THE NEOTIA UNIVERSITY

ज्ञानम् आत्म प्रदीपाय

Principles of Integrated Pest and Disease Management
Practical Manual
Course no-CC-AGP 535

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Prepared By

Dr. Krishna Ray and Dr. Koushik Sen

Department of Plant Pathology
School of Agriculture and Allied Sciences

The Neotia University
Jhinger Pole, Diamond Harbour Rd, Sarisha, West Bengal 743368

Introduction:

The subject Plant Pathology under the discipline Agriculture is an important branch. This branch is deals with the detection and diagnosis of agriculturally important diseases, symptoms, their causal agents, favourable environment and management aspects. Being an applied science and detailed study of plant diseases, laboratory work under this subject is indispensable.

Keeping this view, ICAR has framed a syllabus for practical classes of each courses of Plant Pathology for undergraduate students. Therefore, we have tried to prepare a laboratory manual for the course of “Principles of Integrated Pest and Disease Management” for benefits of the students. In this manual, we have tried to arrange topics and contents in such a manner that students will get an easy understanding of the principles and methods of the experiment in advance. The content of this manual is framed according to the syllabus of the course-“ Principles of Integrated Pest and Disease Management” as mentioned in ICAR Fifth Dean Committee. In this manual, the syllabus for practical of this course has divided into fifteen lessons.

Content

Sl. no.	Title of the experiment	Page no.	Date	Remarks and Signature
1	Identification of important diseases of different crops	1-4		
2	Methods of detection and diagnosis of plant diseases	5-7		
3	Estimation of disease intensity	8-9		
4	Estimation of disease dynamics on a selected crops	10-11		
5	Isolation of Antagonists from rhizosphere soil by serial dilution technique	12-13		
6	Methods of assessment of antagonistic property of potential bio-control agents against plant pathogen	14-16		
7	Procedure and laboratory techniques involved in mass multiplication of *Trichoderma* sp.	17		
8	Techniques and procedures involved in mass production of *Pseudomonas* sp.	18-19		
9	Methods of Diagnosis and Detection of Various Insect Pests	20-22		
10	Methods for Assessment of Insect Pest Population	23-29		
11	Assessment of Crop Yield Losses and Calculations Based on Economics of IPM	30-35		
12	Identification of Biocontrol Agents, Different Predators and Natural Enemies	36-38		
13	Mass Multiplication of *Trichogramma* and Nuclear Polyhedrosis Virus (NPV)	39-46		
14	Identification and Nature of Damage of Important Insect Pests and Their Management	47-64		
15	Crop (Agro-ecosystem) Dynamics of a Selected Insect Pest	65-66		
16	Plan & Assess Preventive Strategies (IPM Module) and Decision Making. Crop Monitoring Attacked by Insect Pests.	68-70		

EXPERIMENT1-Identification of important diseases of different crops

Objectives: To gather knowledge about the common disease symptoms of different agricultural crops.

The identification plays a major role in assessing the pest infestation in crop and hence helps to manage them. Identification of insect pest and diseases is the foremost step for integrated pest and disease management. A plant disease is the abnormal phenomenon of plant health that leads to altered appearance and physiolological activity of a plant. Plant diseases caused aberrations in normal physiological activities which in turn affect other activities too. It does not occur instantly like injury, changes in plant system occur over time. Diseases not only reduce yield but also deteriorate the quality of the seeds. Symptoms are the visible reflections of the infected plants manifested by continuous irritation of plant pathogens. It can be the changes of leaf color, shape, size or any other morphological and physiological disturbances whereas, signs are the physical evidence of the pathogen like bacterial ooze, fungal mycelia, sclerotia etc. Symptoms and signs help plant disease identification.

Few examples of signs and symptoms of common diseases incited by fungi, bacteria and viruses are mentioned here:

Fungal disease symptoms:

Spot: It is sharply defined lesion of diseased tissue; appear either on leaf or fruits.

Lesion: A localized area of diseased tissue.

Blight: Spots that formed after coalescing of numerous small spots. In advance stage, the rapid decline and death of young plant parts occurs. This term generally used to signify the health condition of infected plant. (e.g. Botrytis blight, blossom blight).

Blotch: This term indicates irregular dead areas of leaf tissue. Infected area are larger than the spot.

Rot: Rotted condition of a plant parts is manifestation of disintegrated cell wall and cell membrane due to some bacteria or fungi that produce pectinolytic enzymes.

Wilt: Due to water stress condition or clogging of xylem vessels with fungal mycelia or expolysaccharides of bacteria, plants become droopy, pale and died later on. e.g. Fusarium wilt, Bacterial wilt of solanaceous vegetables by *Ralstonia solanacearum*.

Plant droops due to water stress; can be systemic (xylem) or due to root rot e.g. Fusarium wilt of banana.

Dieback: In this symptom, progressive drying and death of shoots from tender tips is observed. This symptom may be caused by a root or stem related disease, insect injury,

nematode feeding and a number of abiotic factors, such as winter injury or moisture stress.
e.g. chili dieback

Scorch: Foliar leaf tissues, specially the leaves shows burning symptoms along the marginal parts or tips.

Shot-hole: Spotted portion of leaf tissue will be dried, become papery and fall off. Which will gives an appearance of numerous small holes on the leaf surface. E.g. Cercospora leaf spot.

Patches and decline: These terms often used in association with grasses (turf, grain crops).
e.g. patches caused by *Rhizoctonia* sp.

Anthracnose: Firstly, symptoms of a**nthracnose** appear as small, irregular faded yellow or brown **spots**. These spots darken as they age and may also expand, covering the whole leaf and become sunken with numerous small dot like fruit bodies embedded on this**.** e.g. Chili anthracnose by *Colletotrichum capsici*.

Rust: It is a fungal disease that produces dusty appearance due to exposure of spores and spore bearing structures from broken epidermis. Colors of the spores may be orange, yellow, brown, black or white and called pustules when form cumulatively. e.g. Black rust of wheat (*Puccinia graminis tritici).*

Smut: A fungal disease of cereals in which parts of the ear change to black powder Form black powdery spore masses that resemble soot or smut. e.g. Loose smut of wheat caused by *Ustilago tritici.*

Downy **mildew:** Initially symptoms appear as yellow colored small spots on the upper surface of the foliage. On the reverse side of the spotted areas, massive mycelia growth can be seen with spores and sporophores growing downwardly. As the leaf spot dies, the fluffy growth darkens to grey in colour. e.g. Downy mildew of cucurbits caused by *Pseudoperonospora cubensis*.

Powdery mildew: It is a common disease of **cucurbits**. A **powdery mildew** disease gives white powdery appearance on the affected plant parts. Infested areas become pale yellow in color due to interference with photosynthesis. e.g. Powdery mildew of cucurbits caused by *Sphaerotheca fuliginia*.

Pustule: Pustules are the small dotted blister like appearance, appear cumulatively. Over the mature pustules, epidermis becomes ruptured, helps to expose the spores of the pathogen.
E.g. rust pathogen.

Conk (also Conch): This refers to fruiting bodies of the wood rotting fungi.

Damping-off: Mostly in nursery beds of the vegetables, seeds decayed after sowing due to infection of soil borne fungi. Either seedling not emerged or become infected at the soil line after emergence. E.g. *Pythium* sp, *Phytophthora*sp and *Fusarium* sp.

Symptoms of bacterial diseases:

Canker: It is sunken, necrotic areas on twig, leaves, stem or trunk of plant**, surrounded by corky dead tissues.** e. g. Citrus canker caused by *Xanthomonas campestris pv. citri*

Vascular discoloration: Darkening of the plant's vascular elements.

Scab: Crust like rough brown colored area on the surface of a plant organ. e.g. Potato scab caused by *Streptomyces scabies.*

Other symptoms are-

- Leaf spots and blights – water soaked, greasy (Bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *oryzae*)
- Soft rots of fruits e.g. soft rot of Potato caused by *Pectobacterium carotovorum* pv. *carotovorum*
- Leaf curling
- Etiolation
- Virescence
- Sheperd's crook stem ends on woody plant

Symptoms of viral diseases:

Dwarfing or stunting: Reduced growth of plants.

Mosaics: Light green, yellow or white areas intermingled with green–leaves or fruits. Symptom of certain viral diseases of plants are characterized by intermingling patches of normal green and light green or yellowish colors. e.g. Bean golden mosaic virus.

Chlorosis: This is results of loss of chlorophyll. Due to destruction or breakdown of chlorophyll, green leaf tissue become white or pale yellow.

Ring spots: Concentric rings of chlorotic or necrotic tissues on leaves, stems and fruits. e. g. Papaya ringspot virus

Curling: Rolling, cupping, or puckering of leaves. e.g. Tomato leaf curl virus.

Necrosis: Dead plant tissue. Color may be brown, black, tan, or grey. e.g. Tobacco necrosis virus

Mottling: Different shades of color will be mingled on the surface of infected tissue.

Rugose: The blistered or warty crinkled foliar parts of an affected plant e.g. Potato rugose mosaic virus

Vein banding: Infected leaves show banded areas with darker region along veins and chlorotic areas at interveinal regions. This symptoms generally induced by viruses.

Vein clearing: Vein tissues become chlorotic due to destruction of chlorophyll. It is mainly the result of virus infection.

Witches' broom: Excessive proliferation of foliages of vegetative branches gives a broom like appearance. Generally caused by viroids. E.g. Potato withes broom.

Distortion: Malformed plant tissues

Exercise:

Materials required:
Pen, marker pen, record book, polythene packet, rubber band

Work out:

1. Visit the field and by random sampling method collect the samples.
2. Keep the sample into polythene packet containing a wet cotton swab and close the mouth of the polythene packet with rubber band.
3. During collection, record the important information like; name of the plant, date of collection, location, symptom of the collected plant parts, name of the suspected causal agent etc.

Video link:
https://www.youtube.com/watch?v=dQaeiPdntKA

Observation:

Lists of the diseases observed:

Serial no.	Date of collection	Host plant	Plant part collected	location	Symptom	Causal agent

EXPERIMENT2- Methods of detection and diagnosis of plant diseases

Objectives: To study the different detection techniques of plant diseases.

Materials Needed:
Paper and/or data sheets, disease identification books, hand lens, zip lock bags if specimens are to be brought for identification in laboratory, microscope and other necessary equipment.

Steps involved in Detection and diagnosis:

1. **Field survey:** This is the first step of detection and diagnosis of plant diseases. We should familiarize our-self with symptoms of diseases. Field survey is a procedure conducted over a defined period of time to determine the characteristics of a disease population or to determine which pathogen species occur in an area.
2. **Sample collection and packaging:** Second step is sample collection. Samples submitted to the lab must be representative of the symptoms observed in the field. Specimens must be fresh. Samples should be packaged to prevent contamination during transport. Proper packaging may include a combination of layering with damp paper towelling, use of paper bags or enclosure in a plastic bag. If a sample cannot be transported immediately, we need to keep it in refrigerator and out of direct sunlight.
3. **Visual estimation from symptoms:** All the plant pathogens can detect through characteristics symptoms which they have produced in different plant parts. For proper visual identification, we can use the reference books on symptoms or we can go through internet.
4. **Detailed examination of samples in laboratory by microscope:** Microscopic examination is generally required to enable identification of the pathogen and diagnosis of the disease. The identification of fungal pathogens is based initially on morphological features, such as spores and spore-forming structures. For example, most fungal pathogens that cause leaf diseases produce spore forming structures; perithecia, pycnidia, acervuli, sporangiophores or conidiophores with the fungus body (mycelium) that can be readily examined microscopically. The shape, size, color and manner of arrangement of spores on the sporophores or in the fruiting bodies as well as the shape and color of the sporophores or fruiting bodies are sufficient characteristics used to identify the taxonomy of fungi, the class, order, family, and genus.
5. **Study of cultural and morphological characteristics:** For a correct identification of the causal agent of plant diseases and make reliable conclusions, appropriate isolation procedure must be followed. Obtaining of pure culture will be helpful to identify the pathogen on the basis of morphological and cultural characteristics.
6. **Pathogenicity testing:** Pathogenicity test can be done by following the steps of Koch's Postulates. These steps includes i)Association ii)Isolation iii)Purification iv) Re-inoculation v) Comparison of the symptoms of re-inoculated plants with symptoms of infected plants

7. **Serological methods:** Serological methods are based on production of antibodies and reaction between antigen and antibodies.
   These are ELISA and its variant: Direct antigen coated, double antibody sandwich ELISA.
8. **Molecular approaches:** The recent and advanced method of detection and diagnosis of the pathogen is the molecular detection method at species level identification. Some of the nucleic acid based techniques includes direct visualization of entire genomes, restriction digestion and electrophoresis of DNA, hybridization of DNA and RNA and the polymerase chain reaction (PCR). Molecular approaches are having their reliability and accuracy for identification of the pathogen but these are cost effective methods.
9. **Final identification and confirmation of the pathogen:** Once the genus of the fungus has been determined, descriptions of the known species are found in monographs of genera or in specific publications in research journals. Books, keys and manuals should be kept as resources in diagnostic laboratories. Many scientific publications on taxonomy can be accessed via the internet for proper identification.

Work to be done:

We will be learnt the section cutting and teasing process of diseased sample followed by slide preparation of diseased sample in laboratory.

Materials required: Sample (Diseased Plant tissue), razor blade, watch glass, distilled water, blotting paper, camel hair brush, slide, cover slip, lacto phenol, cotton blue stain, compound microscope.

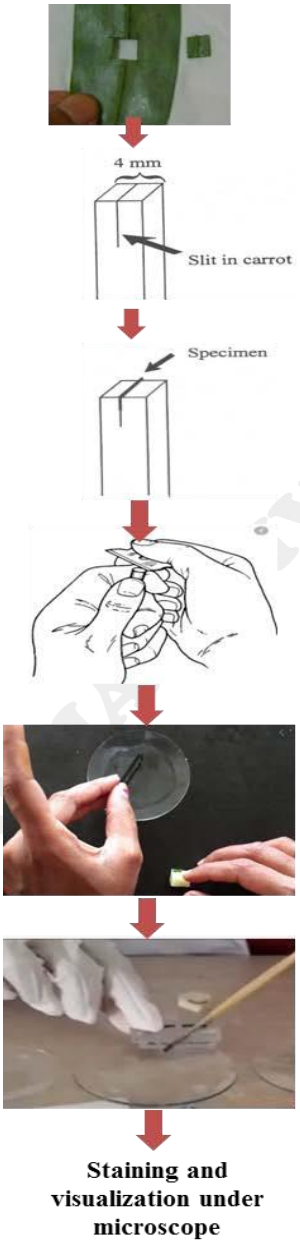
Procedure:

1. Obtain a new double edge razor blade. To minimize the risk of cutting oneself, cover one edge of the razor blade with masking tape.
2. Insert the thin diseased leaves, small and soft specimens such as roots, tissue pieces into a small piece of pith such as a carrot root.
3. Hold piece of carrot firmly. The material should be held against the side of the first finger of the left hand (or right hand) by means of the thumb.
4. Take the razor blade in the right hand (or left hand) and place it on the first finger of the left hand (or right hand), more or less at a right angle to the specimen. Draw the razor across the top of the material in such a way as to give the material a drawing cut (about 45° in the horizontal direction)
5. Cut several sections at a time. Sections will certainly vary in thickness.
6. Transfer sections to water, always using a brush, not a forceps or needle.
7. Select and transfer the thinnest section and stain and observe under microscope.

Video link:
https://www.youtube.com/watch?v=-bLBHiqlmOU
https://www.youtube.com/watch?v=gE-JOlfwIeo

Date:

Observation and conclusion:



Date:

EXPERIMENT3-Estimation of disease intensity

Objective: To learn the methods of quantification of plant diseases from an infected area.

Materials required: Disease affected field, Note book, Pen, Pictorial scale of disease measurement, Marker pen, Polythene packets and rubber band.

Procedure:

Calculation of Percentage Disease Incidence:

1. Count the total number of infected plant and record the data
2. Calculate the PDI using following formula

$$\textbf{Disease incidence:} \quad \frac{\text{No. of infected plants x100}}{\text{Total no. of plant assessed}}$$

Table:1: Recorded data of infected and non-infected plant from diseased field

Obs 1	Obs2	Obs3	Obs4	Obs5	Obs6	Obs7	Obs8	Obs9	Obs10
I	NI	NI	I	I	NI	I	NI	I	NI
Obs 11	Obs12	Obs 13	Obs 14	Obs 15	Obs 16	Obs 17	Obs 18	Obs19	Obs 20
NI	NI	NI	I	NI	NI	I	NI	I	NI
DI=	8*100/ 20			= 40%					

Obs. = Observation
I=Infected
NI=Not Infected
DI= Disease Incidence

Calculation of Disease severity Index:

1. Record the disease data of randomly selected plant in an infected field using either pictorial scale or numerical scale.
2. Calculate the DSI using following formula

$$\textbf{Disease severity:} \quad \frac{\text{Sum of all disease rating x 100}}{\text{Total no. of rating x maximum disease grade}}$$

Table 2: Recorded data of infected plant from diseased field using "0-9"scale							
45 DAS	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**Total**
P1	0	5	7	0	9	3	**24**
P2	1	9	5	7	3	0	**25**
P3	3	7	3	7	3	1	**24**
P4	5	7	0	5	1	0	**18**
P5	7	9	3	7	3	0	**29**
P6	0	3	1	1	9	7	**21**
Total	**=141**						

Where, L1-L6= Number of leaf observed, P1-P6=Number of plant observed

Disease grade	No. of rating	Total ratings
0	**7**	**0**
1	**5**	**5**
3	**8**	**24**
5	**4**	**20**
7	**8**	**56**
9	**4**	**36**
	=34	**=141**

Calculation of Disease severity:
Maximum Disease grade = 9
Total rating = 34
Sum of all ratings= 141
Dis. Severity = {141/ 34 x 9} X 100 =46.07%

Date:

Experiment-4Estimation of disease dynamics on a selected crops

Disease dynamics should be studied for safe and minimum utilization of fungicides. Disease dynamics on a crop can be estimated by calculating the area under the disease progress curve (AUDPC) that is a useful quantitative method of disease intensity over time.

Objectives: To estimate disease dynamics on a crop for routinely use of fungicides.

The trapezoidal method is the most frequently used method for estimating the AUDPC.This method discretize the time in different units(hours, days, weeks, months, or years) and then calculate the average disease or pest intensity between each pair of adjacent time points which are summed over time intervals

Materials: Immediately sown crops, disease rating scale, camera, data book, pen

Methods:

1. Regular monitoring of a crop for recording of disease data
2. During recording of data, we have to use disease measurement scale (pictorial/numerical) as discussed in previous chapter
3. Tabulate the data and calculate disease severity at 15 or 30 DAS
4. By using the following formula calculate AUDPC***
5. Draw the Area using ms-excel or spss software.

Formula** AUDPC $= \sum_{i=1}^{n} \left(\frac{y_i + y_{i+1}}{2}\right)(t_{i+1} - t_i)$

in which,

n = total number of observations,

y_i = injury intensity (usually incidence in crop health data) at the ith observation

t = time at the ith observation.

For example:
Suppose Disease severity of a disease on a selected crops for three consecutive months is May=0, June=21.11, July=58.88. What will be area under disease progress curve?

Months	**DSI**
May	0
June	21.11
July	58.88

Example:

MAY 30.05.20							JUNE30.06.20							JULY 31.07.20						
	L1	**L2**	**L3**	**L4**	**L5**	**L6**		**L1**	**L2**	**L3**	**L4**	**L5**	**L6**		**L1**	**L2**	**L3**	**L4**	**L5**	**L6**
P1	0	0	0	0	0	0	P1	0	1	0	0	0	1	P1	0	9	7	7	7	3
P2	0	0	0	0	0	0	P2	1	0	9	1	7	3	P2	7	7	1	0	7	5
P3	0	0	0	0	0	0	P3	3	7	0	0	0	3	P3	5	7	0	9	9	7
P4	0	0	0	0	0	0	P4	0	0	1	9	1	5	P4	5	7	5	0	9	9
P5	0	0	0	0	0	0	P5	1	1	0	3	0	0	P5	9	3	0	7	7	1
DSI	0						DSI	21.11						DSI	58.88					

$$\text{AUDPC} = \frac{0+21.11}{2}(30-0)+\frac{21.11+58.88}{2}(60-30)$$

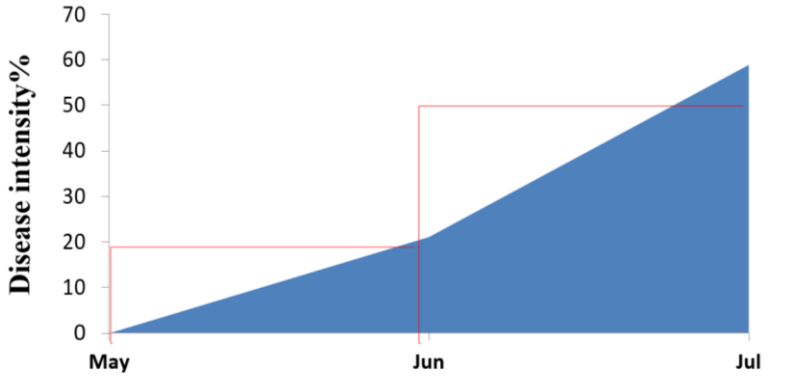


Illustration of midpoint rule method for calculating area under the disease progress curve

Video Link: https://www.youtube.com/watch?v=WWhJDCXcjWE

EXPERIMENT5-Isolation of Antagonists from rhizosphere soil by serial dilution technique

Objectives:

- To learn the sampling and isolation technique of soil inhabiting biocontrol agents from soil.
- To identify the biocontrol agents on the basis of morphological features.

Materials required:

- 1 Conical flask with 90mL sterile distilled water
- 10 gm of soil sample
- 5 numbers of test tube containing 9ml distilled water each
- 100µL micropipettor with sterile tips
- Sterile and molten media (PDA for fungi/NA for bacteria)
- Sterile Petri dishes
- Ethanol and absorbent cotton
- Vortex
- Test tube rack
- Marker pen

Procedure for isolation of BCAs (soil inhabiting Bacteria and fungi) from soil

1. Collection of rhizospheric soil samples

Collect the soil sample from rhizosphere region of different crop rhizosphere. Nearly ½ Kg soil should collected in plastic bags from each rhizosphere region. Spread the samples to be dried and use for further study.

2. Isolation of *Trichoderma spp.*

i. Mix 10 gm of soil aseptically into 90 ml of sterile distilled water. Mix it thoroughly using Vortex mixture or mix the bottle by inverting it 20 times. It will give 1:10 dilution (W/V). Label the bottle 10^{-1}

ii. Using a fresh pipette, transfer 1 mL from the stock solution to the second blank. Mix as before. Label the second bottle 10^{-2}.

iii. Using a fresh pipette, transfer 1 mL from the first blank to the second blank. Mix as before. Label the second bottle 10^{-2}.

iv. Using a fresh pipette, transfer 1 mL from the first blank to the third blank. Mix as before. Label the second bottle 10^{-3}.

v. Using a fresh pipette, transfer 1 mL from the first blank to the forth blank. Mix as before. Label the second bottle 10^{-4}.

vi. Using a fresh pipette, transfer 1 mL from the first blank to the second blank. Mix as before. Label the fifth bottle 10^{-5}.

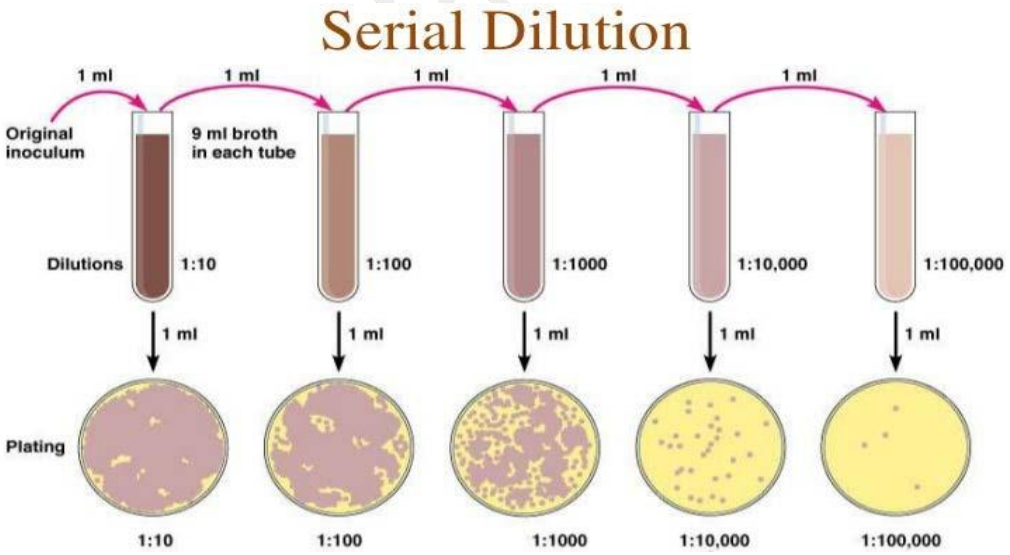
vii. Label the Petri dishes: 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6}, respectively.

viii. Transfer liquid from the dilution blanks to the Petri dishes. Use a separate pipette for each blank, not for each plate (i.e. if more than one plate uses liquid from a single blank, a single pipette may be used for that blank).

ix. One at a time, add a tube of molten nutrient agar/PDA to each Petri dish. After adding the agar, gently swirl the dishes in pattern for 30 seconds to mix the bacteria with the agar.

x. After the agar has thoroughly solidified, incubate the plates at required temperature.

Observe the culture plate at 4-5 days of incubation and identify the target



Video link: https://www.youtube.com/watch?v=FdzKgotzjC4

Work to be done:

Whole process of isolation of BCAs by use of serial dilution technique will be learnt in laboratory.

Observation and calculation:

EXPERIMENT6-Methods of assessment of antagonistic property of potential bio-control agents against plant pathogen

Objective: To check the potentiality of the antagonists (BCAs) against plant pathogens.

Materials required:

- Pure culture of any plant pathogen
- Pure culture of bio-control agent
- PDA
- Petri dish
- Cork borer
- Inoculating needle
- Marker pen
- Centimetre scale

Procedure: For Fungal BCAs

1. Cut 10 mm diameter disc of antagonist fungi and placed the disc at one side of Petri dish containing PDA
2. Cut 10 mm disc of pathogen and placed at the opposite side of the antagonist and equidistant position from periphery of the same plate
3. Incubate the plates at 28± 1°Cat inverted position in BOD
4. Take regular observation for data recording till the pathogen attain full growth in control plate and calculate Percentage inhibition of the pathogen by the antagonists.

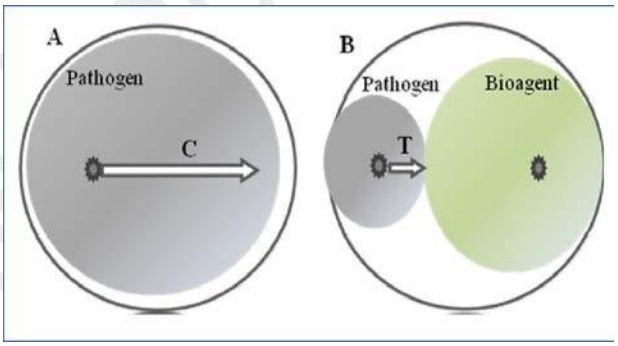


Fig1: A: Control plate, B: Dual culture plate

Procedure: For Bacterial antagonist (BCAs)

1. Streaked a loop of bacteria 1.5 cm from periphery of petri plates
2. Cut 10mm diameter disc of pathogen using cork borer and inoculate in the same manner (1.5 cm from periphery of Petri plates) just opposite position of the bacteria

3. Incubate the plates at 28± 1 °Cat inverted position in BOD
4. Take regular observation for data recording till the pathogen attain full growth in control plate and calculate Percentage inhibition of the pathogen by the antagonists.

Calculation of Percent Inhibition:

The percentage of inhibition of fungal growth will be calculated by using the following formula,

Percent inhibition (Radial growth) = (Rc-Rt)/Rc x 100%

Where, Rc= Growth in control, Rt= Growth in treatment

Note:***Control plate-** At the same time, one 10 mm disc of the pathogen will be placed on PDA to obtain growth of the pathogen and this will be considered as control plate.

Work to be done:

We will learn the above said techniques of dual culture method in laboratory. If the antagonist is the potential one then it will make more than 50% inhibition. After selection of an efficient antagonist, we can go for mass multiplication and field level trial to evaluate the efficiency of antagonists on disease suppression and crop growth

Control plate **Treatment Plate**

Fig: 2 Comparative growth of pathogen in control plate and dual culture plate

Video Link:
https://www.youtube.com/watch?v=37guajkSAQM

Exercise:

1. If the radial growth of a pathogen at 5 days of incubation is 9 cm and radial growth of pathogen in a dual culture plate is 5 cm, then what is the percentage inhibition? Should we consider it as a potential bio-control agent?

2. Suppose percentage of inhibition of Strain A = 50%, B=40%, C=75%, D=90%. Which one is better for further study? Justify your answer.

Date:

EXPERIMENT7-Procedure and laboratory techniques involved in mass multiplication of *Trichoderma* sp.

Objective: To learn the techniques of mass production of *Trichoderma* sp.

Material required

Pure culture plate of *Trichoderma* sp., cork borer, distilled water, conical flasks, autoclave, jaggery, yeast extract, cotton plugs, streptocyclin, inoculation needle, muslin cloth, talcum powder, carboxy methyl cellulose, rubber bands.

Procedure: The whole process will be done by two steps-

Step1: Preparation of mother culture

1) Prepare Molasses yeast medium by mixing 5gm yeast powder and 30 gm molasses into 1000 ml water.

2) Dispensed the prepared medium into conical flasks and sterilized at 15 lb pressure for 15 minutes in an autoclave.

3) Inoculate the cooled media with 10 days old fungal disc of *Trichoderma* and incubate for 10 days for fungal growth.

Step2: Mass multiplication

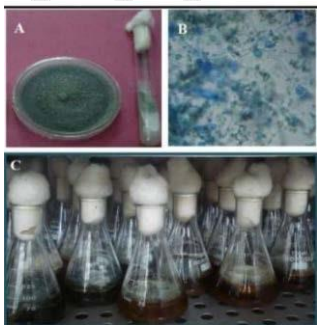
1) Molasses yeast medium is prepared in fermentor and sterilized as described earlier.

2) Then after the medium is cooled, the mother culture is added to the fermentor @ 1.5 lit / 50 lit of the medium and incubated at room temperature for 10 days.

3) The fungal biomass collected from fermentor is mixed with talc powder at 1:2 ratio.

4) The mixture is air dried in shade and mixed with carboxy methyl cellulose (CMC) @ 5 g / kg the product.

5) It is packed in polythene bags and should be used within 4 months.




Video link:

https://www.youtube.com/watch?v=TruIZMdLMVY

Date:

EXPERIMENT8-Techniques and procedures involved in mass production of *Pseudomonas* sp.

Objective: To learn the techniques of mass production of *Pseudomonas* sp.

Materials required

- Pure culture of *Pseudomonas* sp.
- Distilled water
- Conical flasks
- Autoclave
- Cotton plugs
- Inoculation loop
- Talcum powder
- Rubber bands
- Peptone
- Dipotassium phosphate (K_2HPO_4)
- Magnesium sulphate ($MgSO_4$)
- Glycerol

Procedure: The whole process will be done by two steps-

Step1: Preparation of mother culture

1) Prepare **king's B** medium by mixing necessary components (**Peptone: 20.0g K2HPO4:1.5g MgSO4:1.5g Glycerol: 10ml**) into 1000 ml water.

2) Dispensed the prepared medium into conical flasks and sterilized at 15 lb pressure for 15 minutes in an autoclave.

3) Inoculate the cooled media with a loop of *Pseudomonas* sp. and incubate for 2 days.

Step2: Mass multiplication

1) The king's B medium is prepared and poured into the fermentor and sterilized at 15 lb pressure for 15 minutes.

2) After the broth has cooled, the mother culture of *Pseudomonas* sp. is added to the king's B medium in the fermentor at the rate of 3 lit for 40 lit of the broth.

3) Then it is incubated in the fermentor for 2 days with frequent mixing of the broth by operating the stirrer.

4) Then the broth containing the bacterial growth is collected in plastic buckets and used for mixing with talc powder (1:2 ratio) for commercial formulation.

Video link:

https://www.youtube.com/watch?v=n0jivNVfC1Q

EXPERIMENT 9: Methods of Diagnosis and Detection of Various Insect Pests

Symptoms of crop damage caused by different phytophagous insects based on their different types of mouth parts

Crop plants suffered most damage from different phytophagous insects is a result of direct feeding on above-ground and below-ground plant parts as they utilize the plants to secure food and derive their nutrition or as a shelter. Almost all portions of plant *viz.*, roots, stem, bark, leaves, buds, flowers and fruits are attacked by these insects which causes economic losses to the farmers. The type of feeding injury or damage caused by insect pests is related to the type of mouthparts of the insect. The mechanism of mouth parts and type of feeding determine to a larger extent the pest management strategies including the type of pesticide to be used. The nature and symptoms of damage caused by phytophagous insects based on their feeding habits according to the modification of their mouthparts is described below.

I. Biting and Chewing type

This type of mouth parts is supposed to be the most primitive type as the other types are believed to be evolved from biting and chewing type of mouth parts. They are adapted for biting and chewing of the plant material. Biting and chewing pests bite into and chew the leaves, stems, buds, flowers, and even the roots of plants. Some examples are grasshoppers, cutworms, caterpillars, beetles etc. Based on the symptoms of damage due to feeding of different plant parts, chewing insects can be classified into different groups as mentioned below.

1. **Stem borers:** Larvae bore the stem and feed on internal contents. As a result, damaged part is cut off from the main plant and affected part wilts, dries up and exhibits symptoms like dead heart during vegetative stage and white ear heads during reproductive stage in case of paddy due to larval feeding inside the stem and they can be easily pulled out and bunchy top in case of sugarcane (destruction of growing point results in the activation of side buds, just below the growing point and produces a bunch of side shoots called bunchy top). Example- stem borers of paddy, millets, sugarcane and brinjal.
2. **Shoot borers:** Larvae infest and feed tender shoots and bore inside during vegetative stage of crop growth and cause wilting, drooping of terminal plant parts which later dries up. Example- shoot borers of brinjal, okra, cotton and castor.
3. **Defoliators/Skeletonizers:** Larvae feed on the leaves completely leaving only midrib/veins or scrape the chlorophyll content of leaves or cause numerous holes. Example- castor semilooper, ash weevils, tobacco caterpillar, epilachna beetle on brinjal.

4. **Leaf miners:** Larvae mine leaves/leaflets between the epidermal layers and feed on greenish matter, resulting in the appearance of translucent mines/white patches/zig-zag galleries. Example- leaf miners of citrus, cashew and rice hispa.
5. **Leaf webbers:** Larvae web leaves/ leaflets by means of silken threads and feed on the chlorophyll content by remaining within the web. Often faecal pellets/frass are found within the web. Example- leaf webbers on gingelly, ground nut, sapota, mango and cashew shoot webber.
6. **Leaf folders:** Larvae fold leaves from tip to base/longitudinally/margin to margin there by giving appearance of a fold/roll. Example- rice leaf folder, cotton leaf folder.
7. **Gall makers:** Larvae feeding inside the stem/tiller/leaf/flower bud stimulates excessive growth of cells at the affected portion and distorts normal growth. It results in malformation of plant parts, exhibiting gall formation and provides shelter to the pest. Example- paddy gall midge, tobacco stem borer, cotton stem weevil etc.
8. **Pod/capsule borers/boll worms:** During the reproductive stage of the crop larvae enter in to the pods, capsules and feed on the seeds/lint exhibiting symptoms like webbed condition of pods /bolls or web few pods/capsules with frass and excreta or holes of different sizes and shapes/damaged tissues (chilli/lint on Cotton). Example- spotted pod borer, capsule borers of castor and gingelly, red gram pod fly, tobacco caterpillar, gram caterpillar, pink boll worm etc.
9. **Fruit borers:** Larvae enter into the tender fruits and feed on fresh matter/pulp and plug the larval burrow with excreta. Example- fruit borer of brinjal/okra/tomato, mango stone weevil, cashew apple and nut borer.
10. **Bark borers:** Larvae remain in a small tunnel at the axils of branches, under the bark constructing galleries of frassy web on the stem and near bark/angles of branches and move about, conceal inside the silken gallery and feed on the bark by scraping. Example- bark eating caterpillars of citrus, mango, guava etc.
11. **Tree borers:** Larvae bore deep into the tree trunk, make the tunnels in zig-zag manner and feed on inner tissues, arresting translocation of sap to top portions of tree, there by the trees exhibit symptoms like yellowing, withering of leaves, drying of twigs or complete drying of tree. Sometimes, gummy material oozes from the affected portion on the tree trunk. Example- tree borers of mango, cashew, coconut red palm weevil etc.
12. **Root feeders:** Larvae feed on root/root nodules or nymphs and adults suck sap form the roots resulting in stunted growth/poor tillering/drying of plants in isolated patches. Example- white grubs, termites, rice root weevil and ragi root aphid.

13. **Seed feeders (Stored grain pests):** Grubs/larvae and adults feed on stored seeds either internally or externally by webbing the food particles. Example- rice weevil, red flour beetle, rice moth etc.

II. Sap Suckers or Feeders

These pests have part or all of the mouthparts modified into a piercing proboscis or stylet. Sap is sucked either from the phloem or xylem or from general tissues of foliage, roots or fruits. This type of mouth parts is found in planthoppers, leafhoppers, thrips, paddy gundhi bug, red cotton bug, sorghum ear head bug, aphids, mealy bugs, scales, whiteflies, mites etc. Nymphs and adults suck sap from the base of the plant/leaves/tender terminal plant parts/ flowers, thereby affect the vigour and growth of the plants or from developing ovaries/milky grains resulting in the formation of shriveled or chaffy grains. Different insects exhibit different symptoms. In case of severe infestation, sooty mould develops on the plant parts covered with honey dew excreted by insects while feeding.

1. **Hopper burn, complete drying of leaves and plants in patches, giving scorched appearance:** paddy brown planthopper, white backed plant hopper, paddy leafhopper.
2. **Curling of leaf margins/mottling/necrotic patches:** cotton leafhopper
3. **Upward curling of leaves:** chilli thrips
4. **Downward curling of leaves/elongation of petioles of older leaves/reduction in leaf size and clustering at tip of branch/brittleness:** chilli mites
5. **Leaf drying from top to bottom:** onion thrips
6. **White/yellow blotches on upper surface of leaves:** mites on castor/coconut/okra
7. **Reduced vigour/sooty mould/square/flower drop:** cotton whiteflies
8. **Yellowing/crinkling of leaves:** thrips on groundnut and pulses
9. **Reduced vigour/stunted growth/yellowing/sooty mould:** aphids

Observation:

Lists of the pests observed:

Serial no.	Date of collection	Host plant	Plant part collected	location	Symptom	Causal agent

Video Link:

https://www.youtube.com/watch?v=0Pts39jBuAI

https://www.youtube.com/watch?v=dUqIROwMEQk&t=2s

EXPERIMENT 10: Methods for Assessment of Insect Pest Population

Population estimation of insect pests is done to determine a pest species, its population distribution, change in population in space and time, to determine local or newly introduced population, and to monitor pest level to control and recommend when, where and how to deal with specific problem. Total counts of insect populations are in most cases labour intensive and time consuming. When the number of insect present on an area is relatively less, counting is done by visual observation. If the insect population is high and the population assessment is labourious, representative samples are taken which is known as sampling.

Population Estimation Methods

A. Survey

Using fixed plot survey or roving survey population assessment is done either by visual observation or sampling.

1. Fixed plot survey: The plot is fixed in an area and the counts are made periodically at weekly intervals from seedling to maturity phase. Choose a one acre field. Enter the field and walk at least 10 m and start selecting 25 plants at random by zig zag walk. Record the observations at weekly intervals.

2. Roving survey: Data on insect population and damage will be gathered from randomly selected plots in an area. Record the observation from 10 randomly selected plants by diagonal walk method from south west corner.

B. Sampling insect populations on single plants

Insects are small and often numerous. They can hide under leaves, at the base of stems and other places that make them hard to see and count. Estimating their numbers on a small plant or in a large field can be quite a challenge. This problem can be solved by counting the individuals in a "sample" part of the plant or habitat and then use this sample to estimate the total population. Consider the behavior of the insect being counted before choosing a sampling method. Note the overall distribution of insects to be counted (base of plant, under leaves, at new growth, etc.). In addition, the time of day and/or the season can affect results.

1. Using randomly selected leaves: For evenly distributed species, count the insects on three randomly selected leaves on each plant. The "randomly selected leaf" will be the sampling unit. Average the results and multiply by the number of leaves on the plant to get an estimate of the total population.

2. Using a unit area or Quadrat: When individuals are clustered on one part of the plant, sampling a unit area within that part of the plant may be necessary. For example, cabbage aphids form tight clusters on the underside of large cabbage leaves. By counting the aphids within a square centimeter placed within the cluster of aphids and then measuring the diameter of the cluster, one can estimate the number of aphids within a cluster of that size. Perform a similar calculation for the other clusters on the plant, add them all together in order to obtain an estimate of the total population. In this case the unit area is the sampling unit.

3. Using a leaf position: Another method for sampling insects that tend to favour a particular part of the plant, is to use a leaf position as the sampling unit. Select a leaf position that appears to have the highest density of insects on most of the plants in the study. Whatever leaf position selected, be consistent and count the same leaf position on each plant. Note that this method does not give an estimate of the total population. It is best used to determine the relative level of insect population growth on a plant.

C. Absolute Methods

Absolute methods yield estimates in density per unit such as locusts per land area, eggs per leaf or pupae per tree. Every insect per unit has to be counted. Most reliable data can be gathered from insect counts in square plots or standardized rings of 0.1 m^2 area that are placed along a transect line. The results of absolute methods can be directly compared with the results of previous assessments or assessments at different locations. However, the price of this advantage is literally very high not only in terms of the required time and labour. Suitable absolute methods are leaf-counts, manual collection, the use of suction devices, rotary nets, emergence traps and Berlese extractors.

1. Capture-recapture method: An interesting absolute method for the assessment of the population density is the capture-recapture method (Peterson-Lincoln index or proportionality method). Insects are captured randomly and marked, for instance with coloured nail polish. After marking the insects are released. Care must be taken to ensure, that the insects intermingle with the rest of the population before recapturing is carried out. An estimate of the population density can be calculated from the ratio between the number of marked and released insects, the recaptured insects and the marked recaptured insects. A microscopic dye was offered to the termites and the number of termites feeding upon this. These animals eventually became coloured.

D. Relative Methods

Relative methods are less labour and time intensive, therefore commonly used by entomologists. Most catching and trapping methods are relative methods such as visual

searches, fixed time collection, sweep-net catch, shaking and beating, vacuum traps, Malaise traps, window pane traps, sticky traps, pitfall traps and traps using attractants like pheromones.

Insect Collection and Trapping Methods

There is a large variety of methods available for catching and trapping insects, each being suitable for a particular assessment method and group of insects. Traps usually immobilise insects and are either active or passive. The time and the location are important for successfully collecting and trapping insects. Some common trapping devices and collection methods are:

1. Manual Collection: Manual collection is definitely the method of choice for many purposes. Beetles, most moths, all sorts of larvae can be easily collected by the use of hands, without any further devices.

2. Visual Searches: During visual searches all individuals of the species to be assessed are counted or collected from the leaves of the host plant, from the stem, from the litter below the plant, from under rocks and fallen logs, etc.

3. Fixed time collection: Fixed time collection is a relative method that uses visual searches carried out for a certain time. For example, the pests on a particular host plant are counted for ten minutes.

4. Nets: Nets are the ultimate devices for catching flying insects like butterflies, that are difficult to catch by any other means. Once the insect is trapped the net is flipped over its rim so that the insect cannot escape.

Fig. 1: Nets

5. Light traps: Light traps are used to catch nocturnal insects like moths, beetles and many more. Those insects are actually attracted to light because they become completely confused by an artificial source of light.

6. Malaise traps: Malaise traps and quick traps are tent-like or soccer goal-like devices that are commonly used for the relative assessment of agricultural pests. The traps are open on one side allowing access for the insect and are funneled into a collecting vessel attached to highest point.

7. Vacuum or Suction Traps: Vacuum or suction traps and aspirators are suitable for the relative assessment of ground dwellers and of insects on low vegetation. Suction devices suck insects into a net from which the trapped animals can no longer escape. The current of air is either produced by a hand-held vacuum cleaner-like device or simply by the lungs of the collector.

8. Barber traps or Pitfall traps: Barber traps or pitfall traps are used as a relative method for the assessment of ground dwelling insects, mostly beetles or other arthropods, that walk on the ground and accidentally fall into the pit. Pitfall traps can also be lured with attractants or baits.

9. Windowpane traps: Windowpane traps consist of a transparent Plexiglas screen mount vertically above a trough containing a suitable preservative. When an insect hits the invisible screen it drops down into the pan containing preservative and drowns. This method is also suitable for determining the flight direction of insects.

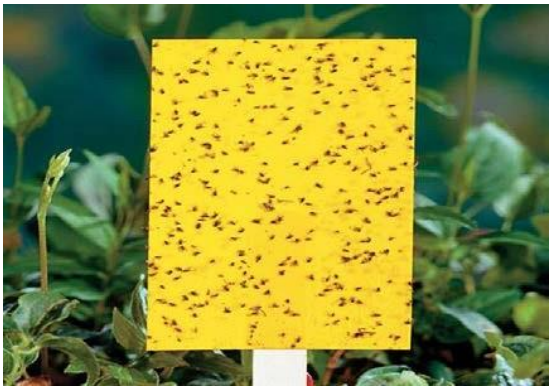
10. Combined light and suction traps: Combined light and suction traps attract nocturnal insects to the source of light. When an insect is close enough, it is sucked into the trap by a current of air. The trap is equipped with a funnel with smooth and steep walls from which a trapped insect slips into a killing jar. A disadvantage of this kind of trap is that larger specimens like moths are easily damaged in the trap.

11. Emergence traps: Emergence traps are used for the absolute assessment of insect larvae and pupae hidden in soil or litter. The cage-like device is placed over the respective site and left there to trap the adults emerging from the soil.

12. Shaking and Beating: The method is suitable for catching insects associated with lower vegetation like smaller trees and shrubs. A beating tray, canvas or piece of cloth is held or placed below the plant to be assessed. Then the stem of the plant is beaten or vigorously shaken so that insects fall on to the beating tray from where they can be collected. Fast moving insects however might easily escape from the tray or canvas, therefore an aspirator can be very helpful.

13. Rotary Nets: Rotary nets are devices used for the absolute assessment of insect populations. The devices consist of two or more revolving nets in which flying insects get caught. The method yields good results independent of the wind speed.

14. Sticky traps and greasy traps: Sticky traps and greasy traps are used for the relative assessment of diurnal insects. The device is coated with a very sticky adhesive or grease suitable for immobilizing insects. Insects are attracted to the trap either by its bright colour like yellow or white or by an attractant like a sex pheromone. The advantage of a greasy trap is that the immobilized insect can be removed from the trap in one piece.



15. Pheromone traps: Pheromone traps are used for the relative assessment of insect populations. The attracted insects either fall into a container with preservative or are immobilized on adhesive if the trap is used in combination with a sticky trap. Pheromone traps containing sex attractants usually attract only one particular sex, example: the males. The traps are very simple, cheap and effective.

Video Link:

https://www.youtube.com/watch?v=kWIWPsZCJaM&t=307s

https://www.youtube.com/watch?v=5Dn1Ug5By_w

Date:

EXPERIMENT 11: Assessment of Crop Yield Losses and Calculations Based on Economics of IPM

(A) Assessment of crop yield losses

Objective: To understand the methods of assessment of crop yield losses due to insect damage which will help in deciding the timing of control measures in order to avoid indiscriminate use of insecticides.

❖ **CROP: RICE**

1. Chewing insects (damage is assessed in 10 randomly selected hills)

Rice stem borer: Assessment is based on eggs and larval damage. Presence of yellowish brown egg mass near the leaf tip and presence of dead heart at vegetative stage or white ear at reproductive stage.

Eggs in the nursery: Number of egg masses/m^2 (ETL: 2).

Larval Damage: count the total tillers and affected tillers in a unit area and arrive at a percentage.

$$\text{Percent Dead Heart} = \frac{Number\ of\ infested\ tillers\ or\ dead\ hearts}{Total\ number\ of\ tillers} \times 100\ (\text{ETL} - 10\%)$$

$$\text{Percent White Ear} = \frac{Number\ of\ infested\ tillers\ or\ white\ ears}{Total\ number\ of\ productive\ tillers} \times 100\ (\text{ETL} - 2\%)$$

Gall midge: Assessment is based on damage on damage, silver shoot or onion shoot (ETL- 10% silver shoot).

$$\text{Percent Silver Shoot} = \frac{Number\ of\ silver\ shoot}{Total\ number\ of\ tillers} \times 100$$

Leaf Folders: Assessment is based on damage, folded and scrapped leaves in 10 randomly selected plants (ETL- 10% at vegetative stage or 5 % at flowering stage).

$$\text{Percent Infested Leaves} = \frac{Number\ of\ damaged\ leaves}{Total\ number\ of\ leaves} \times 100$$

Whorl maggot: Assessment is based on damage, marginal blotching and yellow patches on the leaves in 10 randomly selected plants (ETL- 25% infested leaves)

$$\text{Percent Infested Leaves} = \frac{Number\ of\ damaged\ leaves}{Total\ number\ of\ leaves} \times 100$$

2. Sucking Insects

Thrips: Feeding results in longitudinal curling and yellowing with pointed leaf tips mostly in the nursery. Leaves may dry in due course. Pass wet palm or table tennis bat over the seedling in five places and count the number of thrips (ETL- 25/5 passes or 10% of affected seedlings).

Green leafhopper (GLH): Feeding on leaves results in yellowing. It is the vector for rice tungro virus disease (RTV). Count the number of insects per seedling in the nursery (ETL- 50/100 seedling) or number per hill in the field (ETL- 5/hill at vegetative stage, 10/hill at reproductive stage, 2/hill in RTV endemic area). Sweep net can also be used for sampling (ETL- 60/25 sweeping).

Brown plant hopper (BPH): Feeding on stem just above water level results in hopper burn. Count the total number of insects in 10 hills selected random in one square meter area (ETL- 1/tiller or 2/tiller if predatory spider is present).

Earhead or Gundhi bug: Black spot at feeding point on the grain and individual chaffy grains. Insects emit stinky odour. Count the number of bugs in 100 earheads selected at random (ETL- 5 bugs at flowering stage or 16 bugs at milky stage/100 panicles).

$$\text{Percent Chaffy Grains} = \frac{Number\ of\ chaffy\ grains}{Total\ number\ of\ grains\ in\ 10\ randomly\ selected\ hills} \times 100$$

❖ **CROP: BRINJAL**

Shoot and Fruit borer: At vegetative stage, attack the shoot resulting drying and dropping of shoots. Count the total number of shoots damaged and arrives at a percentage.

Number basis: Count the infested as well as healthy fruits and arrive at a percentage.

Weight Basis: Weigh the damaged and healthy fruits and work out the percentage at harvest.

$$\%\ \text{Plant or Shoot or Fruit Infestation} = \frac{Number\ of\ infested\ plant\ or\ shoot\ or\ fruit}{Total\ number\ of\ plant\ or\ shoot\ or\ fruit} \times 100$$

Ash weevil: Adults feed on leaves resulting notching of the edges of the leaves, while the grubs feed on roots causing wilting. Count the total number of leaves, the number of leaves showing notching symptom and arrive at a percentage. Count the total number of plants, the number of dried plants and arrive at a percentage.

$$\text{Percent Leaf or Plant Infestation} = \frac{Number\ of\ infested\ leaves\ or\ wilted\ plants}{Total\ number\ of\ leaves\ or\ plant} \times 100$$

Defoliators

Method 1: Select10 plants per plot at random, count the total number and number of leaves affected and arrives at a percentage.

Method 2: Divide each leaf into 4 quarters, count affected quarters and work out the damage.

$$\text{Percent Damage} = \frac{Number\ of\ damaged\ quarters}{Total\ number\ of\ leaves \times 4} \times 100$$

Method 3: Tracing the margin of whole leaf and affected portion on a graph sheet to measure the area and work out per cent area of damage.

Method 4: Introduce the infested leaf into the leaf area meter and compare it with healthy leaf and difference will give the area damaged by the insect.

❖ **CROP: OKRA OR LADY'S FINGER**

Fruit Borer: Count the total number and number of fruits damaged in a plot and arrive at a percentage.

Leafhopper: Based on number of insects in three fully opened leaves, expressing as numbers per leaf. Grading the damage visually by observing the leaves in sample plants.

Grade I: Free from hopper burn

Grade II: Crinkling and curling of a few leaves mostly in upper portion of the plant and yellowing.

Grade III: Crinkling and curling of leaves all over the plant and stunted growth.

$$\text{Mean Grade Index} = \frac{G1N1+G2N2+G3N3}{N}$$

Where G1, G2, G3 are grades; N1, N2, N3 are number of plants in each grade; N is total number of plants sampled

(B) Calculations based on economics of IPM

After assessing the insect population, decision regarding the types of control measures to be followed is done based on the Economic Threshold Level (ETL) and Economic Injury Level (EIL) of the pest. The beginning point of EIL is known as Gain Threshold.

$$\text{Gain threshold} = \frac{\text{Cost of management (Rs. per ha)}}{\text{Market value of commodity (Rs. per kg)}} = \text{.....kg/ha}$$

EIL is also known as Action Thresholds Levels: The EIL concept is flexible and may vary from area to area, crop to crop depending upon the specific agronomic practices. The EIL decreases as the value of the crop increases.

Economic Injury Level (EIL) or Action Threshold Level: Stern *et al*., 1959 defined EIL as the lowest population density that will cause economic damage. It is the lowest population at which the pest will cause economic damage or it is the pest level at which the damage can no longer be tolerated and therefore it is the level at or before which the control measures are initiated. EIL is usually expressed as the number of insects per unit area.

EIL= C/VID

EIL= Number of injury equivalents per production unit (insect/ha)

C= Cost of management activity per unit of production (Rs./ha)

V= Market value per unit of product (Rs./tonnes)

I= Crop injury per pest density

D= Damage per unit injury (tone reduction/ ha)

Whether expressed as numbers or injury equivalents, the EIL is governed by five primary variables: cost of the management tactic per production unit, (C), market value per production unit (V), injury units per pest (I), damage per injury unit (D), and the proportional reduction in pest attack (K). If the relationship of these variables is linear or roughly so, the EIL can be given as:

$$EIL = \frac{C}{V \times I \times D \times K}$$

where,

EIL = Economic injury level in insects/production (or) insects/ha

C = Cost of management activity per unit of production (Rs./ha)

V = Market value per unit of yield or product (Rs./tonne)

I = Crop injury per insect (Per cent defoliation/insect)

D = Damage or yield loss per unit of injury (Tonne loss/% defoliation)

K = Proportionate reduction in injury from pesticide use (if the proportionate reduction of injury is 60%, the K value is taken as 0.6)

Worked examples of EIL

Calculate EIL in terms of pest population/ha with following figures

C = Management cost per unit area = Rs.3,000/- per ha

V = Market value in Rs./unit product = Rs.1,000/tonne

I = Crop injury/pest density = 1% defoliation/100 insects

D = Loss caused by unit injury = 0.05 tonne loss/1% defoliation

K = Proportionate reduction in injury by pesticide application = 0.8 (80% control)

$$EIL = \frac{C}{V \times I \times D \times K} = \frac{3000}{1000 \times 0.01 \times 0.05 \times 0.8} = 7500 \text{ insects/ha}$$

Economic Threshold Level: ETL is defined as the population density at which control measures should be implemented to prevent an increasing pest population from reaching the economic injury level or refers to number of insects per unit area when management action should be taken to prevent the pest from reaching EIL. Although measured in insect density, the ET is actually a time to take action, i.e., numbers are simply an index of that time.

ETL is experimentally designed as follows

- Measure the yield of crop for a range of pest densities, including zero (control plot) under controlled experiments.

- Measure the yield and total crop revenues in the same type of experiments for each management practices to be analyzed.
- Compute total crop revenue for each management at each pest density (Yield × Price per unit of output).
- Compute net revenue (subtract cost of each management action from crop revenue at each pest density).
- The pest density where the net revenues under controlled and uncontrolled conditions are equal is the Economic Threshold Level.

Or

The pest density where Marginal crop revenue is equal to the management action cost is also ETL (a hypothetical example is given in the table).

Marginal crop revenue = Crop revenue from taking action – Crop revenue from not taking action

It is clear that crop value and management cost are the two important factors deciding the EIL and ETL. In the given example if the price of fruit goes down to Rs. 1 per kg the management cost also should reduce by same proportion i.e. 10.40-5.20 to maintain the same ETL. In the given case if the management cost remains at the same level of Rs. 10.40, then the ETL will come down.

Table 1: Influence of crop value and management cost on ETL for a moringa plant affected by moringa fruit fly, *Gitona distigma*

Pest density (% affected fruits)	Yield/Plant (Kg)	Management cost @ Rs. 10.40 per plant	@ Rs. 2/kg of fruit	
			Revenue	Net Revenue
0	40.00	It is uniform for all plants	80.00	69.60
1	39.60		79.20	68.80
2	39.20		18.40	68.00
3	38.80		77.60	67.20
4	38.40		76.80	66.40
5	38.00		76.00	65.60
6	37.60		75.20	64.80
7	37.20		74.40	64.00
8	36.80		73.60	63.20
9	36.40		72.80	62.40
10	36.00		72.00	61.60
11	35.60		71.20	60.80
12	35.20		70.40	60.00
13	34.80		69.60	59.20
14	34.40		68.80	58.40
15	34.00		68.00	57.60

16	33.60		67.20	56.80
17	33.20		66.40	56.00
18	32.80		65.60	55.20
19	32.40		64.80	54.40
Uncontrolled	32.00	0	64.00	64.00

7 per cent affected fruits gives a net revenue of Rs. 64 which is equal to net revenue from uncontrolled condition.

Marginal crop revenue at 7% of affected fruits

= **Crop revenue from taking action – Crop revenue from not taking action**

= 74.40-64.00

= Rs. 10.40

So, the marginal crop revenue at 7% of affected fruits is Rs. 10.40 which is equal to the management cost.

Therefore, ETL is 7% affected fruits per plant.

Video Link:

https://www.youtube.com/watch?v=-qtjL-5fYVE

Date:

EXPERIMENT 12: Identification of Biocontrol Agents, Different Predators and Natural Enemies

1. Ladybird beetle: *Cheilomenes sexmaculata* (Coccinellidae: Coleoptera)

Cheilomenes sexmaculata is a very important, polyphagous predator of aphids and other soft bodied insects. It has been recorded in most crop ecosystems, particularly where aphids are serious pests. It has been produced in the laboratory and used for the suppression of *A. craccivora* on groundnut.




2. Ladybird beetle: *Cryptolaemus montouzieri* (Coccinellidae: Coleoptera)

The adults and larvae of these insects eat scale insects, especially mealybugs. Females lay their eggs among the egg sack of mealybugs. Larvae feed on mealybug eggs, young crawlers and their honeydew. They become adults in 24 days, after three larval stages and a pupal stage. The life span lasts two months.



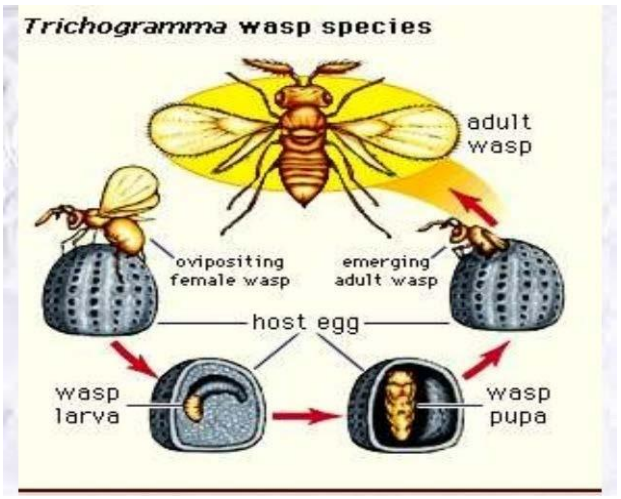

3. Green lace wing: *Chrysoperla carnea* (Chrysopidae: Neuroptera)

Larvae are important predators of insect pests viz., aphids, mealy bugs, eggs and smaller larvae of various insects of agricultural importance and mites. Each larva has potential to feed on average 12 aphids/day or about 120 aphids during the entire developmental period.




4. Egg parasitoid: *Trichogramma* sp. (Trichogrammatidae: Hymenoptera)

Trichogramma sp. are of common occurrence and distributed throughout the world. They parasitise eggs of Lepidopteran mainly but are also reported from Coleoptera, Neuroptera and Diptera. In India it is commercially available for the pest suppression of sugarcane, cotton, sorghum, maize and paddy borers.



5. Larval parasitoid: *Bracon hebetor* (Braconidae: Hymenoptera)

It is a well known external, gregarious larval parasitoid of several lepidopteran pests.

6. Pupal parasitoid: *Tetrastichus israeli* (Eulophidae: Hymenoptera)

The pupal parasitoid was observed to parasitise the pupae of *Opisina arenosella* and an average 90 adult parasitoids emerged from a single pupa under natural conditions. It can be mass reared on fresh pupae of *S. litura*, *H. armigera*, *Plusia sp*., or *Ergolis* sp.

Video Link:

https://www.youtube.com/watch?v=SNnPahBxCPk

https://www.youtube.com/watch?v=8eJFA_XpX1Q

https://www.youtube.com/watch?v=053rfBMtaaI

Date:

EXPERIMENT 13: Mass Multiplication of *Trichogramma* and Nuclear Polyhedrosis Virus (NPV)

(A) Mass Multiplication of *Trichogramma*

The genus *Trichogramma* is cosmopolitan in distribution and present in all terrestrial habitats and is one of 80 genera in the family Trichogrammatidae. *Trichogramma* primarily parasitize eggs of Lepidoptera, but parasitism also occurs in eggs of other orders such as Coleoptera, Diptera, Hemiptera, Hymenoptera and Neuroptera. In India it is commercially available for the pest suppression of sugarcane, cotton, sorghum, maize and paddy borers.

(a) Biology

Fecundity: 20-200 eggs

Egg period: 1-2 days

Larval period: 3-4 days

Pupal period: 4-5 days

Adult longevity

Male: 5-7 days

Female: 5-20 days

(b) Materials required

Corcyra cephalonica eggs, Nucleus culture of *Trichogramma*, Polythene bags, Rubber bands, Scissors, Gum, Tea strainer, Brush, Mesh sieve (40 mesh size), Tricho cards, 50% honey solution, Stapler, Refrigerator/fridge, B.O.D. incubators and UV lamp/LED light.

c) Rearing

In India, *Trichogramma* sp. are reared on the eggs of rice meal moth. Freshly collected eggs of Corcyra are cleaned of the scales, mites and other foreign matter associated with these and are glued on the Trichocard with uniformly thin layer using 2 per cent gum Arabic in distilled water (W/V). The sprinkling of the eggs is done either with camel hair brush or a fine sieve which does not allow more than one or two eggs to pass through its hole at a time. Thus 18000-72000 (1 ml) frozen host eggs are glued on a trichocard (15 x 7.5 cm). If the eggs were not frozen the trichocard should be exposed to UV lamp for about 10 minutes. The card is further divided through punching into 6 strips each of 7.5 x 2.5 cm size which can be easily pressed and separated. A strip containing glued eggs on it was inserted into a glass tube (10 x 2.5 cm) having newly emerged adults. The adult parasitoids are provided with honey streaks (50% honey dissolved in water) drawn on inner side of the tube and secured tightly with muslin cloth and rubber bands. The card is changed after 24 hours

and replaced with fresh card. Thus, continuity of changeover is maintained for 3 to 4 days or till female survive and remain productive. The host eggs oviposited by female turns black after 3 days of parasitization. The parasitoid completes its life cycle in 7-9 days at 27 ± 2°C and 75 ± 5% RH.

Precautions

1) If host eggs are not frozen/treated with UV rays to kill the embryo, the moth's larvae may hatch out from the unparasitized eggs. These larvae should be brushed out gently since they eat away the unparasitized eggs.

2) Avoid super parasitism either by exposing host eggs upto 8 hours or providing 6 eggs for one parasitoid.

3) Maintain pure species of different species of Trichogrammatids through proper handling and regular examination.

4) Do not offer frozen eggs to *T. japonicum* as it does not develop well on such eggs.

5) Do not rear *T. brasiliensis* at the temperature exceeding 26°C where undesired male formation is more.

6) Do not cold store parasitized eggs at 5-10°C for more than 15-20 days as beyond this storage biological attributes of the parasitoids are affected.

7) Use healthy eggs of host for healthy parasitoid.

8) Do not put excess gum while sprinkling the host eggs.

9) Do not rely on super parasitized parasitoids as they are normally weak and unfit for the production of healthy progeny.

(B) Mass Multiplication of Nuclear Polyhedrosis Virus (NPV)

Among viruses of the group baculoviridae, nuclear polyhedrosis viruses are utilized for the successful suppression of various insect pests of many agricultural and horticultural crops. Nuclear polyhedrosis viruses of *Helicoverpa armigera* and *Spdoptera litura* are highly specific to their respective live hosts for multiplication. So, production of viruses for use as insecticides needs mass production of their hosts as a first step. Basic steps in the production of nuclear polyhedrosis viruses of any insect are-

1. Mass culturing and maintenance of host insects
2. Host inoculation with viruses
3. Harvesting of viruses
4. Purification
5. Storage

❖ **Host used for NPV rearing**


1. Tobacco caterpillar (*Spodoptera litura*)- *Sl*NPV


2. American boll worm (*Helicoverpa armigera*)- *Ha*NPV

❖ **Mass culturing of *Spodoptera litura* larva**

Materials required

Aluminium tray (50 x 50 x 4 cm), Working table, Plastic tub (38 cm diameter x 21 cm height), Beaker 250 ml, Measuring cylinder, Scissors, Forceps, Water pans, Honey, Vitamin E, Castor leaves, Black cloth, Cotton wool, Nerium leaves, Black chart paper, Cello tape, Rubber band.

Steps in *Spodoptera litura production*

- Collect the adult moths from light traps. Allow 5 pairs inside a plastic container close with muslin cloth. Provide sugar 10% solution in a cotton swab as adult feed. Provide a castor leaf as an egg laying substrate.

- Collect the egg masses from the fields every day and place it over another leaf in a plastic bucket. For 3 days larvae will feed by scraping the leaves.
- Insert 4-5 fresh castor leaves along with cotton wool in 150 ml conical flask having water and then place an egg mass on leaves and keep the conical flask inside the plastic jar (16 cm diameter x 20 cm height) covering its mouth with black cloth.
- Allow 300 first instar larvae in a conical flask containing castor leaves. If it is second instar, allow 200 larvae and if third instar 100 larvae are allowed.
- Place a newspaper in the bottom of the plastic tub (38 cm diameter x 21 cm height), keep 10-15 castor leaves with wet cotton, allow 50 fourth instar larvae and cover with black cloth. Do this till pre – pupal stage.
- Spread the heat sterilized sand (at 100°C temperature for 30 minutes in hot air-oven in a plastic jar upto 2.5 cm height.
- Allow 25 pre –pupae for pupation. For pupation provide sand inside the bucket, when the larvae were 12-15 days old. Within 3-5 days adult will emerge.
- Dissolve 100 ml honey in 300 ml distilled water and add 400 mg vitamin E capsule and provide diet for adult.
- Insert Nerium leaves along with cotton wool in conical flask having water and keep it in a plastic jar, allow 10 pairs of adults and cover with black cloth, provide diet through cotton swabs.
- Cut Nerium leaves containing the egg masses, keep on fresh castor leaves inserted in a conical flask for another cycle.

❖ **Mass culturing of *SlNPV***

Materials required

Plastic tub, Conical flask, Nucleus of *Sl*NPV solution, Distilled water, Disinfectant, Brush, Black cloth, Blender, Centrifuge, Beaker, Funnel, Sieves, Filter paper, Castor leaves, Wash bottle, Cotton wool, Compound microscope, Haemocytomter, Staining chemicals (Eosine), Sticker.

Procedures

- Collect 3rd instar larvae. Starve larvae for 4 to 5 hours before feeding.
- Prepare 1x10^{8} POB/ml NPV suspension or dilute solution in plastic tub and add sticking agent. Pluck castor leaves with the petiole & dip in the virus solution. Dry the leaves in shade.
- Keep the newspaper at the bottom of bucket & provide the treated leaf for feeding & cover mouth of bucket with cloth.
- Repeat twice after 24 hours, 4 days after inoculation, disease symptoms start to appear and larvae will die within a week.
- Take 250 ml conical flask, add 150 ml distilled water, 100 diseased larvae in it and tighten the mouth with cotton and keep the flask for 15 days for purification.
- Blend the solution for homogenization and filter through muslin cloth. Centrifuge the filtrate for 5 minutes at 500 rpm.
- Collect the supernatant and again centrifuge at 4000 rpm for 30 minutes.
- Collect sediment with distilled water and keep in glass bottle. Store in refrigerator until use.
- Field Use: Dosage: 450 LE/ha two to three times at 10-15 days interval. Use 0.05% Teepol as the sticking agent.

❖ **Mass culturing of *Helicoverpa armigera* larva**

Materials required

Plastic jars, Plastic tubs, Pencillin vials with cotton plugs, Bhendi vegetables, Black cloth, Khada cloth, Saw dust, 0.025 % Sodium hypochlorite, Chickpea/groundnut seedlings, Bleaching powder, Coffee powder, Multivitamin syrup, 10 % sucrose, Beaker 500 ml, Measuring cylinder, Egg laying chamber.

Steps in *Helicoverpa armigera production*

- Release 10 males and 5 females at 2:1 ratio in plastic containers and cover with thin black cloth. Female require multiple mating to lay fertile eggs.

- To induce the moths to lay more eggs multivitamin syrup 2 drops + 10 % sucrose is given through cotton swabs.
- Daily collect the egg cloth after 3rd day of copulation. Provide 25-28°C, 80-90% R.H during egg laying. A female lays 300–700 eggs.
- Sterilize the egg cloth in 0.025% sodium hypochlorite for ten seconds and immediately dip the egg cloth in distilled water in 3 different buckets having distilled water one by one and then dry it in shade.
- Raise chickpea or groundnut seedlings in a week interval and provide for feeding.
- Place newly hatched larvae on chickpea/groundnut seedlings along with egg cloth for one day or place 3-4 eggs in vials containing artificial diet.
- Pick young larvae and rear on bhendi vegetable individually in penicillin vials to avoid cannibalism.
- Daily change diet till pre pupal stage.
- Collect pre –pupae and allow for pupation in plastic container having saw dust.
- Pupae sterilization is done with the help of coffee filter by dip method.
- Transfer the pupae inside the egg lying chamber by keeping them on a separate petri dish without lid.

Larvae in plastic containers

Mating of *Helicoverpa armigera* moth in glass chamber **Pupation box**

- **Mass culturing of *Ha*NPV**

  Materials required

  Blender, Nucleus *Ha*-NPV solution, Distilled water, Centrifuge, Beaker, Measuring cylinder, Bengal gram/Bhendi, Haemocytometer, Sticker.

  Procedures

  - Collect 3rd instar or early 4th instar larvae. Starve larvae for 3 to 5 hours before feeding.
  - Prepare bhendi vegetable for larval feed. Introduce piece of the virus contaminated diet in each container with pre-starved larvae.
  - Pour 2-3 drops of *Ha*-NPV suspension in the penicillin vial and feed to the larvae. Replace uneaten part of diet after 2-3 days & clean the containers.
  - Repeat the inoculation process twice after 24 hours. Within 4 days disease symptoms appear and larvae die within a week.
  - Take the diseased larvae in distilled water. Keep the flask for 15 days for putrefaction. Filter the solution through muslin cloth.
  - Centrifuge the filtrate for 5 minutes at 500 rpm. Collect the supernatant and again centrifuge at 4000 rpm for 30 minutes.
  - Collect the sediment with distilled water and keep it in glass container. Store the pure *Ha*-NPV in refrigerator until use.
  - Field Use: Dosage: 450 LE/ha two to three times at 10-15 days interval. Use 0.05% Teepol as the sticking agent.

Video Link:

https://www.youtube.com/watch?v=_53jRrrUBvc

https://www.youtube.com/watch?v=M4eflDcndRI

https://www.youtube.com/watch?v=NHXnsct6Mus

https://www.youtube.com/watch?v=T51rRaIvO9A

https://www.youtube.com/watch?v=jarc4RAHSiM

https://www.youtube.com/watch?v=rowB2K-C-0c

https://www.youtube.com/watch?v=-zA3yCfWjNc

Date:

EXPERIMENT 14: Identification and Nature of Damage of Important Insect Pests and Their Management

I. Insect Pests of Rice (*Oryza sativa*)

1. Rice stem borer, *Scirpophaga incertulas* (Pyralidae: Lepidoptera)

Identification: Moth: Female yellowish brown, male pale yellow with pointed head. A prominent black spot present on each of the fore wings of the female, absent in male. Tuft of anal hairs present in female. **Caterpillar:** Yellowish white with a dark brown head and prothoracic shield.

Nature of damage: Larva feeds inside the stem causing drying of the central shoot called 'dead heart' in young plant or drying of the panicle called 'white ear' in older plants. October-December has been found conducive for the multiplication of the insect.

Management:

(i) Removal and destruction of rice stubbles from field and also collection and destruction of egg masses.

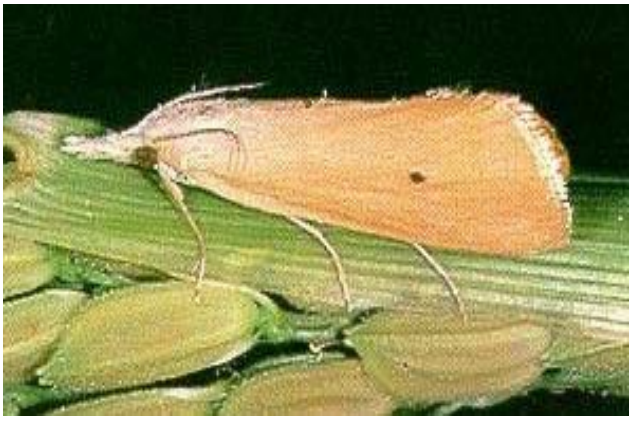
(ii)) Clipping the tip of the seedlings prior to transplantation to eliminate egg masses.

(iii) Collection and destruction of moths using light traps.

(iv) Spraying of etofenprox or cartap hydrochloride or chlorpyriphos or phenthoate at 0.5 kg a.i./ha or fipronil 5% SC at 1 litre/ha if the economic threshold level of 10% dead heart is crossed in the nursery a week prior to pulling out the seedlings and the second after 15 days of transplantation.

(v) An economic threshold level of 10% dead heart in vegetative stage and presence of 1 moth or 1 egg mass/sq.m. in the ear-head bearing stage has been suggested for adoption of chemical method of control by giving a third spray with one of the above chemical pesticides.

(vi) Seedlings root dip treatment for 12 or 14 hours before transplanting in 0.02% chlorpyriphos gives protection upto 30 days against stem borer.



2. Rice gall midge, *Orseolia oryzae* (Cecidomyiidae: Diptera)

Identification: Adult: A dipteran fly with long slender legs. Female is bright red while male is darker in colour. **Caterpillar:** Pale red, apodous, tapering anteriorly.

Nature of damage: The gall formed by this fly is popularly known as 'silver shoot' or 'onion shoot' because of the formation of hollow pink or purple, dirty white or pale green cylindrical tubes bearing at their tips a green reduced leaf blade complete with ligules and auricles. It infests the rice even in the nursery but usually tillers are preferred. The loss in yield in a heavily infested crop may be up to 50%.

Management:

(i) Seed treatment with chlorpyriphos 0.2% emulsion for 3 hours or seed mixing with either chlorpyriphos (0.75 kg a.i./100 kg seeds) or imidacloprid (0.5 kg a.i./100 kg seeds) provide protection for 30 days in the nursery.

(ii) Seedling root dip in 0.02% chlorpyriphos emulsion before transplanting for 12 -14 hours gives protection for 30 days.

(iii) Removal and destruction of weeds that serve as alternate host plants.

3. Green leaf hoppers, *Nephotettix nigropictus* and *N. virescens* (Cicadellidae: Hemiptera)

Identification: The female of *N. nigropictus* is green and the male has two black spots extending upto the black distal portion on the fore wings. It has a black tinge along the anterior margin of pronotum and a submarginal black band on the crown of the head. In *N. virescens* black submarginal band on the crown is absent and the black spots on forewings do not extend upto the black distal portion.

Nature of damage: Both nymphs and adults suck the plant sap and cause browning of leaves. Both the species are known to be vectors of virus diseases of rice such as rice transitory yellowing and rice yellow dwarf.

Management:

(i) Spray of imidacloprid 70% WG @ 30-35 ml/ha or imidacloprid 30.5% m/m SC @ 60-75 ml/ha or ethofenoprox 10% EC @ 500-750 ml/ha or acephate 75% SP @ 666-1000 g/ha or buprofezin 25% SC @ 800 ml/ha.

4. Brown plant hopper *Nilaparvata lugens* (Delphacidae: Hemiptera)

Identification: Two forms *viz*., macropterous (long-winged) and brachypterous (short-winged) are noticed and they are ochraceous brown dorsally and brown ventrally. Nymphs are pale white with brownish tinge.

Nature of damage: It infests the rice crop at all stages of plant growth. Due to feeding by both nymphs and adults at the base of the tillers, plants turn yellow and dry up rapidly. At early infestation, round yellow patches appear which soon turn brownish due to the drying up of the plants and this condition is called 'hopper burn'. *N. lugens* is a phloem feeder. Very high infestation causes lodging of the crop resulting in yield loss ranging from 10 - 70%.

Management:

(i) High dosages of nitrogenous fertilizers, close spacing, and high relative humidity increases planthopper populations.

(ii) Sensible use of fertilizer by splitting nitrogen applications can also reduce chances of plant hopper outbreaks.

(iii) Draining rice fields can be effective in reducing initial infestation levels. The field should be drained for 3 - 4 days when heavy infestations occur.

(iv) Growing no more than two crops per year and using early-maturing varieties reduces planthopper abundance and damage.

(v) Synchronous planting (planting neighboring fields within 3 weeks) and maintaining a rice-free period may be effective.

(vi) Spray of imidacloprid 70% WG @ 30-35 ml/ha or imidacloprid 30.5% m/m SC @ 60-75 ml/ha or ethofenoprox 10% EC @ 500-750 ml/ha or acephate 75% SP @ 300-500 g/ha or buprofezin 25% SC @ 800 ml/ha.

II. Pest of Sorghum, Maize and Millets

1. Sorghum shoot fly, *Atherigona soccata* (Muscidae: Diptera)

Identification: Adult: Dark grey in colour and looks like a small housefly. Abdominal segments of male and female bear 6 and 4 dark spots respectively, arranged in two rows. **Maggot:** Pale yellow, apodous and tapering at one end.

Nature of damage: The maggots bore into the shoot of young plants, a week after germination to about one month and as a result the central shoot dries up resulting in 'dead heart'. If it is a little later the mother plant may produce side tillers. But the tillers also may be attacked. The infestation often goes as high as 60%.

Alternate hosts: The fly infests wheat, maize, small millets and grasses, besides sorghum.

Management:

(i) A higher seed rate @ 12 kg/ha is adopted and the affected seedlings are pulled out and destroyed.

(ii) Application of 10% phorate (Thimet) or carbofuran 3% granules at the time of sowing at the rate of 2.5 kg a.i./ha.

(iii) Spraying of cypermethrin @ 0.005% or cartap hydrochloride 0.5 kg a.i. /ha or triazophos @ 0.5 kg a.i. /ha twice a week after sowing or during second week.

2. Sorghum stem borer, *Chilo partellus* (Crambidae: Lepidoptera)

Identification: Adult: Straw coloured with pale yellow grey forewings with black specks along caudal margin. In males, hind wings are pale straw coloured and in females, hyaline. Caterpillar: Dirty white with brown head having many dark spots on the body.

Nature of damage: Presence of 'dead heart' in the early stages is the main symptom. The bore holes may be visible in contrast to the dead-heart caused by the stem fly. Later it acts as an internode borer and is found till the time of harvest. Yield is affected much and the quality of the fodder is also reduced. The damage caused to the crop by this pest is estimated to range between 70 – 80 %.

Management:

(i) Collection and destruction of the stubbles which are left in the field or heaped in one corner of the field since they act as a source of infestation, as the larvae hibernate in them.

(ii) Spraying of carbaryl 0.1% thrice at an interval of 15 days from a month after sowing.

(iii) Two whorl applications of 10% carbaryl or 4% cartap hydrochloride granules, first at 5 kg /ha at 25 – 30 days after crop emergence and second at 10 kg/ha 10 - 15 days later. If infestation is severe, three applications at 5.0, 7.5 and 10.0 kg/ha are recommended.

3. Sorghum midge, *Contarinia sorghicola* (Cecidomyiidae: Diptera)

Identification: Adult: Slender and abdomen bright red. Wings when folded extend just beyond the tip of the abdomen. Maggot: Newly hatched maggot creamy white, later turn to orange red.

Nature of damage: The maggots feed on the developing grains and cause the developing grains to shrivel and severe infestation has a significant effect on the overall production of grains. The loss varies from 20 - 50 %.

Management:

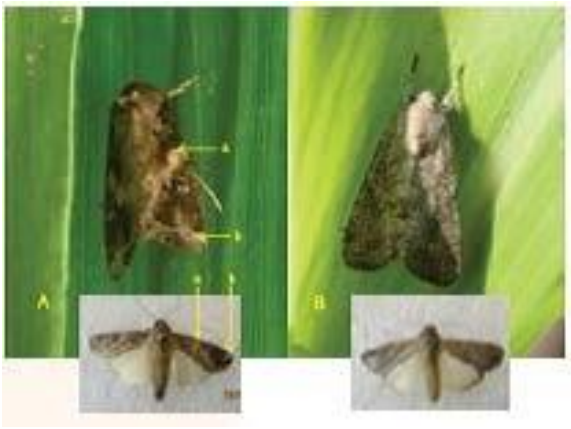
(i) Spraying of Malathion 50 EC 1 litre, or carbaryl 50WP 2 kg per hectare at nearly 90% ear-head emergence and repeated after 4 or 5 days.

(ii) Malathion 5% or carbaryl 10% or quinalphos 1.5% dust at 12 kg/ha is also effective.

4. Fall Army Worm, *Spodoptera frugiperda* (Noctuidae: Lepidoptera)

Identification: Adult moth is a strong flier, can fly over 100 km in search of host plants. Pheromone traps specific to FAW will attract male moths. Male moth has two characteristic markings, viz., a fawn coloured spot towards the centre and a white patch at the apical margin of forewing. Forewing of female is dull with faint markings. Larvae appear in shades

of green, olive, tan and grey with four black spots in each abdominal segment and has three creamy yellow lines running down its back. It is easily identified from any other armyworm species by its tail end, where the black spots are bigger and arranged in square pattern on abdominal segment 8 and trapezoid on segment 9. The head has a predominant white, inverted Y-shaped suture between eyes.



Nature of Damage: Young larvae initially consume leaf tissue from one side, leaving the opposite epidermal layer intact. By the second or third instar, larvae begin to make holes in leaves, and eat from the edge of the leaves inward. Feeding in the whorl of corn often produces a characteristic row of perforations in the leaves (shot holes). Older larvae cause extensive defoliation, often leaving only the ribs and stalks of maize plants, or a ragged, torn appearance. Larvae also will burrow into the growing point (bud, whorl, etc.), destroying the growth potential of plants, or clipping the leaves. In maize, they sometimes burrow into the ear, feeding on kernels. The FAW feeds by burrowing through the husk on the side of the ear.

Management:

(i) Selection of Single cross maize hybrids. Choose cultivars with tight husk cover, especially for sweet com.

(ii) Deep ploughing before every crop season to open up the soil to expose FAW pupae to sunlight and predators. If zero-tillage is practiced, spread neem cake @ 500kg/ha. Maintain fields weed free and follow balanced fertilizer application.

(iii) Plan for maximizing plant diversity by inter cropping of maize with suitable pulse crops of particular region. Eg: Maize + pigeon pea/black gram /green gram. Plant Napier grass in the border rows to act as FAW trap crop.

(iv) Plan the sowing time at community level to follow synchronous planting.

(v) Seeds treated with Cyantraniliprole 19.8% + Thiomethoxam 19.8% @ 4 ml per kg seed reported to offer protection up to 2-3 weeks after germination (Note that this

formulation is not registered in India and also has not been evaluated in AICRP programme).

(vi) If staggered sowing is unavoidable as in peri-urban baby corn and sweet corn cultivation, spray the crop with 5% NSKE or azadirachtin 1500 ppm @ 5ml/l at weekly interval or Release *Trichogramma pretiosum* or *Telenomus remus* @ 50,000 per acre at weekly intervals, starting within a week of germination till harvest.

(vii) Install FAW pheromone traps @ 5/acre on or before germination of the crop to monitor pest arrival and population build-up. Use 15 traps/ac for mass trapping of male moths to keep population build-up under control.

(viii) Erect bird perches @ 10/acre as soon as sowing is completed.

(ix) Follow weekly scouting and adopt symptom based control measures on action thresholds.

(x) While scouting, hand pick and destroy egg masses and neonate larvae by crushing or immersing in kerosene water.

III. Pests of Sugarcane (*Saccharum officinarum*)

1. Early shoot borer, *Chilo infuscatellus* (Crambidae: Lepidoptera)

Identification: Adult: Small grayish brown/ straw coloured with labial palpi projected forwards. A row of white dots presents along the outer margin of fore wings. Caterpillar: White with five violet stripes dorsally and dorso-ventrally on its body and with a dark brown head.

Nature of damage: The borer enters into young shoots and tunnels downwards. The upper portion of the central leaf whorl is thus cut off and dries up causing dead hearts in shoots from about a month old to 2 - 3 months crop. If the attack is in early stages the mother shoot dies completely and late attack induces profuse tillering.

Management:

(i) Light earthing up of the tillers at the early stages of the crop (month old) during May and June reduces the incidence. A second earthing a month later reduces the borer attack considerably.

(ii) Mulching with cane trash at the early stages also has been reported to reduce the incidence and help in conserving moisture.

(iii) Cutting the affected tillers as close to the ground as possible and destroying them.

(iv) Soil application of granules of cartap hydrochloride at 1 kg a.i./ha at planting followed by another application on 45th day for late planted crop.

(v) Cartap hydrochloride 4G, sevidol 8G and chlorpyriphos 10G at 1 kg a.i./ha as whorl application at 35th and 65th day are also found effective.

(vi) Inundative releases of the egg parasitoid *Trichogramma chilonis* @ 50,000/ha from first month of planting at 7 - 10 days interval till one month prior to harvest.

(vii) At 30th, 45th and 60th day of crop growth spray granulosis virus of *Chilo infuscatellus* (10-7 – 10-8 inclusion bodies/ml) at 500 l/ha.

(viii) Release of 125 gravid females of *Sturmiopsis inferens* (Tachinidae) per ha at 45th day of crop growth.

2. Internode borer, *Chilo sacchariphagus indicus* (Crambidae: Lepidoptera)

Identification: Adult: Small and straw coloured, forewings have a marginal dark line and hind wings are uniformly white. Caterpillar: White with brown head and dark spots on body.

Nature of damage: It infests the crop after the third month when internodes begin to form and continues till the time of harvest. Symptoms will be visible only on close examination. The affected node will be thinner than the other nodes. Mostly the attack is found on the first five internodes. It feeds on the internal tissue making it turn red. The bore hole is plugged with excreta. Due to the attack the quality of juice is reduced and in severe cases cane formation is affected resulting in loss of weight.

Management strategies:

(i) Inundative release of the egg parasitoid *Trichogramma chilonis* @ 50,000 parasitoid/ha/week from the 4^{th} up to 11^{th} month after planting affords protection.

(ii) Use of resistant varieties are CO 285, 453, 513, 617, 853, 915, 1007, 1287, 6806 and COJ 46.

3. Top borer, *Scirpophaga excerptalis* (Pyralidae: Lepidoptera)

Identification: Adult: Creamy white, slightly bigger than early shoot borer. A tuft of crimson (deep red) coloured hairs present at the tip of abdomen of female and a black spot on forewings of male. Caterpillar: Pale white in colour.

Nature of damage: Tunneling of midrib in a leaf, small holes in a parallel line in the freshly appeared leaves, dead heart which is reddish brown in the young crop (2 - 4 months old) and a bunchy top in a grown up crop are the characteristic symptoms. Sprouting of the eye buds affects the quality of the juice. Since the growth is restricted, the yield is also affected. It accounts for 20 - 30 % reduction in yield resulting in low juice quality and early maturity of the crop. The sucrose per cent in juice decreases by 2 units.

Management strategies:

(i) The egg masses and also the infested portions of plants may be collected and destroyed during the brood emergence period.

(ii) Release of the ichneumonid parasitoid, *Gambroides javensis* has been found to be promising.

(iii) Variety Co 419 is comparatively resistant to this borer. Other resistant varieties are CoS 767, CoJ 67 and Co 1158.

(iv) Soil application of carbofuran at 2 kg a.i. /ha or phorate at 1 kg a.i./ha for the third brood during first week of July is recommended.

4. Sugarcane Leaf hopper, *Pyrilla perpusilla* (Lophopidae: Hemiptera)

Identification: Pale greenish yellow eggs in clusters. Eggs are laid on the underside of leaves, covered over with a white filamentous waxy material secreted by the female. Newly hatched nymphs are milky white in color. They possess a characteristic feather like processes covered by wax. Adults are straw coloured with wings folded like a roof on the back. Head is prominently drawn forward as a sort of rostrum.

Nature of damage: Both the adults and nymphs are very active, jumping from leaf to leaf on slight disturbance. They suck the cell sap from the leaves and secrete honey dew which attracts the black fungus. Due to this feeding the leaves turn yellow and finally look withered and burnt with black encrustation.

Management strategies:

(i) Release of the lepidopteran ectoparasitoid, *Epiricania melanoleuca* @ 4000-5000 cocoons or @ 4 - 6 lakh eggs/ha checks its multiplication.

(ii) In case of severe infestation without the occurrence of the ectoparasitoid, spraying of imidacloprid 17.8 SL is quite effective.

5. Termite, *Odontotermes obesus* (Termitidae: Isoptera)

Identification: Adults are cream coloured tiny insects resembling ants with dark coloured head.

Nature of damage: A major problem in light soils. poor germination of setts (after planting), characteristic semi-circular feeding marks on the margin of the leaves in the standing crop. Entire shoot dries up and can be pulled out. Setts hollow inside and may be filled with soil. Cane collapses if disturbed; rind filled with mud.

Management:

(i) Locate and destroy the termite colony.

(ii) Destroy the affected setts from the field.

(iii) Treat setts with Imidacloprid 70 WS 100-150 g per 100 setts.

(iv) Spray chlorantraniprole 18.5 SC 500-625 ml or imidacloprid 17.8 SL 350 ml with 500 L water/ha.

IV. Pests of Oilseeds

1. Red hairy caterpillar, *Amsacta albistriga* (Arctiidae: Lepidoptera)

Identification: Adults are medium sized moths. In *A. albistriga* forewings are white with brownish streaks all over and yellowish streaks along the anterior margin and hind wings white with black markings. A yellow band is found on the head.

Nature of Damage: The larvae feed on the leaves gregariously by scraping the under surface of tender leaflets leaving the upper epidermal layer intact in early stages. Later they feed voraciously on the leaves and main stem of plants. They march from field to field gregariously. Severely affected field looks as though they are grazed by cattle. Sometimes it results in the total loss of pods. They also feed on sorghum, cotton, finger millet, castor, pulses and cowpea, etc.

Management:

(i) Organize campaign to collect and destroy the pupae after summer ploughing on receipt of showers.

(ii) Grow cowpea or red gram as an intercrop to attract adult moths to lay more eggs.

(iii) Set up 3-4 light traps and bonfires immediately at the onset of rains at 4 weeks after sowing in the rainfed season to attract and kill the moths and to know brood emergence.

(iv) Collect and destroy egg masses in the groundnut, cowpea and redgram.

(v) Collect and destroy gregarious early instar larvae on lace like leaves of inter crops viz., red gram and cowpea.

(vi) Organize campaign by involving school children (or) general public to collect and destroy the migrating grown up caterpillars from the field.

(vii) Dig out a trench around the field to avoid the migration of caterpillars, trap larvae and kill them.

(viii) Use nuclear polyhedrosis virus @ 250 LE/ha.

(ix) For young caterpillars - apply carbaryl 10 D 25 kg/ha.

(x) Organize mass ground spraying in endemic areas if necessary, in the case of outbreak of the pest.

(xi) For grown up caterpillars - spray dichlorvos 625 ml/ha or chlorpyriphos 1250 ml/ha in 375 litres of water.

2. Leaf miner, *Aproaerema modicella* (Gelechiidae: Lepidoptera)

Identification: Adult is dark brown with a white spot on the coastal margin of each forewing. The small hind wings are covered by fringe of minute hair. Caterpillars are cylindrical, tapering posteriorly, brownish/light green in colour with dark head and prothorax.

Nature of Damage: It prefers rainfed crop and bunch varieties. Young newly hatched green caterpillar mines into the leaflets and feed on green tissues resulting in brownish dried up patches. Later instars caterpillars fold the leaves together and feed on the green tissues by remaining inside. Severely infested crop presents a burnt up appearance. Caterpillars or pupae can be seen inside the mines and folded leaflets. It also attacks red gram and soybean.

Management

(i) Grow resistant cultivars like ICGV 86031, ICGS 156 (M 13), FDRS 10, ICG 57, 156, 541, 7016, 7404, 9883.

(ii) Sow groundnut early and synchronously in rainy and rabi season. Intercrop groundnut with pearl millet @ 4:1 ratio.

(iii) Set up light traps between 8 and 11 PM at ground level.

(iv) Apply carbaryl 10 D at 25 kg/ha when the pest crosses ETL.

(v) Spray any one of the following insecticides - dichlorovos 76 SC 625 ml/ha, quinolphos 25 EC 750 ml/ha, lambda cyhalothrin 5 EC 200-300 ml in 375 L of water.

3. Mustard aphid, *Lipaphis erysimi* (Aphididae: Hemiptera)

Identification: They are louse like, pale-greenish insects abundant from December to March.

Nature of Damage: Both the nymphs and adults suck cell-sap from leaves, stems, inflorescence or the developing pods. Vitality of plants is greatly reduced. The leaves acquire a curly appearance, the flowers fail to form pods and the developing pods do not produce healthy seeds. The yield of an infested crop is reduced to one-fourth or one-fifth.

Management:

(i) Early sowing of mustard before 15th October will help to escape the attack of the pest and economic damage.

(ii) Spray application of oxydemeton methyl 0.05% or imidacloprid 0.01% or acetamiprid @ 0.01%.

V. Pests of Pulses

1. Gram pod borer *Helicoverpa armigera* (Hb.) (Noctuidae: Lepidoptera)

Identification: The moth has a V-shaped speck on the light brownish fore wings and a dark border on the hind wings. The full grown larva measures 35 – 45 mm long and is greenish with dark gray lines laterally on the body. While feeding it thrusts its head inside the pod leaving the rest of its body outside.

Nature of Damage: The larvae feed on leaves and bore into pods. As the internal contents of pods are devoured the yield of pulses is considerably reduced.

Management:

(i) Setting up of pheromone traps @ 5 traps/ha before the initiation of flowering and collection and destruction of moths caught in the traps.

(ii) Spray application of phosalone 0.07 % or profenofos 0.05 % or cypermethrin 0.005% or the combination with *Bacillus thuringiensis* var. kurstaki three times at fortnightly interval commencing from flowering affords protection.

(iii) Dusting of carbaryl 10% dust @ 25 kg/ha once at initiation of flowering controls the pest on Bengal gram.

(iv) Spray application of *Ha*NPV at dusk @ 250 larval equivalent /ha.

2. Plume moth, *Exelastis atomosa* (Pterophoridae: Lepidoptera)

Identification: Adult: Slender, grey with long narrow wings. Fore wings divided into two parts while hind wings cut into three parts and are provided with fringe like hairs. Caterpillar: Greenish brown with short hairs on the body.

Nature of Damage: Caterpillar first scrapes the surface of pods, enters into the pod by cutting a small hole and feeds on seeds. Seed is completely eaten away by the caterpillars, unlike pod fly. It feeds on flower buds and causes severe shedding of buds, flowers and pods.

Management:

(i) Install bird perches @ 50/ha to pick the larvae.

(ii) Set up light trap to monitor, attract and kill the moths.

(iii) Set up pheromone traps @ 12 nos./ha.

(iv) Spray nuclear polyhedrosis virus (NPV) @ 500 LE/ha in 0.1% teepol.

(v) Spray Azadirachtin 0.03% @ 2.5-5.0 lit./ha or Emamectin benzoate 5 SG @ 220 g/ha or Indoxacarb 14.5 SC @ 333-400 ml/ha or Spinosad 45 SC @ 125-160 ml/ha.

3. Pod fly, *Melanagromyza obtusa* (Agromyzidae: Diptera)

Identification: Adult: A small metallic, black fly with strong legs and ovate abdomen. Wings clear veined and brownish yellow at the base. Maggot: Creamy white in colour.

Nature of Damage: Maggots cause damage by boring into the soft seeds and feed on grains. The damaged seeds are unfit for consumption as well as for germination. The extent of damage may be even upto 60-70% during severe infestation.

Management:

(i) Spray Carbaryl 50 WP 1.5 kg or lambda cyhalothrin 5 EC 400 -500 ml or Lufenuron 5.4 EC 2.5 L with 700 L water/ha.

VI. Pests of Brinjal

1. Shoot and fruit borer, *Leucinodes orbonalis* (Pyralidae: Lepidoptera)

Identification: Adult: White moth with pink brown markings on wings and blackish brown head and thorax. Caterpillar: Pinkish with sparingly disturbed hairs arising on warts all over the body.

Nature of Damage: Larva bores into tender shoots and causes withering of terminal shoots/ dead hearts- also bores petioles of leaves, flower buds and developing buds, causes withering of leaves, shedding of buds and make fruits unfit for consumption. Attacked fruits are with boreholes plugged with excreta. Fruits become out of shape also.

Management:

(i) Collect and destroy the damaged tender shoots, fallen fruits and fruits with bore holes to prevent population buildup.

(ii) Use light traps @ 1/ha to attract and kill the moths.

(iii) Release egg parasitoids *Trichogramma chilonis* @1.0 lakh/ha.

(iv) Spray Bt formulations of *B. thuringiensis* var. *kurstaki* such as Dipel @ 1.5 to 2 ml /L of water.

(v) Spray any one of the insecticide starting from one month after planting at 15 days interval. Carbaryl 50 WP @ 2 kg + wettable sulphur 50 WP @ 2 kg, Quinalphos 25 EC @ 1.5 L + Neem oil 1.0 L, NSKE 5%, Azadirachtin 1.0% @ 1.0-1.5 L or Fenpropathrin 30 EC @ 250-340 ml or Thiodicarb 75 WP @ 625-1000 g or Flubendiamide 20 WG @ 375 g with 500 – 750 L water/ha.

VII. Pests of Cruciferous Vegetables

1. Diamond back moth *Plutella xylostella* (Plutellidae: Lepidoptera)

Identification: Adults are small grayish brown with narrow forewings having pale white marking at anal region which form a diamond like patch, when folded. Larvae small greenish with short hairs on body which tapers towards both the ends.

Nature of Damage: First instar larvae mine epidermal surface of leaves producing typical white patches. Larvae, second instar onwards feed externally making holes on the leaves and soil them with excreta. Heavy infestations leave little more than the leaf veins.

Management:

(i) Mustard sown as trap crop twice i.e. 12 days preceding planting cabbage and again 40 days later controls DBM.

(ii) Spraying cypermethrin @ 30 g a.i. or fenvalerate @ 50 g a.i. or deltamethrin @ 10 g a.i. or cartap hydrochloride @ 175 g a.i./ha once at primordial initiation (22 days after planting) and repeated either thrice at 7 days interval or twice at 10 days interval.

(iii) Spray application of *Bacillus thuringiensis* var. kurstaki @ 1 kg/ha.

2. Leaf webber, *Crocidolomia binotalis* (Pyraustidae: Lepidoptera)

Identification: Adults are small with light brownish forewings. Larvae bears red head with brown longitudinal stripes and rows of tubercles on the body.

Nature of Damage: Young larva feeds gregariously on leaves, later webs together the leaves and feeds. Due to gregarious feeding, rotting of cabbage heads and cauliflower curds are common. Regular pest of minor status but occasionally turn to serious proportions.

Management:

(i) Spray phosalone 50 EC 1.0 L, fenvalerate 20 EC or cypermethrin 10 EC or deltamethrin 28 EC 250 ml, cartap hydrochloride 50 SP 500 ml, spinosad 45 SC 125 ml/ha or azadirachtin 0.03% 2.5-5.0 L/ha. Do not repeat the insecticides with similar mode of action.

3. Cabbage borer *Hellula undalis* (Pyraustidae: Lepidoptera)

Identification: Adult: Small pale brown with grey wavy lines and central elliptical marking on forewings. Caterpillar: Brownish with a black head and four longitudinal lines on the body.

Nature of Damage: Larva aborts head formation. Caterpillars first mine the leaves later feed on leaves, shoots sheltered within silken passage and finally bore into the stems. They prevent head initiation causing multiple shoots or heads.

Management:

(i) Same as leaf webber.

VIII. Pests of Mango

***1.* Mango hoppers, *Idioscopus niveosparus, I. clypealis, Amritodus atkinsoni* (Cicadellidae: Hemiptera)**

Identification: *A. atkinsoni*: largest light brown with two spots on scutellum. *I. clypealis*: smallest, light brown with spots on scutellum and a dark spot on vertex. *I. niveosparsus*:

medium sized, with three spots on scutellum and prominent white band across its light brown wings.

Nature of Damage: Both nymphs and adults suck the sap from tender shoots and inflorescence resulting in withering and shedding of flower buds and also wilting and drying of shoots and leaves. The flower stalks and leaves in infested trees become sticky due to the deposition of honey-dew secreted by the hoppers that encourages the growth of black sooty mould on foliage and other parts. The hoppers take shelter in cracks and crevices on the bark during non-flowering season.

Management:

(i) Avoid close planting, as the incidence very severe in overcrowded orchards. Orchards must be kept clean by ploughing and removal of weeds.

(ii) Pruning of dense canopy to facilitate aeration and sunlight.

(iii) Avoid excess use of nitrogenous fertilizers.

(iv) Spray dimethoate 30 EC or methyl demeton 25 EC or malathion 50 EC 1.5 -2.0 L in 1500 – 2000 L of water per ha or acephate 75 SP @ 1 g/L, phosalone 35 EC @1.5 ml/L, or new molecules like buprofezin 25 SC 1-2ml/L of water or imidacloprid 17.8 SL 2-4ml/tree or lambda cyhalothrin 5 EC 0.5-1.0ml/L of water at 10 -15 L of water per tree.

(v) Neem oil 5 ml/lit of water can be mixed with any insecticide for spray. Spray 3 per cent neem oil or neem seed kernel powder extract 5 per cent.

2. Stemborer, *Batocera rufomaculata* (Cerambycidae: Coleoptera)

Identification: Adult: Brownish grey with two pink spots and a pair of lateral spines on thorax. Grub: White, fleshy with dark brown head and strong jaws.



Nature of Damage: The grubs feed by tunneling the bark of branches and main stem. Shedding of leaves and drying of terminal shoots takes place in early stage of attack while damage to main stem causes tree death.

Management:

(i) Remove and destroy dead and severely affected branches of the tree.

(ii) Avoid injury at the base of trunk while pruning.

(iii) During off-season, apply absorbent cotton soaked in 10 ml monocrotophos 36 SL per tree by padding without unnecessarily injuring the trunk.

(iv) Use a needle or long wire to pull out the grubs from the bore holes. The bore holes may be filled with DDVP @ 5 ml or monocrotophos 36 WSC 10 to 20 ml or one celphos tablet (3 g aluminum phosphide) or apply carbofuran 3G 5 g per hole and plug with clay + copper oxychloride paste.

(v) Swab Coal tar + Kerosene @ 1:2 or Carbaryl 50 WP 20 g / L (basal portion of the trunk - 3 feet height) after scraping the loose bark to prevent oviposition by adult beetles.

3. Fruit fly, *Bactrocera dorsalis* (Tephritidae: Diptera)

Identification: The adult fly is brown or dark brown with hyaline wings and yellow legs.

Nature of Damage: The female flies lay eggs just below the fruit epidermis (1 - 4 mm deep). On hatching the maggots feed on pulp of those fruits. As a result, a brown patch appears around the place of oviposition and the infested fruits start rotting. These affected fruits drop down prematurely and the maggots come out from these fallen fruits to pupate in the soil. Semi ripe fruits are attacked usually by April-May. Sometimes it becomes serious.



Management:

(i) Row interspaces may be ploughed to expose and kill the soil borne puparia.

(ii) Infested and fallen fruits should be carefully disposed of.

(iii) Apply a bait-spray containing Spinosad 45 SC @ 5.2 ml/ L + 10 g protein hydrolysate + 500 g jaggery before ripening.

(iv) Male annihilation technique: Set up fly trap using methyl eugenol. Prepare methyl eugenol 1 ml/L of water + 1 ml of malathion solution. Take 10 ml of this mixture per trap and keep them at 25 different places in one ha between 6 and 8 am. Collect and destroy the adult flies.

IX. Pests of Banana

1. Rhizome weevil, *Cosmopolites sordidus* (Curculionidae: Coleoptera)

Identification: Adult: Medium, dark brown, ridged, drawn out mouthparts. Half inch-long elytra do not cover the abdomen completely. Caterpillar: Dwarf, stout with red head and powerful mandibles.

Nature of Damage: Grubs tunnel through pseudostem and rhizome making circular hole, which increase in size with the growth of grubs. Tunnels up to 2-3 inches in stem with 6-10 grubs/stem. Plants break down at tunneled portion. Less number of fruits and suckers. Circular holes with black rotten tissue of rhizome, plugged with excreta.

Egg

Grub

Adult

Damage symptom of Rhizome weevil on Banana

Management:

(i) Adopt strict field sanitation by removing infected plants and destroying them.

(ii) Deep ploughing before planting to expose the weevils to sun and predators.

(iii) Use of healthy planting material and removal of outer layer of rhizome and sundry for 3 - 4 days before planting after smearing with slurry of cow dung and ash.

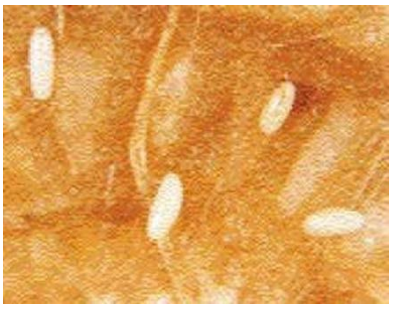
(iv) Setting traps in the field using length-wise split pseudostem of 50 cm length. Adults attracted to it during nights may be collected and destroyed.

(v) Drenching with chlorpyriphos 0.1% emulsion in the soil before planting may afford some relief.

2. Banana Pseudostem Weevil, *Odoiporus longicollis* (Curculionidae: Coleoptera)

Identification: The adult weevils are black-coloured and measures 23 - 39 mm. Red coloured morphs are also encountered. Grubs are fleshy, yellowish white and apodous.

Nature of Damage: Female make holes on pseudostem by making pin holes with the help of snout (1 egg in each pin hole). Grubs bore holes and tunnels in the pseudostem causing wilting of the plant. They also feed on tissues of leaf sheath from the inner surface and also on decaying tissues.




Egg **Grub** **Adult**



Damage symptoms of pseudostem weevil on banana plant

Management:

(i) Field sanitation by removing and destroying the affected plants alongwith rhizome and also the destruction of pseudostem and rhizome of harvested plants is the most important method.

(ii) Application of carbofuran 3g @ 30g/plant at planting and @ 15g/plant at 60th and 90th day after planting.

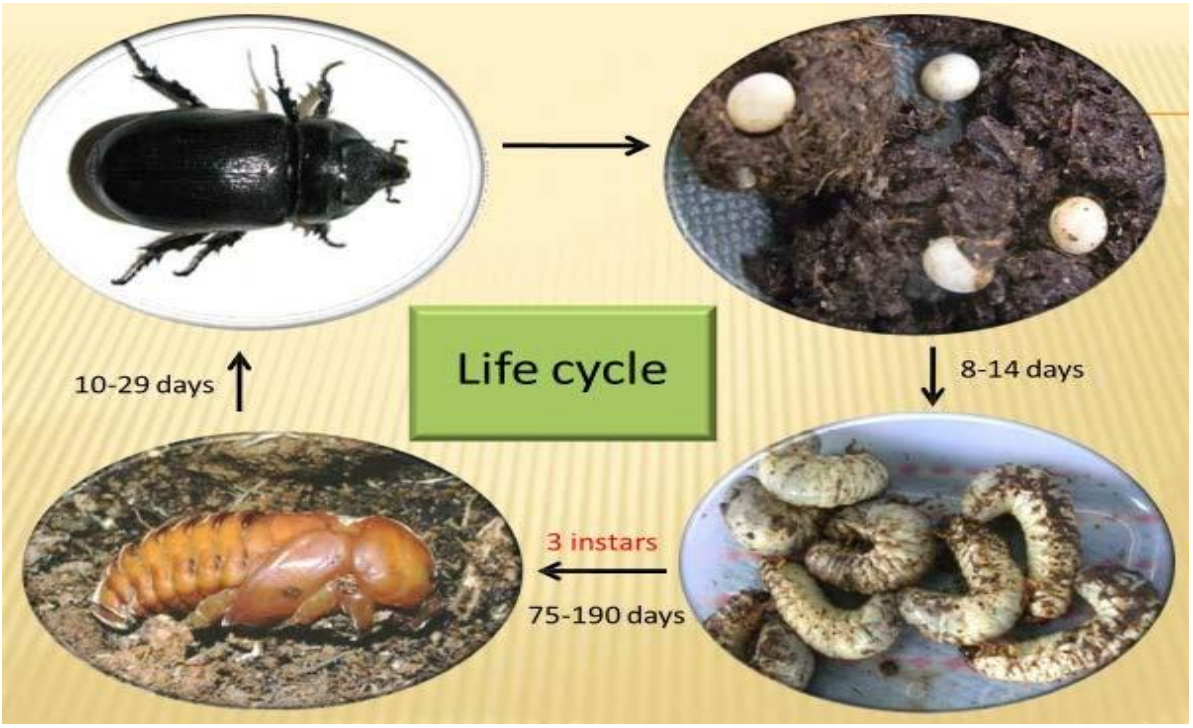
(iii) Inject pseudostem with monocrotophos 36 WSC (50 ml + 350 ml water) @ 2 ml at 45 cm height and another at 150 cm height from ground level at monthly intervals from 5th - 8th month. Beyond 8 months (after flowering), this should not be done.

X. Pests of Coconut

1. Rhinoceros beetle, *Oryctes rhinoceros* (Scarabaeidae: Coleoptera)

Identification: Adult beetles are stout, elongate, shiny and black above and reddish brown and hairy ventrally measuring 3.5 to 5 cm in length. On the face, beetle has a large tapering horn and hence the name, rhinoceros beetle. The cephalic horn is well developed and longer in males than in females. Full grown grub is 9-10 cm long, stout, fleshy, dirty white, curved (C- shaped) with pale brown head and found at a depth of 5 to 30 cm.

Nature of Damage: Adult beetles bore into the center of the crown, injure and chews the young, growing tissues, ingests the juice and throws out dry fibrous part. As they bore into the crown, they cut through the developing leaves. When the leaves grow out and unfold, the damage appears as characteristic V-shaped geometric cuts.



V-shaped geometric cuts

Holes with chewed fibre sticking out in central spindle

Management:

(i) Avoid manure pits in the vicinity of coconut gardens.

(ii) During peak period of population build up (July to September), the adult beetle may be extracted from the palm crown using GI hooks.

(iii) Rake and turn up the decaying manure to expose the developing grub, egg and pupae to sun drying and predation. Then apply the fungal culture of *Metarrhizium anisopliae* to manure pits during cooler months of October - December.

(iv) Dusting of breeding sites i.e. manure pits with carbaryl 50 WP @ 1 g/litre of water for four times a year during January, April, July and October.

(v) Place phorate 10 G @ 5 g in perforated sachets in two inner most leaf axils for two times at six months intervals.

(vi) Filling up the innermost three leaf axils of coconut palm with 12 g Naphthalene ball @ 3 balls/tree covered with fine sand at 45 days interval.

(vii) Apply the mixture of either neem seed powder + sand (1:2) @150 g per palm or neem seed kernel powder + sand (1:2) @150 g per palm in the base of the three inner most leaves in the crown.

2. Red palm weevil, *Rhynchophorus ferrugineus* (Curculionidae: Coleoptera)

Identification: Adult weevil: Reddish brown, bigger sized with curved snout, 3-4 cm in length. Grubs: Light yellowish fleshy and 5 cm long.

Nature of Damage: Holes on the trunk with brownish ooze; yellowing of inner leaves and gradual wilting of central shoot in the crown. Upto 50 Nos. of grubs can be found feeding on the soft tissues inside the trunk.

Egg

Grub

Pupa

Adult

Management:

(i) Set up attractant traps using mud pots with molasses/toddy 2.5 lit + acetic acid 5 ml + yeast 5 g + split tender coconut stems/petioles @ 30/acre.

(ii) Use aggregation pheromone traps @ 1/ha or use ferrolure in combination with food baits consisting of 1 kg sugarcane molasses + 5g of yeast + 5ml glacial acetic acid + split petioles of coconut taken in a bucket of 10 L capacity.

(iii) Insert 1-2 aluminium phosphide tablets inside the tunnel and plug all the holes with clay + copper oxychloride.

(iv) Plug all holes with cement and inject 20 ml of monocrotophos into the stem by drilling a hole above the points of attack.

(v) **Root feeding with insecticide:** Select a fresh and live root, cut sharply at an angle and insert the root in the insecticidal solution containing monocrotophos 36 WSC or triazophos 40 EC @ 10 ml + water 10 ml in a polythene bag in such a way that the cut end is dipped up to the bottom of the polythene bag. Secure the bag tightly to the root with a cotton thread. 24 hours later, check whether there is absorption. If there is no absorption select another root.

3. Coconut Black headed caterpillar, *Opisina arenosella* (Cryptophasidae: Lepidoptera)

Identification: Adult is medium sized, greyish moth measuring about 10-15 mm in length with wing expanse of 20-25 mm. The full grown caterpillars are slender, elongated, cylindrical, grayish brown in colour with blackish head. Caterpillars measure about 15 mm in length. The pupae are obtect, light brown to dark brown in colour and measure about 9 to 10 mm in length.



Larva **Pupa** **Adult**

Nature of Damage: Caterpillars feed on green matter from lower leaf surface causing dried leaflets with galleries of silk and frass and lives under it. In severe attack all the green matter of the leaves eaten up and may show burnt up appearance from a distance.

Management:

(i) Removal and destruction of infested leaflets by burning.

(ii) Inundative release of parasitoids like *Goniozus nephantidis* @ 3000/ha and *Bracon brevicornis* @ 4500/ha under the coconut trees when the pest is in the 2nd or 3rd instar larval stage.

(iii) Release of pupal parasitoids *Trichospilus pupivora* and *Spoggosia bezziana*.

(iv) Application of *Bacillus thuringiensis*.

(v) When infestation is very severe in young palms, spray the undersurface of the leaves thoroughly with Malathion 50 EC 0.05% (1 ml/lit).

(vi) Root feeding with monocrotophos 36 WSC or triazophos 40 EC @ 10 ml + 10 ml water with a waiting period of 45 days after root feeding.

3 to 4 youngest leaves remain green at the centre

Galleries of silk and frass on underside of leaves

Damage caused by Coconut Black Headed Caterpillar

Video Link:

https://www.youtube.com/watch?v=dUqIROwMEQk&t=1182s

https://www.youtube.com/watch?v=52dwhKhCZyo

https://www.youtube.com/watch?v=VKtSWu-2JBo

https://www.youtube.com/watch?v=RL9ZLpqXLfQ

Date:

EXPERIMENT 15: Crop (Agro-ecosystem) Dynamics of a Selected Insect Pest

Rice is the principle food crop in India. Rice crop is prone to stress throughout the crop growth period due to onslaught from different pests such as insects, nematodes, diseases, weeds and rats. Brown plant Hopper (*Nilaparvata lugens*) causes serious insect-pest problem during Kharif season. Brown plant Hopper is a pest of national significance. Agro-Eco System Analysis (AESA) is a process in which farmers observe the crop, analyze the field situation and take crop management decisions based on field observations. The health of a plant is determined by its environment which includes physical factors (i.e. sun, rain, wind and soil nutrients) and biological factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance which exists between herbivore insects and their natural enemies. Understanding the intricate interactions in an ecosystem can play a critical role in pest management. Focus in AESA based IPM is on pest-defender dynamics, abilities of plants to compensate for the damage caused by pests and the influence of abiotic factors on pest build up. The basic components of AESA are-

- Plant health at different stages
- Built-in-compensation abilities of the plants
- Pest and defender population dynamics
- Soil conditions
- Climatic factors
- Farmers past experience

- **Pest dynamics:** Brown Plant hopper is the major problem in rainfed and in irrigated wetland environments and also occurs in the areas with continuous cultivation, submerged conditions in the fields, high shade, use of chemical fertilizers /pesticides and humidity. Closed canopy of the rice plants, densely seeded crops excessive use of nitrogen and early season insecticides spraying also favours insect development.
- **Monitoring and surveillance:** Continual monitoring and accurate forecasting of pest population during the crop growing period could be useful in protecting rice crops against BPH. Accurate and timely forecasting of the pest incidence would support in planning effective mitigation. BPH infestation mostly starts from 1st week of September, hence monitoring should start from 1st week of September. To monitor BPH, the basal parts of some rice plants are to be disturbed mildly with a stick so that the insects jump to standing water from which their occurrence or ETL can be ascertained.

1. **Roving survey:** Undertake roving survey at every 10 km distance at 7-10 days intervals (depending upon pest population). Everyday at least 20 spots should be observed.
2. **Field scouting:** Field scouting for pests and bio-control fauna by extension agencies and farmers once in 3-5 days should be undertaken to workout ETL.
    - The Economic Threshold Level (ETL) for the pest is: BPH: 5-10 insects/ hill in non-endemic area and 2/hill in endemic area.
    - If the insect pest population is above ETL, apply any recommended chemical insecticide if the rice crop is at late vegetative or panicle initiation stage. Pest defender ratio (P:D) 2:1 may be useful to avoid application of chemical pesticides against plant hoppers. Wherever rice crop has become mature or when grain hardening is completed, no insecticide should be applied.

❖ **Field Observations:** Field observations on insect pest infestations are to be initiated after 20 days of transplanting. In each field select five spots randomly (four in the corner, at least 5 feet inside the border and one in the centre). At each spot select four hills randomly for recording observations (total 20 hills/field).

❖ **Plant growth (weekly):** Measure the height of hill, count the number of tiller per hill and number of leaves.

❖ **Crop situation:**

- Plant health: Observe the crop stage and deficiency symptoms etc.
- Count BPH population at different places on the plant.
- Natural enemies: Count parasitoids and predators.
- Soil condition
- Irrigation
- Weather conditions

After assessing all the above mentioned aspects, the suitable and recommended pest management practices for BPH are then to be followed.

Video Link:

https://www.youtube.com/watch?v=STlamQ2DGGM

https://www.youtube.com/watch?v=tlToaMfMctk

Date:

EXPERIMENT 16: Plan & Assess Preventive Strategies (IPM Module) and Decision Making. Crop Monitoring Attacked by Insect Pests.

1. **Grow a healthy crop:**
   - Select a variety which is resistant/tolerant to major pests.
   - Treat the seeds/seedlings/planting material with recommended pesticides, especially bio-pesticides.
   - Select healthy seeds/seedlings/planting material.
   - Improve soil health by nutrient management especially organic manures and bio fertilizers based on soil test results. If the dosage of nitrogenous fertilizers is too high the crop becomes too succulent and susceptible to insects and diseases. If the dosage is too low, the crop growth is retarded. So, the farmers should apply adequate amount for best results. Phosphate fertilizers should not be applied every season as the residual phosphate of the previous season will be available for the current season also.
   - Proper irrigation.
   - Crop rotation.
2. **Observe the field regularly:** Farmers should monitor the field situations at least once a week (soil, water, plants, pests, natural enemies, weeds, weather factors etc.); make decisions based on the field situation and Pest: Defender (P: D) ratio and take necessary action (e.g. remove infested plants etc.).
3. **Plant Compensation Ability:** Compensation is defined as the replacement of plant biomass lost to herbivores and has been associated with increased photosynthetic rates and mobilization of stored resources, for example from roots and remaining leaves.
4. **Understand and Conserve defenders:** Know about natural enemies to understand their role through regular observations of the agroecosystem and avoid use of chemical pesticides.
5. **Insect zoo:** Various types of insects are present in the field where some are beneficial some may be harmful. Generally farmers are not aware about this. The concept of Insect zoo can help in enhancing farmers 'skill to identify beneficial and harmful insects. In this method, unknown predators are collected in plastic containers from the field. Each predator is placed inside a plastic bottle together with parts of the plant and some known insect pests. Insects in the bottle are observed to determine whether the test insect is a pest (feeds on plant) or a predator (feeds on other insects).

6. **Pest: Defender ratio (P: D ratio):** The natural enemies of crop pests include parasitoids, predators and pathogens. Identifying the pests and beneficial insects helps farmers make appropriate pest management decisions. Sweep net, visual count etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The general rule to be adopted for management decisions relying on the P: D ratio is 2:1. However, some of the parasitoids and predators can control more than 2 pests. Whenever the P: D ratio is found to be favorable, there is no need for adoption of other management strategies. In cases where the P: D ratio is found to be unfavorable, the farmers can be advised to resort to release of parasitoids/predators depending upon the type of pest. In addition, bio pesticides such as insect growth regulators, botanicals etc. can be used before resorting to chemical pesticides.

❖ **Pest Management Decision Making**

From the above, we can see that decisions need to be taken by the farmer as to how to implement pest management in the most effective and economic manner. Many of these decisions are taken a long time before any pests appear, such as the crop rotation, time of planting, amount of fertilizer, etc. During the growing season, however, continual decisions need to be made regarding pest management. The pest management decision making process is a continuous cycle that can be summarized as:

- **Detection**: Continual monitoring to see what pests and beneficial insects are present in the crop. This is usually called scouting. Pests are detected before they cause economic loss, and spot treatments can possibly be made. If detection is too late, control will be less effective, more costly, and crop losses will occur.
- **Identification**: The organism must be identified to see if it is a pest, a beneficial insect, or of no importance. If the organism is an insect pest, it is necessary to identify the stage in the life cycle so that control methods can be directed at the most vulnerable stage.
- **Economic significance:** Is the pest causing, or, if left uncontrolled, will it cause, economic damage or loss? Economic damage is the amount of damage that justifies the costs of control. Crop growth stage and economic value also need to be taken into consideration. It should be noted that biological damage (for example, holes in leaves) often occurs without there being any yield or economic loss. The potential (controlling) impact of beneficial species also needs to be considered.

- **Decision:** If the pest level is below the threshold, then no pesticide treatment should be applied. If the pest level is above the threshold, then control treatment is required.
- **Selection of control methods:** The method of control must be effective, practical, economic and safe. More than one control method may be involved for a single pest. For example, the application of an insecticide spray to kill yellow stem borer of rice and clipping of top leaf portion containing egg masses, while at the same time encouraging biocontrol agents to minimize future infestations.
- **Evaluation:** The follow-up of the control method to evaluate the effectiveness. This is a continuation of the monitoring procedure at the beginning of the decision making process, and starts the decision making cycle again.

Crop monitoring attacked by insect pests

1. **Survey/Field Scouting**

The objective through roving surveys is to monitor the initial development of pests in endemic areas. Therefore, in the beginning of crop season survey routes based upon the endemic areas are required to be identified to undertake roving surveys. Based upon the results of the roving surveys, the state extension functionaries have to concentrate for greater efforts at block and village levels as well as through farmers to initiate field scouting. Therefore, for field scouting farmers should be mobilised to observe the insect pest and disease occurrence at the intervals as stipulated hereunder. The plant protection measures are required to be taken only when insect pests and diseases cross Economic Threshold Level (ETL) as per results of field scouting.

(i) Roving survey: Undertake roving survey at every 10 km distance at 7-10 days intervals (depending upon pest population). Every day at least 20 spots should be observed.

(ii) Field scouting: Field scouting for pests and bio-control fauna by extension agencies and farmers once in 3-5 days should be undertaken to workout ETL.

2. **Pest monitoring through pheromones/light traps etc.**

Majority of insect population can be monitored by fixing and positioning of pheromones or light traps at appropriate stage of crop. The State Department of Agriculture can initiate this action at strategic locations at village level as per the following details:

(i) Pheromone trap monitoring: 5 traps per ha may be used to monitor yellow stem borer and moth population.

(ii) Light trap: Chinsurah light trap or any other light trap can be operated for two hours in the evening to observe photo-tropic insect pests.

(iii) Sweep nets or water pans: Besides visual observations sweep-nets and water pans may also be used to assess the population of insect pests, and biocontrol agents to determine the type of pesticides to be recommended or used.

Video Link:

https://www.youtube.com/watch?v=Jg3A1wdPiaY

https://www.youtube.com/watch?v=BdQRLx4hN5o

https://www.youtube.com/watch?v=7UlKUleJWeE

https://www.youtube.com/watch?v=gAxOQwtTf8w

https://www.youtube.com/watch?v=jGAoQdiGpBI

https://www.youtube.com/watch?v=mE5UUW2GFnI

https://www.youtube.com/watch?v=YNcqAl2vKfE

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