Food and Agriculture Organization of the United Nations

Integrated pest management
Training guide for facilitators

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Kizito Kayanda Mwajombe
Janet Maro
Meddy Ayub Njusi
Daudi Edward Gwabara

Sustainable Agriculture Tanzania, Morogoro

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CONTENTS

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FOREWORD

Tipo Nyabenyi

FAO Country Representative, United Republic of Tanzania

The agricultural sector stands at a crossroads, bearing a significant responsibility for the loss of terrestrial biodiversity, estimated at a staggering 70 percent. This loss, largely attributed to unsustainable farming practices, underscores the urgent need for transformative action. Among the myriad challenges, pesticide pollution looms large, with approximately 64 percent of global agricultural land deemed at high risk. While pesticides play a crucial role in safeguarding crops and optimizing yields, their indiscriminate use poses grave threats to both ecosystems and human health.

In the face of these pressing concerns, the imperative for sustainable cropping systems cannot be overstated. Integrated pest management: training guide for facilitators is a linchpin in our efforts to harmonize agricultural productivity with ecological integrity. By embracing a holistic approach that balances pest control with ecosystem preservation, IPM embodies our commitment to fostering resilient food systems.

The European Union-funded programme "Capacity Building Related to Multilateral Environmental Agreements in African, Caribbean and Pacific Countries Phase III (ACP MEAs 3)" implemented field activities in the United Republic of Tanzania and embarked on a journey to equip farmers and extension service providers with the tools necessary for success. The result of this collaboration is this Training Guide, which was meticulously crafted and tailored to reflect local realities and empower stakeholders at every level.

This training guide on IPM for facilitators is a beacon for demystifying the intricacies of IPM and agroforestry while offering practical insights for implementation. By fostering a shared understanding and commitment to sustainable practices, we endeavour to catalyse a paradigm shift towards agricultural resilience.

As we embark on this collective endeavour, let us remain steadfast in our resolve to cultivate a future where agricultural prosperity converges harmoniously with environmental stewardship. Together, let us sow the seeds of sustainable development, ensuring a bountiful harvest for generations to come.

GLOSSARY

Action threshold A specific level of pest population or damage at which a decision is made to take action to manage or control the pests.

Adaption Modification of an organism or its parts that makes it more fit for existence under the conditions of its environment.

Agroforestry Intentional integration of trees or shrubs into a farming system to create environmental, economic and social benefits.

Biodiversity The variability that exists among all living organisms on land, in fresh water bodies and in the oceans.

Biological control The use of one living organism to control a pest species by humans.

Conservation The maintenance and protection of biodiversity.

Ecosystem A relationship between different organisms that interact with each other and their environment.

Ecosystem threshold The level of pest density at which management actions need be taken to prevent an increasing pest population from reaching the economic injury level.

Habitat An area with specific environmental conditions in which an organism lives and reproduces.

Host Any organism on or in which another organism lives.

Infestation The presence of an unusually large number of insects or animals in a place, typically to cause damage or disease.

Insect A large class of small, usually winged, invertebrates (animals without backbones), such as beetles, flies or wasps, having three body parts and three pairs of legs.

Integrated pest management A scientifically based decision-making process that incorporates a variety of technological and management tactics to achieve long-term, environmentally sound pest suppression. A common-sense pest control focused on using multiple tactics and stressing prevention and other least toxic methods.

Life stage An individual stage in the life of insects, having a different appearance to the other stages.

Parasite An organism that lives on or in another organism (the host) causing harm to it.

Pest An organism that is troublesome or destructive to people or their property. Pests can include some fungi, bacteria, weeds and animals.

Pesticide A chemical product designed to kill pest species.

Pheromone A chemical substance that is released by one organism to influence the biology or behaviour of another.

Predator An animal that eats other animals.

Prey An animal that is eaten by another animal.

Species One of the seven taxonomic ranks used to classify living organisms.

Vector An organism that acts as an intermediary host for a parasite and transfers the parasite to the next host.

CHAPTER 1
Introduction

About integrated pest management

Integrated pest management (IPM) is a science-based, common-sense approach to managing pests that can significantly reduce profit losses in crops and livestock from pests, weeds and diseases. It uses a variety of pest management techniques focusing on pest prevention, pest reduction and the elimination of conditions that lead to pest infestations[1]. IPM is basically about three things: (i) don't invite pests in; (ii) block them out; and (iii) if they sneak in, kick them out using the safest and most effective ways.

The IPM approach uses current, comprehensive information on the life cycles of pests, weeds and diseases, and on their interactions with the environment. This information, combined with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible harm to people, property and the environment.

The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home garden and the workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. Environmentally friendly food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals. The aim is to ensure minimal environmental impacts and pest resistance management, preventing non-target effects, addressing public health concerns and ensuring sustainability.

The overall concepts and principles of integrated pest management (IPM) are the same for all crops or pests. However, IPM is not a fixed recipe of recommended practices: crops or pests in different locations may require different IPM practices to be implemented.

Why the need for IPM?

Although pesticides so often succeed at controlling pests, it is better to adopt IPM for the following reasons:

- **To prevent initial pest problems.**
  Many IPM practices are used before a pest problem develops to prevent the introduction, or halt the build-up of, pests. These prevention tactics can save time, money and the environment.
- **To prevent reliance on one tactic.**
  Usually, pests adapt and change to better exploit their environment and survive. Reliance on a single pest management tactic enhances the likelihood that pest populations will increase and become resistant to it.
- **To promote a healthy environment and a good public image.**
  IPM is a thoughtful approach to pest management, which protects humans, domestic animals, wildlife and environmental health, and provides abundant and affordable crops.
- **To conserve natural enemies and agrobiodiversity.**
  Beneficial organisms such as parasites and predators are a key part of the natural enemies for some pest populations. These

1 What Is Integrated pest management? (cdc.gov)

natural controls are considered and protected in an IPM practices that also helps to preserve agrobiodiversity.

- **To protect soil health and crop production inputs.**
  Plant health is dependent on soil health, so protection of soil health is a key component in any IPM programme. Similarly, following an IPM programme that includes plant health will help obtain the best results from composts, fertilizers, micronutrients or other soil amendments, as well as improve irrigation efficiency.
- **To keep the ecosystem intact and functioning.**
  Every ecosystem is made up of living things and their non-living environment. The actions of one creature in the ecosystem will affect other organisms. Many of our actions in an ecosystem may destroy certain species and allow other species (sometimes pests themselves) to manifest and dominate. Beneficial insects, such as ladybird beetles and lacewings, both of which consume pests, can be killed by the improper use of broad-spectrum pesticides, which leaves fewer natural enemies. Other organisms such as soil microbes and protective fungi may be injured by pesticides such as fungicides if used too frequently or when not needed.
- **To maximize the effectiveness of control tactics.**
  Pest management practitioners that apply pesticides on a calendar basis are likely to miss their target pest or apply toxic chemicals when there is no need. The pest life cycle depends on unique environmental factors. Similarly, biological controls may require specific timing so that releases of predators and the application of parasitoids align with the life cycle of the target pest. Using an IPM approach helps to ensure that all control tactics, including pesticides, are used at the proper time to reduce pest damage to acceptable levels. This will reduce environmental and economic costs from unnecessary pesticide applications and help ensure that control tactics are used effectively.

The purpose and justification of the Training Guide

The purpose of the Training Guide is to provide facilitators such as agricultural extension officers and farmers with an overall understanding of the concepts of IPM, together with the principles for its implementation in the crop subsector. The Guide contains all the information that should be presented during the training, together with some additional background information. The facilitators in turn will disseminate the information to other small-scale farmers at the field level. By adopting this Guide in their training, participants should be able to understand the practical implementation of IPM in actual farm and crop situations.

Who is the Guide for?

This IPM Training Guide targets small-scale farmers, agricultural extension officers and other facilitators in agriculture-related fields. Its goal is to provide farmers and extension agents with the tools to dynamically apply practices of agroecology based on specific needs and priorities. The Guide can be used by facilitators, lead farmers and agricultural extension officers who interact directly with farmers to increase crop productivity.

How was the Guide prepared?

The Guide was developed through concerted efforts of individuals from different organizations. It therefore draws from a wealth of experience gathered by these individuals through their long-time service to farmers in different parts of the United Republic of Tanzania. The Guide also benefits from research studies by authors in the agroecology space and experiences from different universities and organizations where IPM has been implemented and lessons documented. Content adopted from other organizations' work including FAO, World Agroforestry (ICRAF), University of California and Cornell University has been duly acknowledged. The guide will be improved periodically based on the users' experiences, innovations and technological advancements, thus supporting transformation towards sustainable agro-ecosystems and reducing the effect of highly hazardous pesticides on human health and the environment.

How is the Guide organized?

The first part introduces the intention for development the Guide. It provides details about its intended users and purpose, as well as the procedure of its preparation and use. Subsequently, the next part provides an understanding of IPM through a detailed definition and discusses its elements, principles, rationale and benefits. It also provides detailed steps for establishing and implementing IPM.

How to use this Guide

This Guide targets both farmers and extension agents who play critical roles in implementing IPM practices to ensure sustainable and effective pest control in agricultural systems. Both benefit from using the Guide as a comprehensive reference tool to help them make informed decisions, tailor strategies to their specific contexts, and implement sustainable and environmentally friendly pest management practices.

SESSION I
Introduction to crop pest and pest management

What is a crop pest?

From an ecological perspective, a crop pest is any organism that interferes with the growth, development and yield of cultivated plants. To a farmer, all organisms, be they insects, weeds, birds or rodents, that cause damage to field crops or stored produce thus reducing the yields of their crops are considered pests. Fungi, bacteria and viruses are also recognized as pests since they act as disease-causing organisms when they lead to conditions that interrupt or modify the vital functions of growing plants or stored produce (Figure 1).

Figure 1 **Armyworm damage on maize crop**

Categories of crop pests

a. Insect pests: These include all insects that destroy or harm crop plants. They have an impact on the crop's basic health and on its productivity. They damage plants by cutting their roots, stems and leaves. They also absorb the plant's cell sap from its diverse parts. Examples of insect pests are aphids, leafhoppers, thrips, whiteflies and mites (Figure 2).

b. Weeds: Weeds include all unwanted plants that grow within crops and compete with them for nutrients, water and sunlight. These plants can also be hosts for other pests and plant pathogens, and hence increase crop damage; however, weeds can also provide benefits for natural enemies. An example of a weed pest is Striga, commonly known as witchweed (Figure 3).

c. Other crop pests include cutworms, beetles, leafminers, etc. The presence of these organisms in crop fields is not a problem until their numbers or size increases to a level that causes substantial reductions in field crop yields or in the quality of harvested and stored produce. When farmers see the numbers and size

Figure 2 **Examples of insect pests that damage crops**

Source: **Sustainable Agriculture Tanzania (SAT)**. 2024. *Our projets [illustration]*. Vianzi. https://www.kilimo.org/what-we-do/our-projects

Figure 3	Maize crop infested with Striga

increase, they are forced to use aggressive and very harmful methods to limit the damage. However, since many smallholder farmers have inadequate knowledge on pest identification and proper strategies of managing a particular pest, yield and quality losses are often substantial.

What is pest management?

Pest management involves practices aimed at keeping pest damage at or below an acceptable level. This acceptable level, or threshold, is economically justifiable; it is the point where the cost of further pest control measures would exceed the benefits. In other words, pest control is applied to reduce pest numbers to a level where additional control efforts would no longer be profitable.

Recently, pest management has commonly been relying on the use of synthetic pesticides; however, their improper application has led to many unintentional effects, including detrimental effects to human health, poisoning of wild pollinators, destruction of the natural enemies of pests, damage to the agricultural ecosystem, and ground- and surface water contamination by pesticide residues, among others.

It is therefore recommended to promote the use of alternative approaches for pest management such as IPM that would prevent or limit the negative impacts to the lowest levels possible. IPM includes biological, physical, mechanical, cultural and chemical control approaches that aim to maintain pest management within economic thresholds.

The need for IPM in the United Republic of Tanzania

There is a need for IPM in the United Republic of Tanzania because pesticides are the major components of modern agricultural production in the country due to their high capability and reliability for crop protection against pests. It is estimated that 81 percent of pesticides used in the United Republic of Tanzania are applied to control pests and disease in the agriculture sector. However, excessive use of pesticides can contaminate the soil and prove fatal to the biotic components that feed on the by-products of agriculture. Pesticides can reach groundwater and make it unfit for consumption.

Some of the specific issues regarding pest management in the United Republic of Tanzania are discussed below.

The wide diversity of insect pests, diseases and weeds

In the United Republic of Tanzania, a wide variety of pests, diseases and weeds occurs because of the favourable humid conditions almost throughout the year, inadequate and/or limited phytosanitary services at the border posts and climate change. As a result, many new insect pests, diseases and weeds evolve or are introduced to the region, mostly by accident. It therefore proves very challenging for farmers to identify and control the different insect pests, diseases and weeds.

An inadequate knowledge of the appropriate application and storage of pesticides
There is little awareness of the direct human health and environmental consequences of the improper spraying of pesticides. In addition, synthetic pesticides and application equipment are usually stored inside homes, where food and children are exposed to them. Also, treated crops are sometimes harvested without proper observation of pre-harvest intervals, thereby exposing consumers to greater health risks. This also reduces the acceptance of the agricultural produce in international markets due to non-compliance notification to the country. Agricultural producers and other value chain actors are therefore at risk of being exposed to health risks associated with improper handling and application of agricultural pesticides.

Inadequate monitoring practices
Many farmers have inadequate knowledge of the cycles of specific insect pests, diseases and weeds, and find it difficult to distinguish their specific characteristics. As a result, they cannot apply suitable preventive measures nor implement proper control measures. Overall, there is also limited accessibility and use of traps in supporting the monitoring of pest and diseases for informed decision and timely action.

Limited access to pesticides
Most small-scale farmers in the United Republic of Tanzania lack the financial resources to buy low-risk chemical pesticides for controlling insect pests, diseases and weeds.

Limited knowledge on suitable pesticides
There is a wide variety of pesticides available on the market, both fake and counterfeit. Most farmers do not adhere to product labelling and protective measures, and thus are unable to make informed choices about the appropriate use of pesticides. Instead, they rely on recommendations from the pesticide retailers, who often lack the proper knowledge of pesticides and are often more motivated to make sales than advise farmers.

The management of insect pests, diseases and weeds is still a challenge to many farmers. In preventing crop losses, they need to be able to implement affordable and more sustainable measures against pest management for increased productivity while minimizing negative impact on human health and the environment.

LESSON PLAN for Session I

Topic

What is a crop pest?	....	20 minutes
The meaning of crop pest management	....	20 minutes
The need for IPM in the United Republic of Tanzania	....	20 minutes

Objectives
By the end of this session, participants will be able to:

a. describe the meaning of crop pest and pest management; and

b. explain the importance of IPM in the United Republic of Tanzania.

Time: 60 minutes
Steps:

1. Define a crop pest and pest management – 40 minutes
2. Explain the need for IPM in the United Republic of Tanzania – 20 minutes

Methodology:

- Discuss the definitions of crop pest and the meaning of crop management.
- Discuss the need for IPM.
- Hold a question-and-answer session.

Materials:
Flip charts, marker pens, notebooks, pens, a projector

Key message:
Understanding the importance of IPM motivates the adoption of IPM approaches.

SESSION II
Integrated pest management

What is IPM?

IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programmes use current, comprehensive information on the of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means and with the least possible hazard to people, property and the environment.

IPM uses all available pest management techniques in an overall crop/pest management programme, which considers all the potential pests. It emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

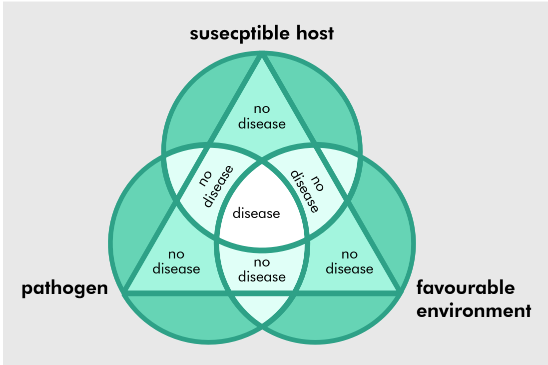
The IPM approach needs to be considered as an integral part of crop production together with all agronomic techniques (i.e. Integrated Crop Management). Pest management cannot be considered on its own; it is a part of the overall production practice of a crop, which include, among others, seed/variety selection, land preparation, fertility and water management. Changes to production practices will affect pest management practices.

The principles of IPM

Principle 1 – Prevention and suppression
The prevention and/or suppression of harmful organisms should be achieved or supported by, *inter alia*, implementing the disease triangle concept that focuses on the environment, pathogen and host. The disease triangle is an important concept in plant pathology (Figure 4).

Disease will **only** occur if these three factors interact simultaneously. All three factors are necessary for the development of a plant disease; thus, a disease can be affected by altering any of these three factors using good agricultural practices such as:

Figure 4 **The disease triangle concept**



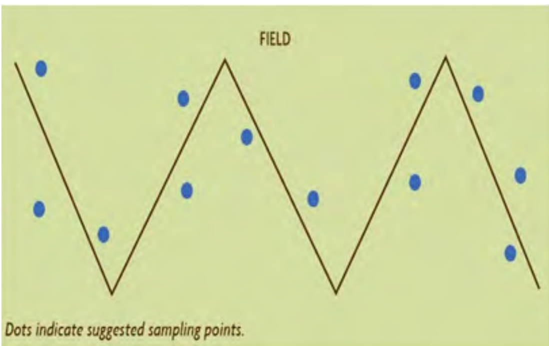
Source: **Sustainable Agriculture Tanzania (SAT)**. 2024. *Our projets [illustration]*. Vianzi. https://www.kilimo.org/what-we-do/our-projects

- crop rotation;
- use of adequate cultivation techniques (e.g. stale seedbed technique, sowing dates and densities, undersowing, conservation tillage, pruning and direct sowing);
- use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and planting materials;
- use of balanced fertilizers, liming and irrigation/drainage practices;
- the prevention of the spreading of harmful organisms through hygienic measures (e.g. by regular cleansing of machinery and equipment); and
- the protection and enhancement of important beneficial organisms, for example, through adequate plant protection measures or the utilization of ecological infrastructures inside and outside production sites.

An example of a good agricultural practice is to replace a susceptible host plant by a disease-resistant variety. Also, a pathogen can be removed by tilling residue, rotating crops so that pathogens do not survive year to year on the same crop, controlling insects that carry pathogens to plants, or using fungicides to kill the pathogen. Finally, the environment can be managed so that it is less favourable for disease, such as by changing row spacing or draining low areas.

Principle 2 – Monitoring
Harmful organisms must be monitored by adequate scouting, which involves looking over the entire crop while moving in a zig-zag pattern (Figure 5) to evaluate overall colour, height and uniformness. Look for plants that have a different aspect from the others, and if there are any troubled areas that stand out, start looking for pests. Once this quick overall evaluation is complete, select plants at random for closer examination.

Figure 5 **An insect pest monitoring pattern**



Source: **Jermaine Hinds**. 2020. *A Whole Farm Approach to Managing Pests*. United States of America, SARE Outreach.

Principle 3 – Decision-making
Based on the results of the monitoring, the trained farmers must decide whether, and if so, when to apply plant protection measures. Decision-making in IPM requires careful evaluations, both economic and environmental, that consider the benefits and costs associated with each management action.

For harmful organisms, thresholds should be quantitative or numerical to be useful. For example, they could be based on:

- the average number of pests per trap each week;
- the percentage of leaves or plants found to be damaged or infested during visual inspection; and
- the number of pests dislodged per beat or shake sample.

Quantitative thresholds can be developed for most pest monitoring methods, such as applying treatment when certain conditions are conducive to disease development or when invertebrate pests or damaged plant parts exceed specified numbers or percentages. For example, management action may be warranted for whiteflies early in production when more than about 5 adults per trap per week are captured on one well-maintained 7.5-cm by 12.5-cm yellow sticky trap deployed per 80 sq. cm. of production. Thresholds for your situations may be very different.

Principle 4 – Selection of control method of choice
The biological control method and physical and other non-chemical control methods must be prioritized before considering chemical methods if they provide satisfactory pest control. Before reaching for pesticides or calling a professional pest control service, it's important to understand the types of pest control methods available and what each is best suited for. The most common techniques for managing pest populations are:

- Natural pest control methods: If you want an eco-friendly, humane and sustainable approach to pest control, natural methods are the way to go. These methods include ensuring hygienic measures and using repellents to effectively discourage pests from entering and multiplying.

- Biological pest control methods by using beneficial insects: Encouraging the presence of natural predators in your garden can help control pest populations. For example, ladybugs and praying mantises are natural enemies of aphids and other common garden pests. You can attract these beneficial insects by planting flowers and herbs.
- Physical pest control methods: These involve the use of traps or physical barriers to prevent or capture pests. These methods are often non-toxic and can be effective for small-scale pest problems.

Principle 5 – Pesticide selection
The pesticides applied should be as specific as possible for the target pest/weed and have the least side effects on human health, non-target organisms and the environment. Practitioners are strongly advised to thoroughly review and comprehend pesticide labels for several key reasons. First, pesticide products can pose significant safety risks if mishandled. The instructions provided on labels cover essential aspects such as safe handling, mixing, application and storage, minimizing potential exposure to harmful substances and averting accidents or health issues.

Second, environmental safeguarding is crucial. Misusing or excessively using pesticides can harm ecosystems, contaminate water sources, and adversely affect non-target organisms such as beneficial insects and birds. Proper understanding of labels helps practitioners apply pesticides judiciously, reducing environmental harm.

Furthermore, correct application ensures optimal pesticide efficacy, preventing reduced pest control and the development of resistant pests. Adherence to label instructions also aids legal compliance, preventing potential penalties and environmental harm. It guides practitioners on application techniques, protective measures for health and safety, residue management, record-keeping and ongoing education. Regularly reviewing labels enhances practitioners' knowledge, promoting responsible pesticide use and up-to-date best practices.

Principle 6 – Reduced pesticide use
Reducing application frequency and resorting to the partial application of pesticides contribute to IPM goals of reducing or minimizing risks to human health and the environment. Effective pest control in agriculture relies on informed decision-making and vigilant monitoring practices that reduce the need for excessive pesticide use. Informed choices grounded in accurate data and IPM strategies enable farmers to minimize their reliance on chemicals.

Farmers armed with knowledge can opt for appropriate pest control methods, such as biological agents, cultural practices and resistant crop varieties, instead of immediately turning to chemical solutions. Routine field monitoring facilitates the early detection of pest populations, allowing timely interventions that prevent outbreaks that would need extensive pesticide application.

Continual education and staying abreast of pest management advancements empower practitioners to refine decision-making and enhance monitoring methods. This path culminates in judicious pesticide use, cost reduction, elevated crop quality and a diminished ecological footprint, collectively fostering sustainable and conscientious agricultural practices.

Principle 7 – Anti-resistance strategies
Where the risk of resistance against a plant protection measure is known and where the level of harmful organisms requires the repeated

application of pesticides to the crops, available anti-resistance strategies should be applied to maintain the effectiveness of the products. This may include the use of multiple pesticides sequentially with different modes of action.

Principle 8 – Evaluation
Based on records on the use of pesticides and on the monitoring of harmful organisms, the professional user should check the success of the applied plant protection measures.

The advantages of IPM

The application of IPM offers many advantages to farmers:

- Unnecessary pesticide use is avoided.
- Pest management costs are reduced.
- Crop losses are reduced.
- Pest resistance to pesticides is avoided.
- Crop production is sustained.
- Biodiversity is sustained.
- The risk of human, animal, food, wildlife and environmental contamination is reduced.

LESSON PLAN for Session II

Topic

The meaning of IPM and the disease triangle	20 minutes
Principles of IPM	40 minutes
The importance of IPM	10 minutes
How is IPM implemented?	20 minutes

Objectives
By the end of this session, participants will be able to:

a. explain the meaning of IPM and the disease triangle;
b. outline principles of IPM;
c. list the advantages of IPM; and
d. describe how IPM is implemented.

Time: 90 minutes
Steps:

1. Define the meaning of IPM.
2. Outline and explain principles of IPM and disease triangle.
3. List the advantages of IPM in agriculture, the environment and human health.
4. Describe how IPM is implemented.

Methodology:

- Initiate discussion on IPM.
- Discuss the principles of IPM.
- Make a presentation of the advantages and disadvantages of IPM.
- Describe how IPM is implemented, focusing on the disease triangle elements.
- Hold a Question and Answer session.

Materials:
Flip chart, projector, marker pens, pens, notebooks, a demo plot, a programmable smartphone.

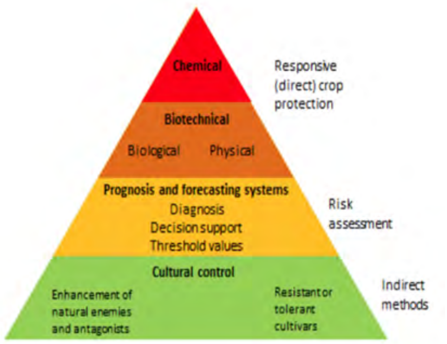
Key message:
IPM principles guide farmers on the best use of IPM technologies.

SESSION III

Integrated pest management approaches

There are many IPM methods, some of which have been used for hundreds of years – before chemical pesticides were invented. With regard to crop production, the methods concentrate on producing a healthy crop or an environment that is unfavourable to pest populations. Many of these methods can be implemented at little or no extra cost to the farmer since they are part of good crop production practices (Figure 6).

Figure 6 **Approaches used in integrated pest management practices**



Source: **Meissle, M., Romeis, J., & Bigler, F.** 2011. *Bt maize and integrated pest management - a European perspective*. Pest Management Science, 67(9), 1049-1058. https://doi.org/10.1002/ps.2221.

A: Agroforestry approach

The integration of agroforestry into agricultural systems can also contribute to pest control, for example:

a. Perennial vegetation separates the annual crop.

b. It reduces the spread of pest, disease or weed.

c. Planting nitrogen fixing plants such as Gliricidia sepium enriches the soil through nitrogen fixation, thereby supporting a stronger and healthy crop that is less susceptible to pests.

As a tree grows, it can be pruned and used as mulch to suppress weeds. Even at a young stage, the tree can provide a home to predatory wasps and other beneficial species. As trees grow, they can provide a home to larger predators such as birds that feed on insect pests. Some woody species, such as Tephrosia, contain chemicals that many insects dislike and act as repellents (Figure 7).

Figure 7 **A shelterbelt on a farm**

Effective agroforestry practices involve planting beneficial hedges, which can be utilized to produce natural pesticides, such as neem extracts, for plant pest control.

There are many natural plant-derived products that can be sourced for pest control from beneficial hedges. One example is the use of neem extract for controlling insect pests. The neem extract is sourced from the neem plant, whose parts used can be leaves, barks, seeds or roots. To make it more efficient, it is mixed with other ingredients such as garlic, onions, hot peppers, gingers and aloe vera (see [Why you need trees and shelterbelts on your farm (pasture.io)]).

B: Intercropping with pest-repellent plants

Intercropping entails the identification and use of plants that can repel pest and subsequent pathogens. These are planted together in alternating lines and/or positions. Intercropping with pest-repellent plants is a crucial component of IPM, a holistic approach to pest control that emphasizes effective management while minimizing environmental impact.

This practice aligns well with IPM principles by introducing diverse plant species into fields, confusing pests through emitted compounds, and deterring their settling or feeding. This disrupts pest life cycles, curbing their reproduction, and promotes a varied habitat that supports natural pest predators.

Intercropping reduces pest concentration, thus reducing the need for chemical pesticides, and enhances the overall resilience of crops to environmental changes. By promoting sustainability, reducing chemical use, and offering economic benefits through increased farm income, intercropping exemplifies IPM principles in practical application, fostering a balanced and sustainable agricultural ecosystem (Figure 8).

Figure 8 **Leafy vegetables intercropped with onions as a pest repellent**

© Sustainable Agriculture Tanzania (SAT)

Examples of intercropping practices

a. **Push-pull technology**, i.e. growing other crops around the field to serve as an alternative source of food to the plant pest, for instance, growing marigold and/or desmodium around the maize farm (push technology), or using napier used around the field to attract pests towards them (pull technology) (Figure 9) .

Figure 9 **Push-pull layout of crops**

© FAO/Marzio Marzo

b. **Crop rotation**. Monocropping with the same crop or with the same plant family can affect the growth of a crop. For example, nematodes can build up by repeatedly growing tomato on the same field; planting legumes before another crop puts nitrogen into the soil, reducing the need for applied nitrogen in the following crop; and crops such as maize and wheat can reduce the level of Fusarium in the soil (Figure 10). Crop rotation helps to minimize the build-up of soil-borne pests, weeds and diseases such as nematodes.

Figure 10 **A crop rotation pattern**

Source: **Natalia Kolkowska**. 2023. *Sustainable Crop Rotation Practices. [illustration]*. https://sustainablereview.com/sustainable-crop-rotation-practices/

c. **Bio-fencing** entails establishing a boundary by planting a closely spaced line of trees, shrubs or herbs that provides protection for crops against pests such as insect pests, birds while tall and thorny plants prevent large herbivores from destroying crops (Figure 11). It acts as a windbreaker and reduces air currents carrying dusts, chemical contaminants or harmful pathogens/pests (https://www.organo.co.in/blog/bio-fences-to-incorporate-not-bifurcate).

Figure 11 **Bio-fencing**

© FAO/Rosetta Messori

d. **The use of cover crops**. Cover crops are crops grown for the protection and enrichment of the soil. Examples of commonly grown cover crops are: lablab, Mucuna and pumpkins. Cover crops also help to control pests and diseases, conserve soil moisture, and increase biodiversity on the farm (Figure 12).

Figure 12 **Cover crops in between crop lines**

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They also help control pests by suppressing weeds and breaking up pest cycles. The added plant diversity can shake up the system and can make life hard for insects, weeds and diseases that are used to the same plant patterns (How to best implement cover crops to ensure your farm's future | AGDAILY).

Other cultural methods

- **Appropriate land preparation.** Appropriate land preparation is important because soil tillage removes hard pans and allows roots to fully penetrate, and a correctly prepared seed bed allows seeds to germinate and grow quickly. Improved soil tilth and drainage reduces nematode levels. Appropriate tillage can destroy the pupae and overwintering stages of many insect pests.

- **Use of clean, certified seed and planting materials**. A clean, certified seed/rootstock is essential for a healthy crop with a high yield potential. No crop management practices are able to compensate for problems arising from poor quality seed or planting materials. Clean and certified seeds and rootstock are free of any weed seeds, pests and diseases, for example, virus-free tomato seed. Seeds and rootstock that are dressed will also protect against soil-borne diseases and early season sucking pests. When establishing an orchard, rootstock should be obtained only from a certified nursery.
- **Time of sowing**. Planting at the correct time promotes healthy plant growth and avoids periods of attack by major pests. Similarly, late planting of broad beans (or faba beans) avoids infestation by aphid from other legumes, and early planting of cotton prevents late season bollworm attack. This practice should be enhanced by using weather information and advisory services appropriately to ensure the timely sowing of crops.
- **Plant spacing**. Plants sown too close together are weaker and more susceptible to pest attack. Plant spacing also provides the suitable micro-climatic conditions within the crop for the build-up of pests and diseases, such as aphids and whitefly in cotton, blight in tomatoes, downy mildew in cucumber, and aphids, mites, blight and mildew in apple (Figure 13).
- **Timing and amount of fertilizer**. Wrongly timed or excess fertilizer can promote vegetative and dense plant growth, which encourages pests such as aphids and whitefly. Excess nitrogen fertilizer weakens plants and makes them susceptible to pests such as aphids and whitefly, and diseases such as mildews and blights.

Figure 13 **Properly spaced maize crop**

© FAO/Fanjan Combrink

- **Weeding**. Weeds compete with the crop for sunlight, nutrients and water, resulting in a weak crop. Cotton, for example, is extremely susceptible to weed competition at the seedling and early growth stage.

  Weeds can also harbour or attract pests and diseases, which then spread to the crop, such as fruitworm in tomatoes. However, weed species can also encourage populations of beneficial insects by acting as refuges, and are often left at the edges of fields, or as 'strips' through the field. Tall weeds in orchards can attract rodents, but a low cover of weeds or grass between trees prevents the dusty conditions that promote red spiders.

- **Use of resistant crop varieties**. Resistant crops varieties have in-built resistance or tolerance to attack by certain pests. The degree of resistance can vary from slight to almost complete.

Biological approaches

Biological control involves managing pests using their natural enemies, i.e. predators and parasites (also called 'beneficial insects') and disease-causing organisms, and encouraging their development. Some pests or, in some cases, non-pest species, must always be available to provide a food supply, and there often is a time lag between the increase of a pest population and the increase of natural enemies.

Unsprayed crops contain a wide range of beneficial organisms (e.g. predators, parasites and disease-causing organisms). These feed on the pests, providing a large measure of control. The conservation and enhancement of these beneficial organisms are the most cost-effective and sustainable means of pest management and must be a priority in any IPM programme.

Figure 14 **Beneficial insects feeding on harmful insects**

The beneficial organisms are present within the crop and also in neighbouring fields and crops, as well as in the vegetation between fields and along canal banks, soils, natural habitats including forest and grasslands water bodies and landscapes (Figure 14).

However, this vegetation can also harbour pests which can spread into cultivated crop areas, and the importance of the surrounding vegetation in harbouring beneficial insects relative to pests should be assessed as part of the IPM programme.

Predators (ladybirds, spiders, birds, etc.) are the most commonly observed natural enemies, but parasites, often referred to as 'farmer's friends', often have the greater control effect (parasitic wasps, flies, etc.).

Some beneficial organisms

Organism	Benefits to agriculture
Bees	Act as pollinators
Dung beetles	Break down animal faeces into small pieces (e.g. cow dung), therefore assisting in improving soil fertility
Lady bird beetles	Feed on aphids, pest eggs and other plant sucking bugs
(Predator) wasps	Act as pollinators decomposers and predators
Beneficial butterflies	Act as pollinators.

In many circumstances, natural enemies are extremely common in fields that have not been sprayed with a pesticide. When certain pesticides are used on a crop, the beneficial insects are also killed. For example, the elimination of brown planthopper in rice is a problem when pesticides are used because the beneficial insects are also killed.

Physical or mechanical approaches

Mechanical control is sometimes called 'physical control' and involves the use of machines or other tools. Some of these approaches are:

- soil cultivation and tillage, which physically kills some pests, buries them, or exposes them to drying conditions on the soil surface or as food for birds or other predators;
- soil cultivation, which also buries and kills weed seedlings, and buries potential food sources for insect pests;
- traps, such as rat traps, sticky insect traps and pheromones traps (Figure 15).

Figure 15 **Examples of traps**


© FAO/Vladimir Rodas

Additional physical approaches are:

- hand picking of insects, leaves/fruits that are diseased, with insect eggs, or infested with insect pests, etc;
- hand weeding;
- using sculptures (Figure 16) and drums;
- using nets to protect fruits:
- removing infested plants/branches – Disease-infested plants and branches provide a source of infestation to healthy plants. They should be removed and burnt to prevent the spread of disease. Plants infested with other parasitic weeds can also be treated in this way during low-level infestations; and
- performing post-harvest sanitation – Crop residues left in the field can provide shelter for insect pests, such as bollworms, cotton stainers and moths, and for diseases such as blight and mildew. Crop residues and fallen fruits, etc. should be ploughed-in, burnt or buried.

Figure 16 **A scarecrow used to scare birds**


© FAO/Michael Alexander Uccello

Chemical control approaches

The use of chemical control methods in IPM is an important component of a holistic pest management strategy. However, it should be employed judiciously and as part of a broader approach that integrates various pest management techniques by considering its potential impact on human health, the environment and long-term sustainability.

The goal is to minimize the use of chemicals while effectively managing pest populations to protect crops and ecosystems. Follow all safety precautions and label instructions provided by the pesticide manufacturer, including the use of appropriate personal protective equipment (PPE) (Figure 17). The objectives of bio- and/or synthetic pesticide application include protecting

Figure 17 **Precautions when applying pesticides**

Source: **FAO and WHO** (World Health Organization). 2020. *International Code of Conduct on Pesticide Management: Guidelines for personal protection when handling and applying pesticides*. Rome. https://iris.who.int/bitstream/handle/10665/330917/9789240000223-eng.pdf

the crop from economic damage or loss (https://jjkellercompliancenetwork.com/institute/pesticide).

How to use bio- and/or synthetic pesticides

Both biopesticides and synthetic pesticides should be used carefully and strategically to effectively manage pest populations while minimizing potential risks to human health, beneficial organisms and the environment. Both can be valuable tools in IPM when used responsibly and in accordance with a well-designed IPM plan. The key is to minimize risks while effectively controlling pest populations to protect crops and ecosystems.

The use of either biopesticides and/or synthetic pesticides must be guided by the following practices:

- **Selection**: Choose the appropriate biopesticide or synthetic product for the target pest. Biopesticides/synthetic pesticides are often strain- or species-specific, so selecting the right one is crucial.
- **Timing**: Apply biopesticides/synthetic pesticides when the pest population is at the susceptible stage to maximize their effectiveness.
- **Compatibility**: Check for compatibility with other pest management methods in your IPM plan. The biopesticides applications can be integrated with cultural practices and biological control techniques.
- **Application**: Follow the label instructions for mixing and application. Both biopesticides and synthetic pesticides require proper handling, storage and application techniques to maintain their efficacy.
- **Protection of beneficial organisms**: Biopesticides are generally less harmful to beneficial insects and organisms. Nevertheless, monitor their potential impact and avoid unnecessary harm to beneficial organisms. For synthetic pesticides, choose pesticides that are specific to the target pest and have minimal impact on non-target organisms, such as beneficial insects, wildlife and humans.
- **Environmental considerations**: Be aware of potential environmental impacts and avoid contaminating water bodies and non-target areas.
- **Monitoring**: Continuously monitor pest populations to assess the effectiveness of the applied control measures. Synthetic pesticides should be considered a last resort when other pest control methods have

proven ineffective or when the infestation poses a significant economic or ecological threat.

- **Record-keeping**: Maintain detailed records of pesticide applications, including dates, locations, quantities used and results. This information helps track the effectiveness of treatments and ensures compliance with regulations.

Farmers are frustrated when a pesticide appears ineffective; they often blame it for its ineffectiveness when this may be due to the improper application of the above practices. Some of the factors pertain to the application process, underscoring the critical importance of precise pesticide application for optimal results. Some farmers tend to mix multiple pesticides, exceeding recommended application rates, or even employing incorrect nozzles, all driven by concerns of potential inefficacy.

LESSON PLAN for Session III

Topic

Agroforestry approaches	30 minutes
Cultural control approaches	20 minutes
Biological control approaches	20 minutes
Physical/mechanical control approaches	10 minutes
Chemical control approaches	20 minutes

Objective
By the end of this session, participants will be able to describe the IPM approches.

Time: 100 minutes
Steps:

1. Explain agroforestry approaches in IPM – 30 minutes
2. Describe cultural approaches – 20 minutes
3. Explain biological approaches – 20 minutes
4. Describe physical approaches – 10 minutes
5. Explain chemical approaches – 20 minutes.

Methodology:

- Begin discussion on IPM approaches through brainstorming.
- Make a presentation.
- Hold a question-and-answer session.
- Discuss IPM practices with concrete examples.

Materials:
Flip chart, projector, marker pens, pens, notebooks.

Key message:
Proper identification of the problem offers the best alternative to a solution.

Integrated pest management
Training guide for facilitators

Integrated pest management (IPM) offers a practical solution for pest control. This approach combines multiple strategies to manage pests effectively while reducing reliance on chemical inputs, thereby supporting healthier ecosystems and more resilient food systems.

In this context, the European Union-funded programme, "Capacity Building Related to Multilateral Environmental Agreements in African, Caribbean and Pacific Countries Phase III" (ACP MEAs 3), implemented field activities and training in the United Republic of Tanzania to mainstream biodiversity into the agricultural sector. The programme aimed to support farmers and extension service providers with the tools and knowledge needed to implement IPM and ecosystem-based practices effectively.

This Integrated pest management: training guide for facilitators was developed as part of these efforts. Designed to reflect local conditions, it provides practical guidance for those working directly with farming communities.

Contact information:
Plant Production and Protection Division - Natural Resources and Sustainable Production

https://www.fao.org/plant-production-protection/about/NSPdivision/en

NSP-Director@fao.org

Food and Agriculture Organization of the United Nations
Rome, Italy

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