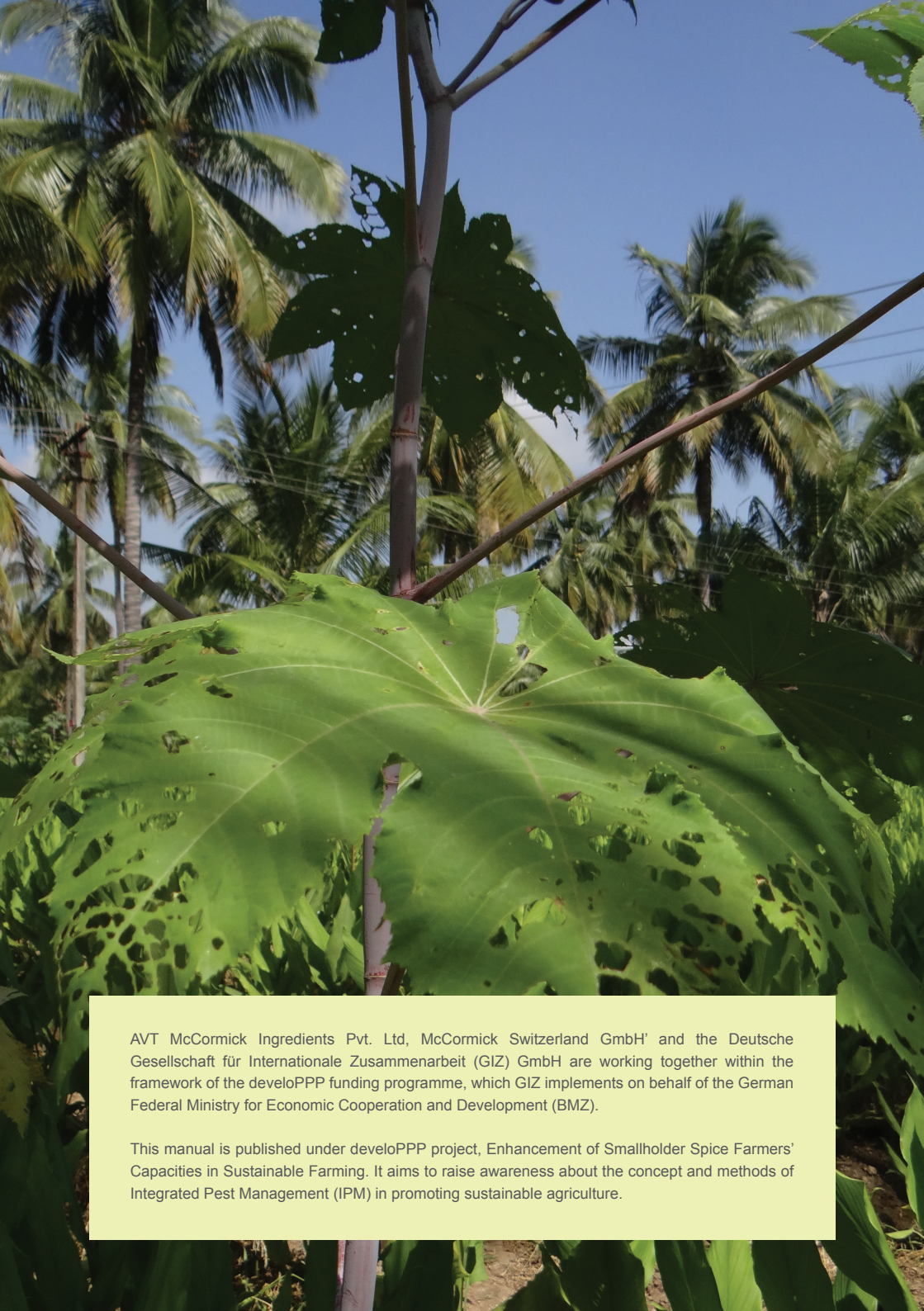
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CONCEPT AND METHODS OF INTEGRATED PEST MANAGEMENT IN SUSTAINABLE AGRICULTURE





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Background

Pesticide is the toxic chemical compound used to kill pests, insects, fungi, bacteria, and weed infestation in the crops. Pesticide is a broad group containing herbicides, insecticides, fungicides, rodenticides, nematocides etc. The use of pesticides is increasing day by day over the past few decades. Globally, more than half of the pesticides are utilised in Asia. India stands 12th in pesticide use globally and 3rd in Asia after China and Turkey (Nayak and Solanki 2021). The pattern of pesticide consumption in India differs slightly from the global trend. In India, 76% pesticide is used as Insecticide compared to 44% globally.

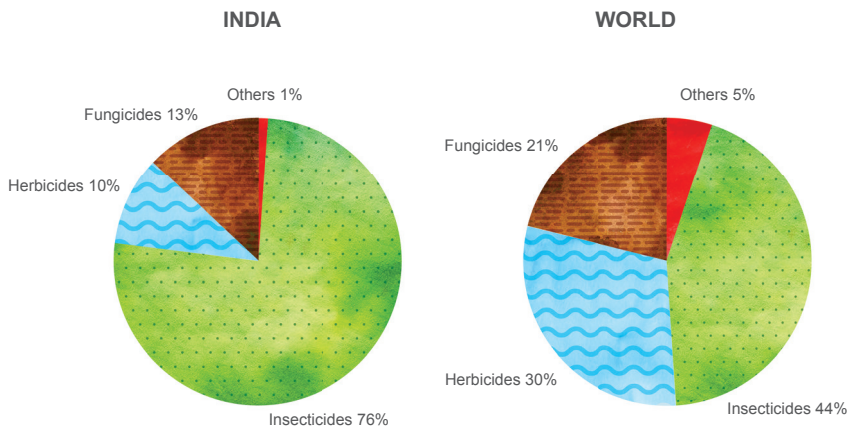


Fig 1: The pattern of pesticide consumption globally and in India¹

In India, the maximum pesticide consumption is in Maharashtra state, followed by Uttar Pradesh, Haryana and West Bengal. Fig.2. On the other hand, per hectare pesticide consumption is higher in Punjab (0.72 kg/ha) followed by Haryana (0.61 kg/ha) and Maharashtra (0.61 kg/ha) Fig 3. The use of pesticides is majorly done in vegetable crops like tomato, potato, cabbage, cauliflower and in foodgrain and cash crops like paddy, wheat, cotton, soybean and sugarcane, and in fruit crops like grapes, pomegranate etc. In the recent years, due to uncertain weather conditions, the incidence of pests and diseases has been increasing resulting in increased use of pesticides. The excessive use of pesticides causes harmful effects on the beneficial insects, soil microorganisms, birds and even aquatic animals due to pesticide contaminated surface and subsurface water. The indiscriminate and excessive use of pesticides for control of pests and diseases in agriculture causes environmental pollution, harmful effects on beneficial insects as well as entry of pesticide residues in the food chain. The presence of pesticide residue in vegetables, fruits and food grain crops above the permissible limit causes long term or chronic health problems in human beings like neurological toxicity, developmental issues, birth defects, cancers, immunotoxicity and disruption of the endocrine system.

¹Fig 1 as it is taken from "Aktar MW, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. *Interdiscip Toxicol.* 2009 Mar;2(1):1-12. doi: 10.2478/v10102-009-0001-7. PMID: 21217838; PMCID: PMC2984095".

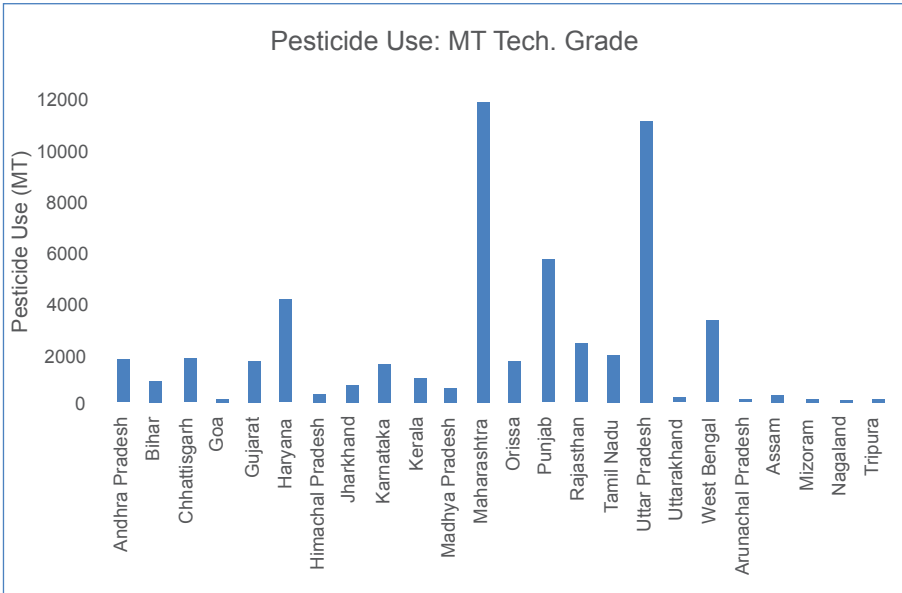


Fig 2: State wise total pesticide consumption in India during 2017-18²

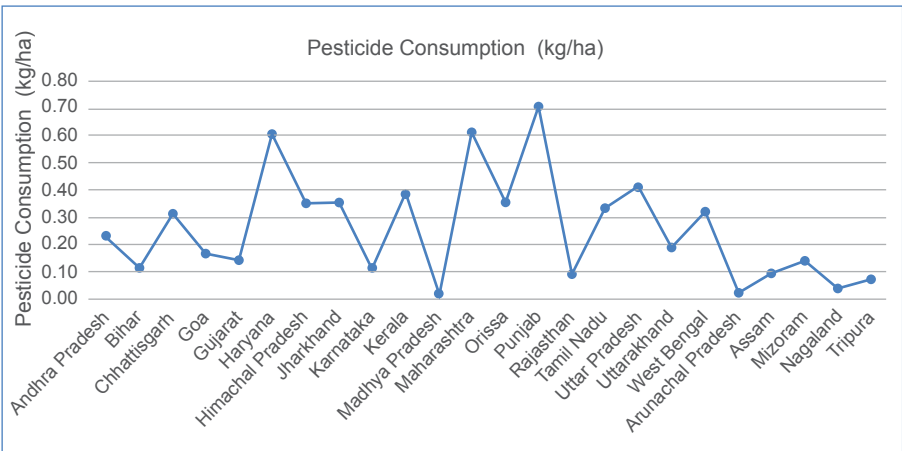
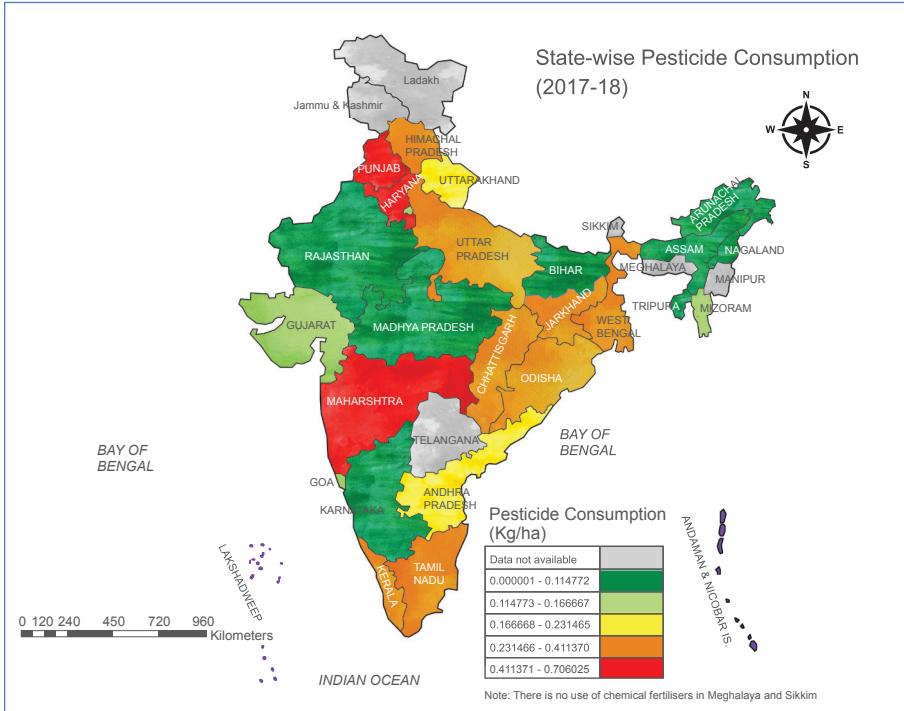


Fig 3: State wise per hectare pesticide consumption in India during 2017-18

² Source: <http://ppqs.gov.in/Statistical Database> | Directorate of Plant Protection, Quarantine & Storage | GOI. (2017). Ppqs.gov.in. <https://ppqs.gov.in/statistical-database>



So, considering the problems and challenges that emerged due to the excessive use of pesticides, the urgent need is to change the current pest and disease management strategy and adopt an approach that helps to manage the pest and diseases in an eco-friendly way with minimal use of pesticides if required. The integrated pest and disease management approach follows the eco-friendly pest and disease management practices and advises label claimed chemical pesticides only if the

pest population crosses the economic threshold level.

What is integrated pest management (IPM)?

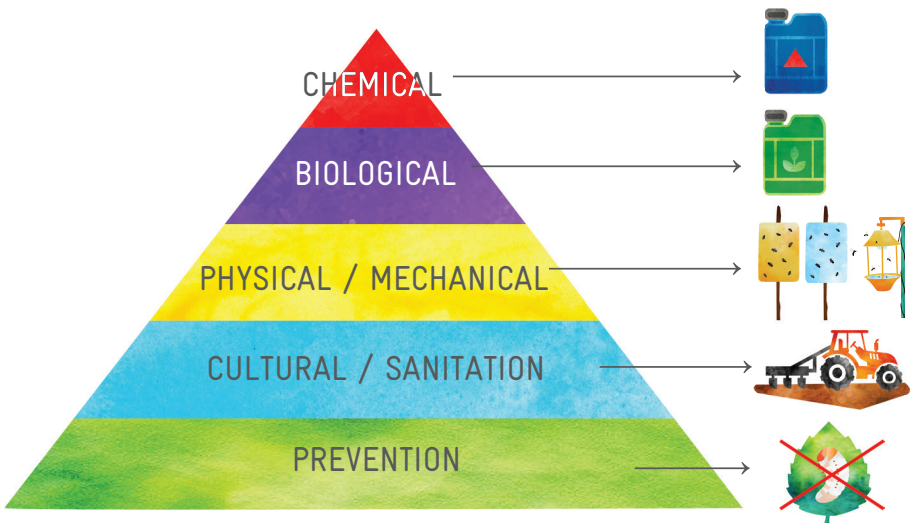
(IPM) is an eco-friendly pest management system that utilises all suitable techniques and methods of pest suppression (Cultural, Mechanical, Biological, Physical and Chemical) in a compatible manner toward sustainable crop production. In the IPM approach, it is important to use the different components according to the phenological stage

of the crop and the severity of pest/disease infestation. The use of preventive pest and disease management approaches i.e. selection of variety, tillage, seed treatment with biofungicide and time of sowing are important to avoid pest infestation during the early growth stage of the crop as well as to enhance the number of beneficial insects i.e. predators and parasitoids. These beneficial insects in the farm help to control the pest population naturally.

IPM does not discourage the spraying of pesticides, but it recommends using them only when the pest population crosses the economic threshold level.

Components of IPM

The major components of IPM include cultural measures, mechanical control, physical control, biopesticides and chemical control measures. Pest monitoring is also one of the important components of IPM to make proper decisions to manage pest problems. It can be done through field scouting, light traps, pheromones and sticky traps.



1.Cultural practices

Cultural methods of pest control consist of regular farm operations in such a way that either destroy the pests, avoid infestation, or prevent them from causing an economic loss of the crop. The various general cultural practices are as follows:

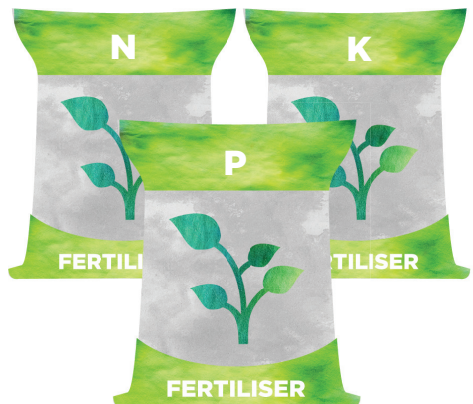
- Deep summer ploughing should be done to expose the hibernated pests and pest stages to sunlight. Ploughing should be done early in the morning or late in the evening, so more predatory birds come behind the tilling tractor and feed on the exposed insects and hibernated stages of the pests.



- Remove plant debris and grass from the field bunds of the nursery plot.
- Balanced use of the nutrients based on the soil test report.



- Select pest and disease resistance certified seeds for sowing.
- Seed treatment should be done with bio-pesticides before sowing to prevent the infestation of seed and soil-borne diseases.
- Select pest and disease resistant/ tolerant varieties.
- Adjust the time of sowing and harvesting to escape the peak season/month of pest attack.





- Crop rotation should be done with non-host crops to break the pest disease cycle.



- Intercropping helps to reduce pest problems by making it more difficult for the pests to find a host crop.

- Avoid excessive use of irrigation because high soil moisture for a prolonged period creates a conducive environment for the development of pests, especially soil-borne diseases.



- Keep weed-free plots as many weeds are the hosts for most of the pests and diseases.
- Thinning and pruning of infected plant parts should be done to avoid further spreading of the infestation.
- Harvest the crop close to ground level, as many stages of the pests and diseases are hibernated in the stubbles of the crops.

1.1 TRAP CROP

Trap cropping is the planting of a trap crop in the main crop or along the field boundary to protect the main crop from the infestation of certain pests.

- The trap crop can be from the same or different family of the crop that attracts the pest.
- There are two methods of planting trap crops; perimeter trap cropping and row intercropping.
- **Perimeter trap cropping** is the planting of trap crops surrounding the main 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 or at a different row ratio with the main crop.



ADVANTAGES OF TRAP CROP

- Trap crop alerts farmers for infestation of the pests. So they can take preventive action against pests to stop the spreading of infestation.
- Reducing the use of pesticides ultimately lowers the pesticide cost.
- Conserves the indigenous natural enemies i.e. Predators and parasitoids.
- Trap crops provide an additional income to the farmer.



Table 1: List of trap crops and targeting major pests in the crop

| Major Crop | Pest | Trap Crop | Sowing method |
|-------------------|--|-----------------------|--|
| Cotton | Bollworm | Okra and Marigold | 1:10 and around the field |
| Maize | Corn Worm | Sorghum | |
| Ground nut | Leaf eating Caterpillar | Castor and Sunflower | Around the field |
| Tomato | Fruit Borer | Marigold and Cucumber | 1:10 |
| Potato and Paddy | Nematode, Snail | Marigold | Along the field boundary Potato: 1:10 |
| Garlic | Thrips | Tulsi and Marigold | Around the field |
| Ground nut | Leaf folder | Cowpea | 1:10 |
| Tomato | Nematode | Marigold | 1:10 ans around the field boundary |
| Groundnut Soybean | Tobacco leaf-eating caterpillar | Castor | Around the field |
| Cotton | Bollworm | Cowpea | |
| Maize | Corn worm | Soybean | Intercropping |
| Cumin | Wilt/Powdery mildew /Alternaria blight | Sorghum | Around the border |
| Turmeric | Root knot nematode | Marigold and Castor | Marigold can be grown as intercrop on ridges |
| Cardamom | Capsule borer Shoot borer | Castor | Boundary |

2. Mechanical practices:

Mechanical pest control involves managing or killing pests by using devices like sticky traps, pheromone traps, barrier nets, hand picking of the pests or making the environment unsuitable for them.

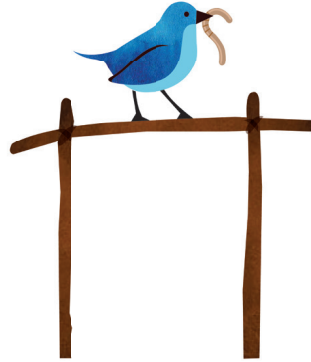
GENERAL POINTS TO BE KEPT IN MIND WHILE MECHANICAL PEST MANAGEMENT

- Removal and destruction of egg masses, larvae, pupae and adults of insect pests.
- Remove and destroy infected plant parts along with the pest wherever possible.
- Use of light traps and destruction of trapped insects.



- Use of rope for dragging for leaf feeding larvae e.g. caseworm and leaf folder, particularly in paddy crop.

- Installation of bird perches in the field for allowing birds to sit and feed on various stages of insects.
- Use of pheromones to know the severity of infestation and mass trapping of the pest.



- Use of yellow/blue sticky traps for the control of sucking pests.
- Use barrier nets around the nursery bed to protect it from sucking pests blown by the wind from adjacent fields.





2.1 PHEROMONE TRAPS

Pheromone traps contain a lure that is "scented" with female pheromones, attracting adult male moths for mating. Pheromones are chemicals released by adult females to attract males of the same species for mating. These traps are generally used to monitor pest incidence, severity of pest infestations, and determine the economic threshold levels of pests. They can also be used for mass trapping of insect pests.

HOW TO INSTALL PHEROMONE TRAPS?

- Pheromone traps should be installed at a height of 15 cm above the crop canopy.
- For the monitoring of the economic threshold level of the pest, install 2 traps per acre and for mass trapping of the pest, install 8-10 traps per acre.
- Change the lure after 21 days of trap installation.
- While changing the lure, avoid direct contact; do not touch it with your hands.

Table 2: Name of the lure, major pest and target crops

| Name of pest | Pheromone Lure | Used in Crop |
|---|-----------------------|--|
| Gram Pod borer (<i>Helicoverpa armigera</i>) | Helilure | Pigeon pea, green gram, black gram, cotton, soybean and chickpea. |
| Tobacco leaf Eating caterpillar (<i>Spodoptera litura</i>) | Spodolure | Pigeon pea, green gram, black gram, cotton, soybean, chickpea, chilli and maize. |
| Fall Armyworm (<i>Spodoptera frugiperda</i>) | Spodolure | Maize, sorghum, pearl millet, sugarcane, wheat, cotton etc. |
| Pink bollworm (<i>Pectinophora gossypiella</i>) | Pectinolure/Gossylure | Cotton |

| Name of pest | Pheromone Lure | Used in Crop |
|--|----------------------|-----------------------------------|
| Spotted bollworm (<i>Earias Vitella</i>) | Ervitlure, Ervinlure | Cotton and okra. |
| Paddy Stem borer (<i>Scirpophaga incertulus</i>) | Scirpofagalure | Paddy. |
| Diamond back moth of cabbage (<i>Plutella Xylostella</i>) | Pectilure | Cabbage, cauliflower and mustard. |
| Cucurbits vegetables | Culure | All cucurbits crops |

2.2 CASTOR POISON BAIT FOR RHIZOME FLY OF TURMERIC

Castor poison bait is prepared from castor powder and water. The castor poison bait attracts and kills the rhizome fly and prevents the further infestation of the rhizome fly in the field.

Materials required



1. Castor powder - 200 grams
2. Flat plastic tub - 3 litres

Procedure

Take 200 grams of castor powder (crushed castor seeds). Mix 1.5 litres of water in it. Keep the mixture for 8 to 10 days in the field for fermentation. After 10 days, a typical smell occurs from the poison bait that attracts rhizome flies and they will fall into the poison bait and die.

Recommendation

Keep five to six poison bait at different locations in the field for one acre area.

2.3 LIGHT TRAPS

Light traps are one of the important components of IPM. It attracts phototropic pests like pod borer, semi looper, tobacco caterpillars, bollworms, beetles etc.



How to Install light traps?

- Install 1-2 light traps per acre depending upon the shape of the farm.
- Install light traps 1-2 feet above the crop canopy.
- Operate the light trap during dusk hours (6-9 pm) when the insects are very active.

Table 3: List of the crop pests attracted to the light trap.

| Crop | Target Pests |
|-----------|---|
| Paddy | YSB, GLH, Leaf folder, Plant hopper and White Grub. |
| Pulses | Pod borer, Semilooper, Cutworm and Grasshopper. |
| Maize | Stem borer and Stalk borer. |
| Soybean | Looper, Green looper and Armyworm. |
| Vegetable | Semilooper, DBM, Leaf miner, Black Cutworm, Shoot and fruit borer. |
| Sugarcane | Pyrrilla, White grub, Grasshopper and Top borer. |
| Groundnut | Hairy caterpillar, Leaf miner and Thrips. |
| Cumin | Tobacco leaf-eating caterpillar. |
| Turmeric | <p>White grub</p> <ul style="list-style-type: none"> • After the first summer shower set up a light trap on the field boundary of the turmeric crop to trap and kill adult grub. • If the neem and karanj trees are planted on the field bunds, then set up a light trap below these trees after the first rain in the summer season. |

2.4 STICKY TRAPS

Sticky traps are mainly used for controlling soft body sucking pests like thrips, whiteflies, jassids, aphids etc. There are mainly yellow and blue color sticky traps available in the market.



How to install sticky traps?

- Sticky traps should be installed 15 cm above the crop canopy.
- Sticky part of the trap should be against the direction of the wind so pests can easily stick to the trap.
- Install 20-25 traps per acre. The number of traps per acre may increase or decrease depending on the infestation of the pest.
- Do not touch directly the sticky side of the trap. Nowadays two-sided sticky traps are also available in the market.

3. Biological practices:

Biological control of pests and diseases is the most important component of IPM. It involves the use of biopesticides, parasitoids, predators and pathogens, NPV and entomo-pathogenic pesticides to maintain or control the pest/disease infestation.

3.1 BIO-PESTICIDES

Biopesticides are the types of pesticides derived from natural materials such as animals, plants, bacteria, and certain minerals. Biopesticides are classified into three main categories: botanical pesticides, predator and parasitoids and microbial inoculants.

3.1.1 BOTANICAL PESTICIDES

- Botanical pesticides are naturally occurring secondary metabolites extracted from different plant parts and are used to prevent and control pests.
- Botanical pesticides are environmentally friendly and not harmful to beneficial insects. Biopesticides can be prepared locally using leaf extracts from various native plant species, cow dung and cow urine.
- The cost of production of a biopesticide is very low and can be used effectively against various types of pests across all crops.

A. DASHPARNI ARK

Materials Required

- 1) Neem Leaves – 5 kg



- 2) Ghaneri (*Lantana camara*) – 2 kg



- 3) Karanj Leaves – 2 kg



4) Kanheri Leaves - 2 kg



5) Jatropha or Castor Leaves - 2 kg



6) Gulvel Leaves - 2 kg



7) Custard Apple Leaves - 3 kg



8) Rui Leaves - 2 kg



9) Papaya Leaves - 2 kg



10) Nirgudi Leaves - 2 kg



11) Cow Urine/ Gomutra - 5 litres



12) Cow dung (Deshi) - 2 kg



13) Water - 170 litres



Method of Preparation

Mix all the above contents in a plastic container or barrel. The mixture should be stirred with a wooden stick clockwise and anti-clockwise for 5-10 minutes every day, in the morning and evening. Keep it for 30 days in the shade. After one month, separate the ark through a sieve. The ark is then ready for spraying as a biopesticide.



How can we can store it?

Dashparni ark can be stored in a small one litre plastic bottle or 5 litres can. At the time of storage, keep the lid of the bottle loose or make small holes on the lid for free air circulation and keep it in the shade.



Otherwise, there is a chance of developing high gas pressure inside the bottle causing an explosion /blast of the bottle. The prepared dashparni ark solution can be effectively used for 2-3 months; after that, its efficacy is reduced.

How to use the Dashparni ark?

The dashparni ark is mainly used for foliar application on the plant to control pests. The recommended dose for spraying is 150 ml of Dashparni ark per 15 litres of water.

Advantages

- 1) It is a natural plant-based biopesticide.
- 2) It prevents and controls the infestation of sucking and larval pests on all crops.
- 3) The cost of production of dashparni ark is very low as compared to chemical pesticides.
- 4) It does not cause any harmful effects on crops, pollinators, natural predators, environment and human beings.

B. 5% NEEM SEED KARNEL EXTRACT

Materials Required

1. Dried neem seeds - 5 kg



2. Plastic bucket of 15 litres capacity



3. Plastic drum of 100 litres capacity

Method of Preparation

Take 5 kg of dried neem seeds, grind them into a powder, mix with 10 litres of water, and let it sit for 24 hours. Then separate the extract by filtering through a cotton cloth and add 90 litres of water to make the final volume of 100 litres. The Neem Ark is now ready for spraying to control the sucking pest during the initial growth stage of the crop.

How to use the 5% NSKE?

The prepared solution of 5% NSKE is used directly for spraying without making any further dilution.

Advantages

It controls the sucking and larval pests like aphids, jassids, whitefly, thrips, leaf eating caterpillars etc. in all crops.

It's a low cost natural biopesticide and does not cause harmful effects on crops, pollinators, natural predators, environment and humans beings.

C. NEEMA STRA

Materials required



1. Plastic drum of 100 litres capacity.



2. Neem leaves - 5 kg



3. Cow urine - 5 litres



4. Cow dung - 2 kg

Method of Preparation

Crush 5 kg neem leaves in water to make pulp. Add 5 litres of cow urine and 2 kg of fresh cow dung to a plastic drum. Mix the content in a plastic drum with the help of a wooden stick. Cover the drum with a lid and place it in the shade, preferably under fresh neem leaves, for 24 hours to ferment. Filter the extract with the cotton cloth, dilute it with water and make the final volume of 100 litres. After the dilution, neemastra is ready for spraying against sucking pests and mealy bugs.

How to use the 5% NSKE?

The prepared solution of Neemastra is used directly for spraying without making any further dilution.

D. AGNI STRA

Materials required



1. Pot of 15 litres capacity



2. Tobacco - 1 kg



3. Cow urine - 10 litres



4. Fresh green chilli - 500 grams



5. Fresh garlic - 500 grams



6. Neem leaves - 5 kg

Method of Preparation

Take a pot of 15-litre capacity. Add 10 litres of cow urine to it. Then, crush 1 kg of tobacco and add it to the urine. Add

Add 500 g each of crushed green chilli and garlic to the pot. Add 5 Kg neem leaves pulp in a pot. Then mix well and boil the contents 5 times continuously. Allow this solution to ferment for 24 hours. Filter the extract with cotton cloth. The filtered ark is ready for spraying after the dilution.

How to use the Agniastra

For spraying on 1 acre, mix 2-3 litres of Agniastra in 200 litres of water and then use it for spraying. It can be used for spraying on any crop. Do not add any other chemicals with Agniastra.

E. BRAHMASTRA

Materials Required



1. Pot of 15 litres capacity



2. Cow urine - 10 litres



3. Neem leaves - 3 kg



4. Custard apple leaves - 3 kg



5. Papaya leaves - 3 kg



6. Pomegranate leaves - 2 kg



7. Guava leaves - 2 kg

Method of Preparation

Crush 3 kg neem leaves in 10 litres of cow urine. Crush 2 kg custard apple leaf, 2 kg papaya leaf, 2 kg pomegranate leaves, 2 kg guava leaves in water. Mix all the content and boil 5 times at some intervals till it becomes half. Keep it for 24 hrs, then filter and squeeze the extract. This can be stored in bottles for 6 months. Brahmastra is useful against sucking pests and pod/fruit borers. It can be used in any crop for the management of pests.

How to use the Brahmastra?

For spraying on 1 acre, mix 2-3 litres of brahmastra in 200 litres of water and then use it for spraying. It can be used for spraying on any crop. Do not add any other chemicals with Agniastra.

3.2 Parasitoids and Predators:




3.2.1 PARASITOIDS



Parasitoids are the organisms that lay eggs in or on the bodies of their hosts. They complete their life cycles, ultimately causing the death of the hosts.. A parasitoid may be of different types depending on the developmental stage of the hosts or on which it completes its life cycle. For example, parasitoids may target different developmental stages of the host, such as egg, larval, pupal, adult, egg-larval, and larval-pupal parasitoids. Examples are different species of Trichogramma, Apanteles, Bracon, Chelonus, Brachemeria, Pseudogonotopus etc.

3.2.2 PREDATORS

These are free-living organisms that prey upon other organisms for their food. Examples are different species of spiders, dragonflies, damselflies, ladybird beetles, Chrysopa species, birds, frogs etc.

Table 4: List of major predators and parasitoids and target pests and diseases

| Predator and Parasitoid | Target Pest/disease | |
|-------------------------|--|--|
| Ladybird beetles | Aphids, whiteflies, scales, mites, mealybugs and other soft-bodied insects. |  |
| Lacewings | Whiteflies thrips, leafhoppers, aphids, spider mites, scales, mealybugs, small caterpillars and insect eggs. |  |
| Syrphid fly larvae | Aphids, scales, thrips and other small soft-bodied insects. |  |

| Predator and Parasitoid | Target Pest/disease | |
|-------------------------|---|--|
| Praying mantis | Feed on many insects, including aphids, flies, beetles etc. |  |
| Parasitic wasps | Aphids, caterpillars, and whiteflies. |  |

3.3 Microbial Inoculants:

These are living microorganisms like bacteria, fungi, viruses, nematodes etc. which infest and cause diseases in their hosts as a result of which hosts are killed. Most common bio inoculants used for pest and disease management are of different species of fungi *Hirsutella*, *Beauveria*, and *Metarhizium* infest and kill large numbers of insects in the fields. Among viruses, the most important examples are nuclear polyhedrosis virus (NPV) and granulosis viruses.

Table 5: Most commonly used bio-inoculants for pest and disease management in agriculture.

| Bio-agent | Target Pest/disease | Dose for spray |
|--------------------------------|--|------------------|
| <i>Metarhizium anisopliae</i> | White grub, Mealybug, Termite, thrips, jassid fruit borer etc. | 5ml/lit of water |
| <i>Beauveria bassiana</i> | White grub termite, fruit borer, semilooper, stem borer, bollworm, thrips, jassid etc. | 5ml/lit of water |
| <i>Verticillium lecanii</i> | All sucking pests. | 5ml/lit of water |
| <i>Trichoderma viride</i> | Root rot, downy-powdary mildew, stem rot and blight. | 5ml/lit of water |
| <i>Pseudomonas fluorescens</i> | Rust and fungal disease. | 5ml/lit of water |
| <i>Bacillus subtilis</i> | Root rot, downy-powdary mildew, stem rot and blight. | 5ml/lit of water |

4. Chemical practices

In integrated pest and disease management, the use of pesticides is the last option and it can be used only when cultural and biological measures fail to control the pest population below the economic threshold level.

Economic Injury Level (EIL)

EIL is the lowest population density of pests that will cause economic damage.

Economic Threshold Level (ETL)

ETL is the population density at which the control measures should be applied to prevent an increasing pest population from reaching the EIL.

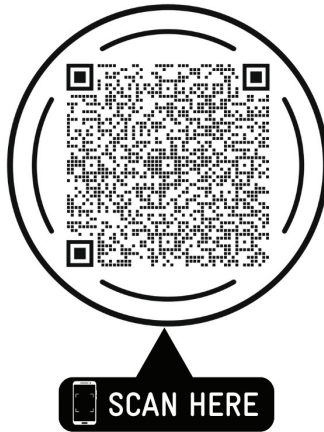
When using chemical control methods, it is important to thoroughly understand what, when, where, and how to spray. Consider the following points:

- The pest-to-defender ratio must be observed.
- Ensure that the Economic threshold level has been crossed by the pest population before spraying of pesticide.
- Do not use the same pesticide frequently or same group of pesticides to avoid pest resistance.
- Use pesticides recommended by the Central Insecticide Board and follow label instructions.
- At the time of spraying take all the necessary precautions and wear all safety measures.
- Do not use weedicide spray pump for the spraying of insecticides or fungicides.
- Do not spray the second dose of pesticide before the completion of waiting period of the first applied pesticide.
- When harvesting and marketing fruits, leafy vegetables, or any other crops, consider the post-harvest interval (PHI) of the pesticide. This will avoid the entry of pesticides into the food chain.

References

Nayak, P, & Solanki, H (2021). Pesticides and Indian agriculture- a review. International Journal of Research - GRANTHAALAYAH, 9(5), 250. doi: 0.29121/granthaalayah.v9.i5.2021.3930.





OTHER AVAILABLE RESOURCES ON THE WEBSITE:

- Handbooks on Concept and Methods of Integrated Pest Management in Sustainable Agriculture, Soil Sampling and Soil Testing, Integrated Nutrient Management and Low-Cost Organic Formulations (English, Hindi, Kannada and Malayalam).
- Farmers' Manuals on Sustainable Production Practices for Cardamom (English and Malayalam), Cumin (English and Hindi) and Turmeric (English, Kannada and Tamil).
- Farmers' Diaries on Cumin (Hindi), Turmeric (Tamil), Dill seed and Celery (Hindi).
- Animated Video Series on Practicing Sustainable Agriculture, Sustainable Food production, organic farming and more (English, Hindi, Kannada and Malayalam).



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