global forum for rural advisory services
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CropLife INTERNATIONAL

Integrated Pest Management

STUDENT GUIDE

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Acknowledgements

In 2017 the Global Forum for Rural Advisory services (GFRAS) launched the New Extensionist Learning Kit (NELK) which focused more on functional skills.

https://www.g-fras.org/en/knowledge/new-extensionist-learning-kit-nelk.html

The Learning Kit contains a series of modules designed for self-directed, face- to-face, or blended learning and can be useful resource for individual extension field staff, managers, and lecturers.

The Integrated Pest Management module is developed as part of the new set of NELK technical series of modules with more emphasis on the 'technical how to' skills.

The IPM module is developed by the GFRAS in collaboration with CropLife International

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Contents

Before you begin

Target audience

This module is for extensionists from the public and private sector, including civil society and lead farmers. Agricultural students will also benefit from this module as an introduction to integrated pest management.

This module provides extensionists with the knowledge and confidence to train and advise growers on IPM, its benefits and how it can be implemented in the field. It also provides an overall strategy for adapting the knowledge for specific crops in different countries and regions in consultation with local extension services and experts.

General instruction

This module should be used in conjunction with the workbook provided. As you read through the module, you will find different visual features that are designed to help you navigate the document.

Figure 1: Icons used to highlight important information throughout the manual

The module uses keywords (difficult or technical words that are important for you to understand). To ensure that you receive the module's full benefit, keywords will be marked the first time they occur and defined in a box containing the keywords symbol. Make sure that you read the definition of any words that you are unsure about.

Activities

Each session in the module will contain various types of activities to help you become knowledgeable and competent. The module contains three types of activities:

A **pre-assessment** is to be completed before reading through the module overview and introduction, and a **post-assessment** is to be completed once the entire module has been covered. This will measure the degree to which your knowledge has improved by completing the module.

Each session contains one or more **session activities** to be completed in the workbook, where indicated in the module. These activities measure your ability to recall and apply theoretical knowledge.

At the end of each study unit, a **summative assessment** needs to be completed. These assessments are longer than the session activities and will test your knowledge of all the work within the study unit.

Assessment instructions

Keep the following in mind before doing any of the assessments:

- All assessments are to be completed in the provided workbook.
- The manual contains all relevant information you will need to complete the questions. If additional information is needed, such as the use of online sources, facilities will be made available.
- Work through the activities in a study unit and make sure that you can answer all the questions before attempting the summative assessment. If you find that you are not sure of any part of the training material, repeat that section until you feel confident.
- The summative assessment must be done under the supervision of your trainer at the end Target of your learning period.

Module 1: Integrated Pest Management

Module outcomes

After completing this module, you will be able to:

1. What is IPM, its history and current approaches
2. Benefits of IPM
3. The components of IPM: Prevention, Observation and Intervention
4. The different interventions that can be made: Cultural, Mechanical, Biological and Chemical
5. Responsible Use of Pesticides, including Management of Pesticide Resistance
6. Different approaches to IPM: role of GMOs, Area-Based Pest Management
7. How to implement IPM: Cost and Record Keeping
8. Training approaches
9. Different examples of IPM in action (Case studies)

Module overview

When you have completed this module you will have the confidence to train and advise growers on IPM, its benefits and how it can be implemented in the field. Adaptations for specific crops in different countries and regions will be possible through use of the overall strategy this module provides and in consultation with local extension services and experts.

The primary target is extensionists from the public and private sector, including civil society and lead farmers. It is also suitable for agricultural students as an introduction to integrated pest management.

Watch the following welcome video by Dr Keith Jones, Independent Consultant on Sustainable Agriculture and Integrated Pest Management:

https://youtu.be/UmiLyNrh7pA

Complete the pre-assessment in your workbook.

Study Unit 1: Introduction to IPM

Study unit outcomes

After completing this study unit, you should be able to:

1. Understand what IPM consists of
2. Understand the benefits and principles of IPM are
3. Know the basic components that should implements in an IPM strategy

Introduction

Agricultural pests are organisms that damage or compete with a crop to reduce yield or quality. Some examples of this are:

- Insects,
- Disease causing organisms,
- Weeds,
- Rodents, and
- Birds.

If these pests are not effectively managed or controlled, they can cause significant losses. While estimates show average losses of 30 – 40%, complete crop loss can occur, especially for smallholder farmers in low-income countries, as they may lack knowledge or lack effective control options. Pests need to be managed to protect livelihoods. As agronomists and pest management experts, you need to help farmers understand that pests can economically impact their farms and thus need to be managed, and then explain how to manage pests without creating unnecessary risk to human health and the environment. You should be able to explain why they should adopt IPM.

Session 1.1: What is IPM?

Session outcomes

After completing this session, you should be able to:

1. Describe what IPM is
2. Understand the underlying basic principles of IPM
3. Understand the benefits of IPM over exclusively using insecticides, herbicides, fungicides and other types of pesticides

Introduction

This session will define IPM and familiarise you with its basic principles. Although a farmer does not need to know the definition of IPM, you do need to know so you will not confuse it with other definitions and approaches. What the farmer needs to understand is the underlying principles and how to apply them on the farm.

Definition of IPM

There are almost 100 recorded definitions of IPM, many of which are contradictory or address a specific objective rather than the overall goal. When asked what the goals of IPM are, responses vary. Example include:

- Reduce the use of chemical pesticides
- Protect the environment
- Reduce impacts on beneficial insects
- Save money on inputs

While these are all possible outcomes of IPM, the goal is to manage pests in an economically viable, environmentally sound and socially acceptable way. To set a goal like 10% pesticide reduction takes the focus away from managing the pest and is likely to fail.

The term IPM has been used since the 1970s, promoting a strategy that uses a range of tools to manage pest populations. However, the idea that relying on one method of pest control is not sustainable has been around for much longer. Thus, the Food and Agriculture Organization of the United Nations (FAO) held a symposium in the 1960s on Integrated Pest Control. Since then, the concept has evolved with the understanding that pests need to be managed rather than just controlled and that this requires understanding the agroecology, including the following:

- How agricultural practices and environmental conditions affect pest populations
- The impact of agricultural practices and pests on the crop
- Natural organisms that can help regulate pests.

Agroecology involves applying ecological science to managing the farming system (the agroecosystem) sustainably. It is a holistic approach to agriculture and agricultural development that links ecology, socioeconomics and culture to sustain agricultural production, farming communities, and environmental health. Agroecosystems differ from natural ecosystems because they:

- Experience frequent major disturbances;
- Are dominated by domesticated plants;
- Have low species diversity;
- Feature a main crop species that is planted, grows and is harvested at the same time;
- Receive nutrients from external sources, therefore the main crop is lush and nutrient-rich.

All of these influence pest build-up, and natural control mechanisms.

The definition of IPM used in the FAO/WHO International Code of Conduct on Pesticide Management states:

Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms.

This definition embraces:

- Maintaining a healthy crop
- Minimising agroecology disruption
- Limiting interventions to only what is necessary

Excessive use and poor application of broad-spectrum insecticides against brown planthopper and other insect pests in rice has two negative outcomes.
First, the insect can develop resistance to the insecticide, and the planthopper is no longer controlled.
Second, broad-spectrum insecticides also kill beneficial insects and spiders that normally help to keep the planthopper population in check, leading to planthopper outbreaks. The risk of pest resurgence is particularly high if broad spectrum insecticides are used early in the cropping season, leading to recommendations to avoid applying them during the first 30 – 40 days after crop establishment. Resistance and resurgence have led to hopper burn, where the crop is completely destroyed. This can be avoided through adopting IPM, including specific insecticides when needed and resistance management strategies.

It recognises that a range of interventions can be used, but that these interventions must be handled and used responsibly to reduce the negative impacts on human health and the environment. This definition was adopted by the FAO conference in 2002, representing the 190+ members of FAO, and is endorsed by non-governmental organisations such as the Pesticide Action Network and the pesticide/biopesticide industry represented by CropLife International, AgroCare and the International Biopesticide Manufacturers Association (IBMA).

Principles and concepts

The first principle you must understand is that and effective implementation of IPM is based on the agro-ecosystem and agroecology. This is an important part of maintaining healthy soil and growing a healthy crop with plant that is strong and vigorous and therefore will be less affected by pest attack. Pest management actions or pest control interventions should consider the system as a whole, or they can have unexpected and undesirable results.

The second principle is that pests do not need to be completely eradicated. Instead, the aim is to keep the pest population at a tolerable level, which is where the cost of the pests' impact on yield or quality is less than the cost of controlling the pest. This level is called the economic threshold and will be explained in detail later. This level is complicated by the fact that some early season damage to a crop can be compensated for by later growth. Another complication is that some crops, like fruit crops, have a maximum potential yield, which means that excess fruit may later be shed, so some damage to a crop may result in a higher yield. An example of this is leaf damage to cotton. You must also take the positive impact of beneficial organisms into account when determining a threshold. Strategies that achieve unnecessarily high levels of control (mainly using chemical pesticides) can cause serious agro-biological problems that can make the pest situation worse.

The third principle is that IPM focuses on maximizing the effectiveness of natural control mechanisms to regulate pest populations. Chemical pesticides and other tactics are used only when natural control fails. Unnecessary interventions can disrupt natural control mechanisms, which can increase pest problems.

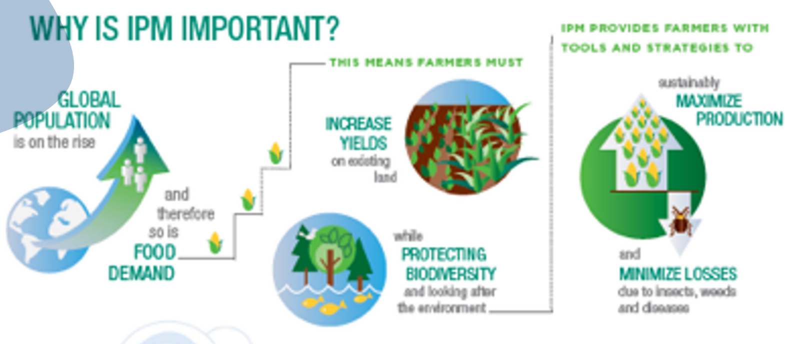
These three principles are why IPM has been described as a holistic approach. IPM is also described as a knowledge-intensive approach. While this is true, the knowledge is readily available from:

- Researchers,
- Private and public extension agents,
- On-line resources and
- Farmers.

The agroecosystem and the impacts of management actions on it vary with factors such as topography, climate and soil type and conditions. There is no one size fits all approach to IPM. This module describes the underlying principles of IPM, but the final approaches and actions taken must be tailored according to local context, knowledge and experience. The IPM strategy adopted must be cost effective and effectively manage pest populations.

Why is IPM important?

IPM is integral to meeting the food requirements of a growing population through reducing crop losses from pest attacks in a sustainable way.



Benefits of IPM

IPM is an essential element of sustainable agriculture by helping to maximise production sustainably while minimising losses due to pests.

IPM provides multiple benefits for the grower, society and the environment, including:

- Improved profitability due to optimising pest control measures, including eliminating unnecessary inputs;
- Improved, stable, reliable and good quality crop yield due to improved crop health and decreased severity of pest infestations;
- Reduced potential for pesticide resistance and pest resurgence caused by destroying beneficial organisms;
- Reduced risk of negative environmental impacts, such as water contamination, from poor pesticide use;
- Reduced risk of user and bystander contamination;
- Reduced risk of users and their families developing health problems;
- Increased consumer confidence in the safety and quality of food and fibre products; and
- Increased access to national and international markets, as more buyers demand that IPM practices be followed.

As a result, IPM helps to address the following Sustainable Development Goals directly, through supporting crop yields and human and environmental health and safety:

- SDG 2: Zero Hunger

- SDG 3: Good Health and Well-Being

- SDG 6: Clean Water and Sanitation

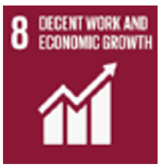
- SDG 14: Life Below Water

- SDG 15: Life on Land

Indirectly, through impacts on sustainable production, improved income, reduced handling of hazardous material and wider environmental impacts resulting from maintaining yields:

- SDG 1: No Poverty

- SDG 8: Decent Work and Economic Growth



- SDG 12: Responsible Consumption and Production

- SDG 13: Climate Action

What IPM is and what it is not

Sometimes IPM is assumed to be the same as organic or biodynamic agriculture, but this is not the case. IPM embraces organic and biodynamic agriculture, but is not limited by them. Each is described below.

Biodynamic farming

Biodynamic farming is a holistic, ecological and ethical approach to farming. It regards the farm as an integrated organism made up of:

- Fields,
- Forests,
- Plants,
- Animals,
- Soils,
- Compost,
- People, and
- The spirit of the place.

Biodynamic farming was first developed in 1924 by Rudolf Steiner, and was the start of the organic agriculture movement. Biodynamic plants are grown in living soil, providing health and nutrition quality that was said to not be possible with chemical fertilizers or hydroponic growing. Fertility is maintained through:

- Composting,
- Integrating animals,
- Cover cropping,
- Crop rotation, and
- Natural products.

Genetically-modified organisms and synthetic pesticides cannot be used. Although biological control can be used, natural control through maintaining a natural balance is preferred. Farms can be certified as biodynamic.

Organic argiculture

Organic agriculture is described by Organics International (IFOAM) as:

> A production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved.

Chemical fertilisers and pesticides are severely restricted, but some are allowed, mainly those that are natural in origin, such as copper and sulphur. Genetically-modified organisms are prohibited in organic agriculture. Farms can be certified as organic under several different schemes.

IPM

IPM uses a range of strategies and tools to manage pests, which can include synthetic chemical inputs, but non-chemical management practices are preferred. When inputs are used, they must be handled safely and used responsibly. Genetically-modified organisms can be used in most IPM systems. Many sustainability certification schemes require IPM to be followed.

IPM can be implemented within the rules of biodynamic and organic agriculture, but the range of tools that can be used are limited. It is generally accepted (but not universally accepted) that yields from biodynamic and organic agriculture are lower than those that can be obtained from conventional agriculture that uses IPM. The net result is that biodynamic and organic agriculture normally will require more land to achieve the same total yield as conventional agriculture.

Complete Activity 1.1 in your workbook.

Summary

In this session you have learnt what IPM is and is not, and how it supports sustainable agriculture and benefits farmers. IPM uses a range of tools and is based on the principle that pests should be managed rather than eradicated. It considers impacts on human health and the environment. You should now be able to explain the benefits of IPM to farmers and why they should adopt it, including reducing production costs and optimizing yields.

Complete the summative assessment in your workbook.

Study Unit 2: Implementation of IPM

Study unit outcomes

After completing this study unit, you should be able to:

1. Describe the three components of IPM in detail
2. Describe the different options available to farmers.

Introduction

Implementing IPM requires three components:

- One: Prevention aimed at preventing the build-up of pests. This includes understanding factors such as the local conditions (agroecology), selection of varieties, crop rotation (where possible) and crop management.
- Two: Monitoring the crop for pest and natural control mechanisms, and damage. This involves regularly inspecting the field, monitoring weather conditions, identifying issues and making decisions on whether action is needed.
- Three: Intervention when needed (using mechanical, biological or chemical measures) to prevent unacceptable losses to yield or quality. This involves choosing action to carry out, planning the approach, and implementing any actions responsibly

These are explained in detail below, and also in the following video:

https://www.youtube.com/watch?v=RdWny0BsDhM

Session 2.1 Prevention

Session outcomes

After completing this session, you should be able to:

1. Understand what prevention involves
2. Know the different options that can contribute to preventing pest infestation

Introduction

Prevention is all about growing a healthy, robust and productive crop that does not provide either a source of pest infestation or become more attractive to infestation. A healthy crop is also more resistant to and able to recover from pest damage. There are several elements involved in this process.

Crop location

Growing crops that are best suited to the climate, soil type and topography provides them with optimal conditions. The choice of location is not normally an option for the majority of farmers. In these cases, the situation of their land must determine what crops are most likely to thrive and what practices are needed to maintain soil health and productivity.

Land preparation

Good land preparation is essential for robust plant growth. For example, proper flattening and puddling of a rice paddy field ensures robust and even growth. Cultivation techniques can also prevent pests from carrying over from one season to the next. For example, traditional ploughing turns the soil and buries crop residues and weeds, which rot before the seed bed is prepared for the next crop. This also exposes soil dwelling insects so they can die or be eaten by predators.

However, there has been a trend to reduce or even completely stop tillage as it leads to:

- Increased soil erosion,
- Loss of soil moisture, and
- Loss of organic matter and sequestered carbon.

In this case, direct seed drilling with the previous crop residues still in the field is carried out. This is facilitated by using herbicide-tolerant biotech crops, which allow the weeds that germinate in the field to be easily controlled in the new crop. The choice of whether to till or not depends on the particular growing conditions, pest problems and tools (such as herbicide-resistance varieties) available.

Seed/variety selection

Choose a crop/plant variety suitable to the local conditions to ensure robust growth. However, if it is available and appropriate, a pest resistant variety should also be considered. In both cases, these varieties can be derived from traditional cross-breeding or modern breeding and biotechnology. You will learn more about this in a later section of this module.

Regarding seed, use good quality and certified seed as much as possible. These are more likely to result in good germination and seedling strength, which avoids the variable crop that can result from replanting or poor growth. It also ensures that the crop seed is free from weeds and diseased seeds. If self-saved seed is used:

- Collect it in a way that reduces or eliminates the presence of weeds and diseased seeds,
- Store it properly before use, and
- Test is for germination before use if possible.

Strategic planting and crop rotation

Avoid planting similar crops together and in subsequent seasons as this can substantially increase pest presence. An example of this is tomatoes and aubergines, which are both from the plant family *Solenaceae*. However, some crops will deter pests from another crop. For example, encourage the planting of onions next to or as an intercrop with other vegetables where possible. In some regions, farmers sow these different crops in alternate rows instead of plots side-by-side. Under-sowing a crop like maize with a legume like cowpea improves soil fertility because legumes trap nitrogen, which acts as a natural fertilizer for the maize. The under-sown crops also reduce weeds. Ideally, crops should be planted synchronously on all farms in a growing area to avoid pests from migrating from a harvested field to a nearby field with a crop at a susceptible growth stage. This is a particular issue with asynchronously planted rice. Synchronous planting requires agreement and co-ordination among farming communities and can be facilitated through farmer clubs or local regulations. The timing of planting is also important, because planting earlier or later in the season can avoid periods of peak pest attack. The flexibility to do this depends on the length of the growing season and the availability of plant varieties that can crop within a shorter period.

Growing different crops in rotation also helps to reduce the build-up of pests, especially pests that live in the soil like root feeding insects, fungi and nematodes. It can also reduce the build-up of weeds.

Sanitation

Sanitation is trying to remove all sources of pest infestation where possible. Examples of this are:

- Removing crop residues that could be diseased or contain pest insects. However, this removes a source of soil organic matter, so approaches such as ploughing in may be preferable to incorporate the remaining plant material in the soil. It also leaves the soil surface exposed, which increases the risk of soil erosion caused by wind or water run-off. Composting the residues is another option, but must be done properly so that the rotting compost heats up to a high enough temperature to kill pests and pathogens.

- Removing pest infested fallen fruit.
- Removing vegetation that surrounds the crop and acts as an alternative host for pests or a source of weed seed. The surrounding vegetation may also be a source of beneficial organisms, so only the plants known sources of pest infestation must be removed.

Optimising plant nutrition

Different soil types contain varying amounts of nutrients. When the crop is harvested, nutrients are removed from the agroecosystem, which need to be replaced with mineral (inorganic) or organic fertilizers. For good crop growth, it is important to ensure that the essential nutrients area available in the right amounts. Fertilizers need to be:

- The right type,
- Applied at the right time,
- Applied in the correct amounts, and
- Applied to the right place.

This ensures that good plant growth and avoids negative effects. For example, excessive or poorly applied fertilizer can lead to run-off, which results in eutrophication in water, which is when water contains too many minerals. If organic fertilizer that has not decomposed before is applied to a field of rice before it is flooded, this leads to anaerobic decomposition, resulting in the production of methane, which is a potent greenhouse gas. In some crops, like rice, too much nitrogen fertilizer causes excessive leafy growth that promotes pest build-up. Both too little or too much fertilizer are detrimental to the crop and increase pest problems. Soils should be tested for nutrient levels. This is ideally done using a soil testing kit, but can also be done using a leaf colour chart in some crops, or testing the foliar concentration of nutrients. Based on the results, the right type and amount of fertilizer can be applied. Timing should be based on the stage of crop growth or season and following recommendations from the local extension services, which may also carry out soil testing. If no soil testing is done, recommendations from the local extension services should be followed.

Figure 1: Soil Test Kit Leaf Colour Chart

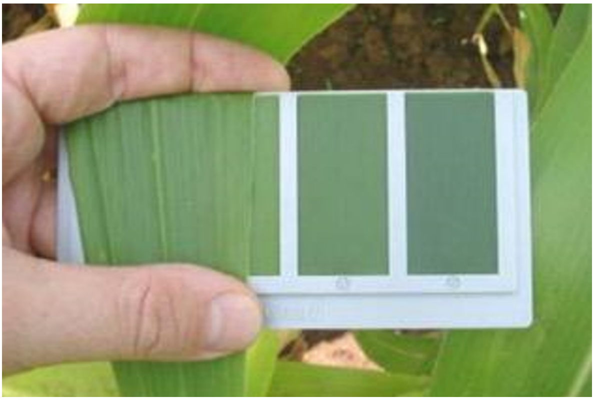


Figure 2: Leaf Colour Chart

Some new plant varieties are more efficient at the uptake of nutrients and should be considered if they are available.

Water management

Supplying water to crops is essential to plant health, and can also influence

- How likely pests are to appear,
- How the pests will impact the crop, and
- The number of beneficial organisms that will appear.

Irrigation is often used where water supply and associated infrastructure is available, which allows for effective water management. Drip irrigation or growing crops on ridges or raised beds helps to conserve water. However, some crops are flood irrigated, like paddy rice, which can help to control weeds, but wastes water, deteriorates soil structure and can negatively affect beneficial organisms. Using alternate wet and dry cycling can make this more water efficient. Poor irrigation (too little or unevenly distributed water) can lead to soil salinisation. Water management should follow recommendations from the local extension services and depends on the crop, variety, available tools and equipment, and the water supply and rainfall.

Soil management

Healthy soil is essential for sustainable and productive crop growth. Soil supports physical, chemical and biological processes, such as providing root support, nutrients, water and gas exchange (oxygen and carbon dioxide). To maintain and improve soil function, soil cultivation practices should be designed to help maintain the appropriate soil structure (including micro- and macropores) and the soil ecosystem (insects, earthworms, nematodes and microbes). Good structure helps the availability of water and gases to plant roots, the living soil ecosystem makes nutrients available, as well as providing a source of natural pest control. Balanced soil fertility management and providing inputs of organic carbon are both essential to prevent degradation through nitrogen and carbon loss (sometimes called mining the soil). Generally, healthy soils are maintained through:

- Avoiding soil compaction (caused for example through poor use of machinery),
- Good drainage to prevent flooding and compaction,
- Crop rotation,
- Reduced tillage, and
- Increased organic matter inputs.

Preventing wind and water erosion through practices such as maintaining cropping cover, proper land preparation (such as levelling), contour farming and terracing

Proper choice and use of chemical inputs (fertilizers and pesticides), when they are needed

Preserving and enhancing biodiversity

Preserving biodiversity in and around the field helps to maintain beneficial organisms that are important to keeping pests below threshold levels. Protecting natural habitats near farmland is the best way to preserve biodiversity. Good management of farm land margins, such as trees, hedges, and unfarmed land, helps to provide cover and food sources for beneficial insects and animals that help to suppress the pest population. These areas also provide a source of recolonisation for beneficial organisms in the field when it has been disrupted. An example of disruption is chemical pesticide application. However, surrounding vegetation may also be an alternative host for pests, which also should be taken into account when considering management options.

Biodiversity can be enhanced by deliberate actions, such as:

- Planting wild flowers around a crop to attract beneficial insects that control pests and act as pollinators.
- Leaving uncultivated strips at intervals through the crop (sometimes called beetle banks) or uncultivated headlands.
- Encouraging predators, such as birds, by placing nesting boxes or bird perches.

A balance must be drawn between these factors. For example, leaving or planting wild plants on bunds (the earth constructed water containing wall around a rice field) on a rice paddy attracts beneficial insects, but they also provide a habitat for rats in rat-prone areas.

Seed treatment

Seed treatment is applying physical, biological or chemical agents to the seed or other planting material before sowing to suppress, repel or control pests (both pathogens and insects) or enhance growth. This is normally done when there is a very high probability of significant pest infestation. While this could be described as an intervention, it is better described as a preventive measure, as it is based on the prediction that a pest infestation will occur. Examples include treating seeds with hot water to reduce the chance of disease. However, soil-borne fungi attack some hot water treated seeds more severely than untreated seeds, and these seeds should also be treated with a protectant before planting. Several biological treatments have been used, like *Trichoderma* species to control wilt, blight and root rot in pigeon peas. There are many chemical seed treatments available for disease control and control of soil pest insects, such as wireworms. Seed treatments are also carried out using systemic insecticides (pesticides that move into the plant itself) to control sucking pests after the plant has germinated.

What prevention method to choose?

In conclusion there are several management actions that can be taken to help prevent pest outbreaks. Deciding what can be implemented depends on:

- The crop,
- The agroecology (location and climate),
- The likely pest pressure or population density, and
- The resources available.

Normally several methods will be used. Seek advice from local experts, when available. Many of the actions that constitute good agronomic practices will improve crop yields and quality, even in the absence of pests.

Complete Activity 2.1 in your workbook.

Session 2.2: Monitoring

Session outcomes

After completing this session, you should be able to:

1. Explain the different methods of monitoring the crop for pest attack
2. Use the information obtained to decide whether or not to intervene with pest management actions.

Introduction

The crop must be observed regularly to determine whether action or intervention must be taken to prevent economic damage to the crop, and what that action or intervention should be. This involves:

- Assessing how well the crop is growing,
- Assessing what damage is occurring, and
- Relative numbers of pests and beneficial organisms.

Monitoring can be done

- Directly by scouting the crop;
- Indirectly, by using techniques like trapping;
- Predictively, using models based on weather and local history of outbreaks; or
- Using remote sensing

Monitoring methodology

Field scouting

Field scouting is the most common method of monitoring. It is when samples (normally ten) are taken at intervals in the field. The intervals could be in a fixed pattern or taken randomly, as shown in Figure 3, Figure 4, and Figure 5. The observations must cover all parts of the field except the edges. Observations are made at regular times (normally weekly) throughout the season. If something cannot be identified by the farmer, it must be collected to show to neighbours, extension agents, pest management experts or other people, such as pesticide retailers, for identification. There are also online tools and apps that help to identify pests and beneficials, such as Plantwise (https://www.plantwise.org), which also has advice on management options.

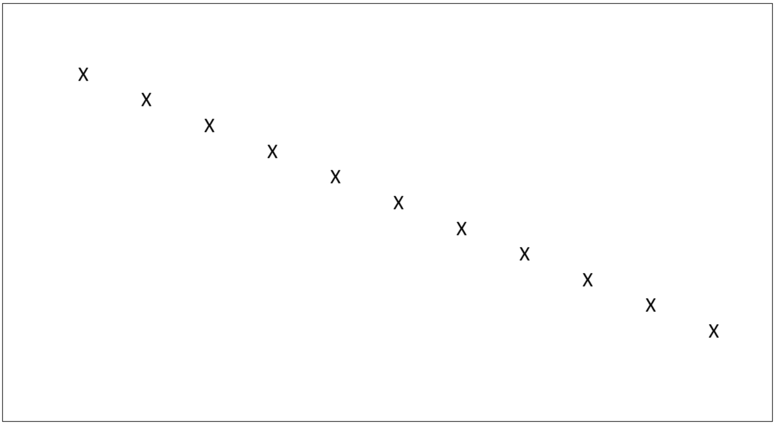


Figure 3: Diagonal pattern

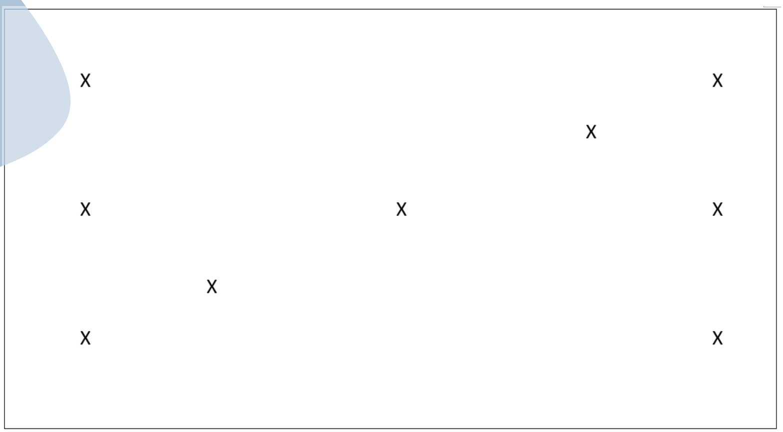


Figure 4: "Z" pattern

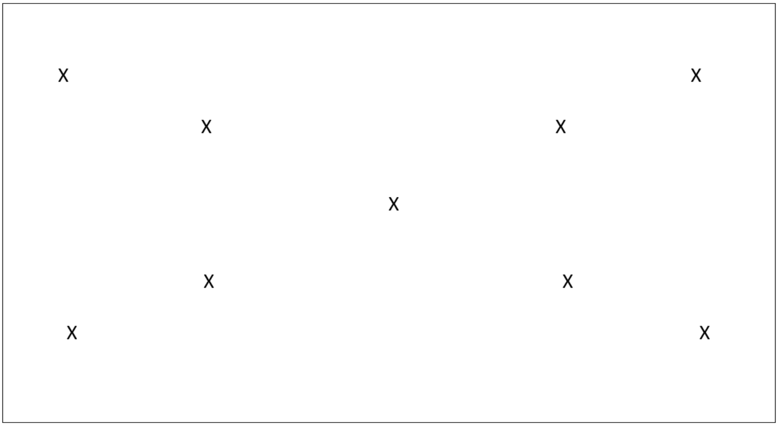


Figure 5: "X" pattern

Each pattern has advantages and disadvantages. The diagonal ignores the bottom left and top right of the field, the Z pattern may over-emphasise the field edges, but in both cases, there may be a reason to do this. Sampling can also follow a random pattern, but this should be done in such a way so that the whole field is covered.

Figure 6: Field monitoring in rice

Trapping

Insect pests can be monitored through trapping. One method using pheromones traps. Pheromones are chemicals released by insects that affect the behaviour of other individuals of the same species. These chemicals have been identified and synthesised for many insect species. An example is a trap with a lure containing female moth sex pheromones to attract male moths. One trap per hectare is placed in the field and the traps are inspected regularly for presence of moths.

Another form of trapping is coloured sticky traps, which are often used for sucking insect pests. Yellow traps are the most common and they attract thrips, aphids and whitefly, among other pests. Blue traps attract western flower thrips. Unlike pheromone traps, both pest and non-pest species may be attracted, including some beneficial insects, so the species trapped must be accurately identified. Trap density ranges from around 2 to 10 per hectare.

Trapping helps to determine population trends rather than actual pest numbers on the crop. Based on these trends, further monitoring actions, such as scouting, or control measures may be necessary. An example is monitoring the overwintering emergence of pink bollworm from previous crop residues, and controls measures are initiated, such as mating disruption.

Figure 7: Pheromone funnel trap

Figure 8: Yellow sticky trap

Remote sensing, precision agriculture and modelling

Remote sensing is being used more frequently to monitor crops for pests and damage. While this technology is not readily available to smallholder farmers, smart phone apps are being developed, which means that it will be used more in the future, including for pest identification (see https://www.rtb.cgiar.org/news/revolutionary-mobile-app-monitoring-crop-pests-diseases/).

Modelling is already used for some pests. For example, weather data, like rainfall and temperature, can be used to predict outbreaks of potato blight and can help to determine whether intervention is needed. For smallholder farmers, extension services will use these approaches and they will advise farmers on what action may be needed.

Analysing results

Direct scouting (with or without trapping)is the most common monitoring method used by smallholder farmers. Observations must be noted on a form that include the following:

- Farm, plot, and date,
- Crop, variety, and stage of growth,
- Scouting method used,
- Pests observed (including the stage of development),
- Number/severity of pests,
- Crop damage observed,
- Comments,
- Beneficials observed,
- Number of beneficials,
- Comments,
- Diagram showing the location of pests/damage in field, and
- Decision on the need for intervention based on threshold.

Additionally, a picture of a crop plant showing damage, pests and beneficials can be drawn to help decide whether intervention or agroecosystem analysis is needed. This is commonly used in farmer field schools (FFS).

Figure 9: Picture summarising field monitoring results

How to decide if there is a need to intervene

After each monitoring exercise, a decision is made on whether intervention is needed. This will be influenced by several factors, including:

- Is the pest population or the beneficial organisms increasing or decreasing?
- If crop damage has been noticed, is the pest that caused the damage still present and in numbers to cause more?
- Are the weather conditions likely to cause an increase or decrease in pest numbers?
- What is the stage of the crop? Is it likely to recover from pest attack? Is it close to harvest?

The main decision-making tool is the economic threshold, which is sometimes called the action threshold. This is the pest density where intervention must be considered to prevent the pest population from increasing to a level that will cause significant losses to yield or quality, which is called the economic injury level. This is defined as the lowest number of pests or injury that will cause yield or economic losses equal to the pest management costs. The thresholds take into account the cost of any action that might be taken. It is not in the farmers interest to carry out pest control measures that cost more than the value of the crop that will be lost due to pest attack. The exceptions to this are:

- If control will prevent losses to other crops on or outside the farm; or
- If it is essential for food security.

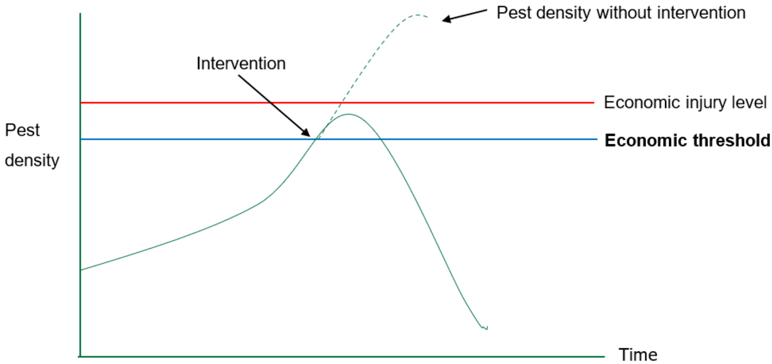
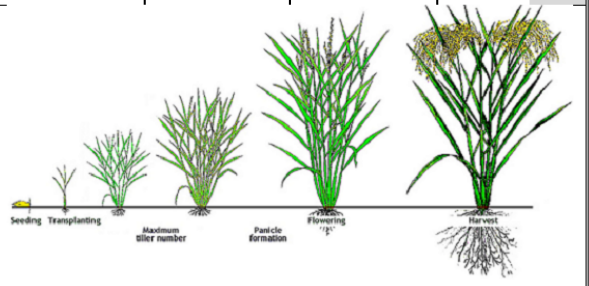


Figure 10: Economic injury level and economic threshold

The economic injury level and the threshold vary according to the stage of the crop and the various factors discussed above. The local extension service or pest management experts should make the information on thresholds available. An example for rice in Vietnam is shown below. It shows the information for several pests, which illustrates these principles.

Crop stage	**vegetative phase: first 40 days.**	**40 days (tillering) to booting**	**booting to flowering**	**Ripening**	**
Key: Pesticide application Avoid if possible or Unlikely to be effective Do not apply pesticides **Pest:**	 				
Plant-hoppers: BPH, WBPH		2-3 insects /tiller if virus diseases are not present on farm (see module 5).			
BPH, GLH & other hoppers: **virus risk**	ONLY in response to warnings from local authorities (agricultural officers) or when symptoms seen in fields				
Leaf-folder and other leaf feeders *		100 living insects per m^2	40 living insects per m^2		
Stem borers		2 egg masses per m^2 (see parasitism¶)	one egg mass per 2 m^2 ¶	Too late for effective control	
Thrips		**Insecticides mostly ineffective or not economic to control**			
Gall midge					
Panicle rice mite/ sheath rot		**identify problem** if > 5% flag leaves with lesions (pesticides probably not effective)		Too late for effective control	
Rice blast (with **susceptible varieties**)	Progressive scouting (see module 7) increasing lesions on 10% of leaves: 10 leaf samples in 4 sides of the field		Spray max. 2 X for neck blast if disease present and humid	Max. 3 sprays / season	
Bacterial leaf blight		Chemical controls have limited efficacy: only apply at early stage of disease			
Late season pests: especially **rice bugs**			10 insects per m^2: at milky stage (7-10d after flowering)		
Herbicides	if direct seeded				
Golden Apple Snails	GAS: 10 /m^2 if >1 ha				
Rodents	Community strategy at early stage			Not effective	

Complete Activity 2.2 in your workbook.

Session 2.3 What intervention?

Session outcomes

After completing this session, you should be able to:

1. Understand the different interventions that can be made
2. Understand the advantages and disadvantages of the various interventions

Introduction

Once the decision has been made to intervene, the next decision is what intervention to make. There are three kinds of that can be made, either alone or in combination:

- Cultural/mechanical control:
  - Cultural practices normally fall under prevention, but some can be used as intervention, such as flooding a rice field to control weeds.
  - Mechanical control, sometimes called physical control, uses farm machinery/tools or manual methods of control, such as collecting moth eggmasses by hand.
- Biological control uses living organisms or the products from living organisms to control pests.
- Chemical control uses organic or inorganic chemicals to control pests.

Advantages and disadvantages of control mechanisms

Each of these methods has advantages and disadvantages, as summarised in this table.

Table 1: Advantages and disadvantages

Control mechanism	Advantages	Disadvantages
Cultural/ Mechanical	• Often no inputs required • Generally no health hazards • Little negative impact on the environment and non-target organisms • Usually, less costly	• Can be labour intensive • Timing can be important • Manual control can lead to skeletal/ muscular fatigue
Biological	• Generally no health hazards • No negative impact on the environment and non-target organisms • Can lead to long-term control • Slow development of resistance	• Generally slow-acting • Availability is uncertain • Timing can be important • Can be expensive

Control mechanism	Advantages	Disadvantages
Chemical	• Normally (but not always) fast acting • High level of control • Can control several pest species	• Some risk to human health and the environment • Risk of rapid resistance development, which decreases effectiveness • Impacts beneficial organisms, which encourages other pest outbreaks or target pest resurgences.

The choice of intervention depends on:

- The effectiveness of the method,
- The cost of the method,
- The risks to human health and the environment,
- The value of the crop and the urgency of control, and
- The availability of different options.

Control mechanisms that have the lowest risk to human health and the environment must be considered first, which are the cultural/mechanical methods and the biological methods. However, depending on available options and stage and type of pest attack, these may not be viable options. If cultural/mechanical and biological methods are not appropriate, chemical control must be considered. Where possible, a specific product rather than broad spectrum product. It must be applied in a way that that minimises the impacts on human health, non-target organisms and the environment. This is an important aspect of IPM, as the most common method of intervention currently used is chemical control.

Cultural/mechanical control

Cultural and mechanical control methods consist of using manual or machine labour, or physical barriers to control or manage the pest. Examples are:

- Hand-picking insect or snail eggs off leaves or other structures,
- Hand-picking diseased leaves or fruits (including collecting fallen fruit),
- Pruning diseased branches from trees,
- Hand or machine hoeing weeds,
- Physical barriers and traps for rats,
- Netting covering crops for birds and flying insects, and
- Roguing (physically removing) badly affected plants.

Biological control

Biological control agents are very specific, which means they might only affect a single species. They occur naturally, or are made from naturally occurring organisms, and present no or very limited risk to humans or the environment. However, this must be confirmed through standard testing and all commercially available biological control agents should have undergone this testing. The main types of biological control agents are shown in Table 2:

Table 2: Main types of biological control agents

Agent	Description
Macrobial	Beneficial macro-organisms, such as insect predator beetles (including ladybugs) that eat insect pests and include insect parasitic/parasitoid wasps that lay eggs in or on insect pests.
Microbial	Mirco-organisms, including insect pathogenic viruses, bacteria and fungi, and other micro-organisms, that are harmful to other pests such as weeds and to the fungi that cause plant disease. Insect pathogenic nematodes are also often considered microbial agents, as most enter the insect and release bacteria that kill the host.

Agent	Description
Semio-chemicals	Mainly insect sex pheromones, that can be used to disrupt mating applied over a large area to prevent males from finding females, or mass trapping insects. Various natural chemicals have also been used to trap fruit flies.
Botanical	Plant extracts, like from neem seeds or leaves, that have been shown to have pesticidal or repellent properties. Plant extracts are also used to attract some insect pests away from the plant, or attract beneficial insects, (called food sprays). In some cases, like neem, the main active ingredient in the plant extract has been isolated and synthesised.
Metabolites	Chemical pesticides produced from living organisms, for example by fermentation of the bacteria *Saccharopolyspora spinosa* to produce spinosad.
Insect growth regulators	Chemicals that mimic the activity of insect hormones, slowing down or stopping the life-cycle of the target. These work by disrupting insect moulting (stopping the juvenile hormone that triggers moulting into a larger larval form or inhibit chitin synthesis so that the insect cannot moult successfully to the next instar) or ecdysone (stopping the transformation of larval tissue to adult tissue during pupation). This group of products is a low-toxicity synthetic chemical insecticide.

Strategies for biological control

Approaches to biological control can be differentiated between whether they use macrobial or microbial agents for classical biological control or augmentative control, which can be used for all biological control agents.

Classical biological control is normally attempted when a new or invasive pest becomes established. The origin of the pest is identified and then natural enemies in the region of origin are searched for. After extensive safety testing to ensure there are no undesired effects, they are released into the area where the new pest has become established. The best known example of this is release of a parasite against the cassava mealybug in Africa. Both the pest and the parasite originated in South America, which is also the origin of cassava. Such strategies are usually coordinated or regulated, by public organizations at a regional, national or even continental scale. They are thus not normally undertaken by smallholder farmers.

The other main strategy is augmentative biological control. This is where release or application of biological control is undertaken to either bolster existing beneficial populations and/or when the action threshold is reached. Inoculative augmentation is when a release/application is made once per season and control is maintained by reproduction of the biocontrol agent. Again this is limited to macrobial and microbial organisms. Inundative releases, which is the most commonly approach, is where releases happen several times a season, based on the action threshold. The action threshold for biological control agents is often lower (but not always) than chemical agents, as they generally take longer to impact the pest population. This information must be on the product label, or available from the manufacturer or retailer.

For pheromones and some trapping techniques the management agent is maintained throughout the pest generation. Examples include mating disruption for pink bollworm in cotton, where the sex pheromone is regularly applied during the growing season to prevent male moths locating and mating with female moths, and traps baited with an attractant that lure and trap fruit flies.

Chemical control

Chemical control uses one of two types of pesticides:
- Inorganic pesticides, or
- Synthetic chemical pesticides.

Inorganic pesticides are derived or refined from non-living natural sources. They are called inorganic because they do not contain carbon compounds. Many of them contain heavy metals that are persistent and toxic to humans.

Synthetic chemical pesticides (sometimes called synthetic organic pesticides) are produced by chemical synthesis and generally contain carbon. They vary widely in how toxic they are to humans.

The terms organic and inorganic lead to confusion within organic agriculture, where some inorganic chemicals can be used, such as copper sulphate and sulphur. Generally, synthetic chemical pesticides can be used in conventional agriculture and naturally occurring chemicals or those synthesised from natural sources can be used in both organic and conventional agriculture. In this section, chemical pesticide refers to both, as both types require the same testing and approval and have potential similar risks.

Types of chemical pesticides

The main types of chemical pesticides are:
- Fungicide to control fungal diseases,
- Herbicide to control weeds,
- Insecticide/acaricide to control insect and mite pests,
- Molluscicide to control slugs and snails,
- Nematicide to control disease causing nematodes (some nematicides are also insecticides), and
- Rodenticide to control rodents such as rats.

Each type of pesticide includes several different pesticides that act in different ways to produce the desired result. For example, some may prevent or slow down protein synthesis or cell division, disrupt cell membranes or interfere with nerve signals among many other mechanisms. This example is what is called the mode or site of action (MoA), which is the biochemical process by which a pesticide disrupts normal pest biology and usually causes the pest to die. Normally this is a target protein binding site or a key biological process. MoAs are classified by the Insecticide, Fungicide and Herbicide Resistance Action Committees (IRAC, FRAC and HRAC) and are designated by a code (a number or letter), which is usually shown on the pesticide label. It is necessary to understand MoA to manage pesticide resistance.

The MoA, along with other pesticide properties, depends on the chemistry of the pesticide. There are many different chemistries, for example:

- Insecticides include:
  - Organoposphates,
  - Organochlorines,
  - Cabamates,
  - Neonicitinoides, and
  - Pyrethroids.
- Herbicides include:
  - Triazines,
  - Sulfonylureas, and
  - Phosphono amino acides.
- Fungicides include:
  - Triazoles,
  - Benzimiazoles, and
  - Strobilurines.

Pesticides can also be classified by how the pesticide reaches the target pest. This is called the method of dose acquisition. For insecticides this can be by:

- Direct contact, where a pesticide spray falls directly onto the insect;

- Secondary contact, where the insect touches a deposit on a surface like a leaf or a fruit;
- Ingestion, where the insect eats a deposit;
- Fumigant action, where the insect breathes in the vapour of the pesticide; and
- Repellent, where the insect is repelled from the pesticide deposit.

Fungicides affect disease development by:
- Protecting the crop by stopping fungus spores from infecting the plant by various methods, for example by preventing gemination.
- Curing a disease by entering the plant and stopping the infection. A pesticide that enters the plant and transported throughout is called a systemic pesticide.

Herbicides kill weeds by:
- Contact action, where the herbicides kill the plants by touching them; or
- Translocation, where the herbicide moves through the plants to the roots and kills them.

Both rodenticides and molluscicides kill by the target ingesting the substance, and nematicides kill by contact action.

Pesticides can be classified by their spectrum of activity, which means how many species the pesticide effects:
- Broad spectrum pesticides affect many species, including beneficial species.
- Specific pesticides affect few species, and are generally safer to non-target and beneficial species.

Older chemical pesticides tend to be broad spectrum pesticides. If possible, a specific pesticide should be used in IPM programmes.

Finally, pesticides are also classified according to their hazards to human health and the environment.

Choice of chemical pesticide

A product must be used in a way that:
- Is effective against the pest,
- Is cost effective, and
- Minimises potential risk.

The general principles are:
- The right type of pesticide for the pest must be chosen (insecticide for insects, fungicide for fungi, herbicide for weeds and so on) that is registered for use against the target pest on the crop and with a specific type of application.
- The pesticide must optimise control, like choosing a systemic insecticide for sucking pests or choosing a systemic fungicide that will cure fungal infections.
- The pesticide should be:
  - As low hazard as possible,
  - A formulation that is safer to handle and use, such as wettable granules,
  - A formulation that increases the bioavialability or improves the action of the active ingredient
  - Used for specific activity rather than broad spectrum activity, and
  - Have safer packaging, for example for small holder farmers, as small packs are easier to handle for measuring and mixing. For example, a sachet containing one backpack sprayer dose, particularly if the package is made of water-soluble material that can be put straight into the sprayer
- If a pest needs to be controlled several times, rotate different active ingredients with different MoAs to delay resistance build up.
- Decide whether to spray the whole field, or to spot spray (only spraying the area where the pest is located) and leave some beneficial organisms unaffected, which uses less pesticide, reduces environmental risk and saves cost.
- The user should always read, understand and follow the instructions on the pesticide label.

Use the least toxic or least hazardous product that is still effective. Consider the likelihood of resistance development and the requirements of produce buyers (some of their requirements prohibit the use of certain pesticides). Advice can be provided by local extension services, the pesticide retailer or other experts.

Complete Activity 2.3 in your workbook.

Summary

In this unit you have learnt about the different interventions that can be made. They provide different levels of pest control and have different risks. Your choice will depend on a balance between the two, considering their advantages and disadvantages, availability and cost.

In Session 2.3 the different ways chemical pesticides can be classified was explained. This is important for you and the farmer to know because it provides information on hazards and how a pesticide works, which are major factors of pesticide choice.

Complete the summative assessment in your workbook.

Study Unit 3: Responsible Use of Pesticides

Study unit outcomes

After completing this study unit, you should be able to:

1. Understand the hazards and risks posed by pesticides
2. Know how to manage the risks

Introduction

The first rule of responsible use and IPM is that chemical pesticides, or any control intervention, should only be used when necessary, which is when an action threshold is reached. If the decision has been made to use a chemical pesticide, it must be handled and used responsibly, and at the correct dose, to minimise risks to human health and the environment.

The responsible use of pesticides is an important part of IPM, which helps to manage risk and keep it at an acceptable level where the benefits of pesticide use outweigh the risks.

Session 3.1: Pesticide poisoning

Session outcomes

After completing this session, you should be able to:

1. Recognise possible pesticide poisoning and know how poisoning can occur
2. Understanding what determines the risk
3. Knowing the general principles of reducing risks from pesticides

Session introduction

Pesticide poisoning is harmful to health, and can result in a loss of work and income. Improper use of pesticides leads to poor pest management and a loss of yield. Impacts on the environment, such as destroying beneficial organisms, can result in more pest problems. The most immediate risk is poisoning. It is important for farmers to understand that if pesticides are not handled properly, they can result in poisoning. This is why everyone must follow the required precautions.

Poisoning symptoms

The symptoms of poisoning depend on type of pesticide and exposure and include:

- Skin irritation (reddening, itching)
- Nausea (feeling sick)
- Headache
- Muscle twitching
- Sweating
- Feeling weak
- Coughing
- Burning of throat and lungs

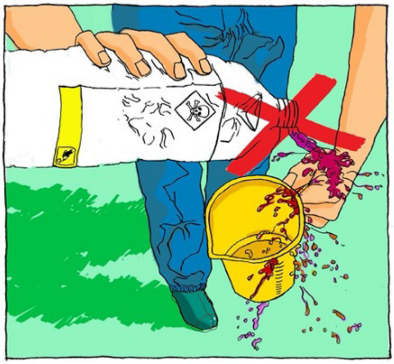
- Eye irritation
- Blindness

Some of these symptoms also occur for other reasons such as heat stress, so a doctor must always be consulted.

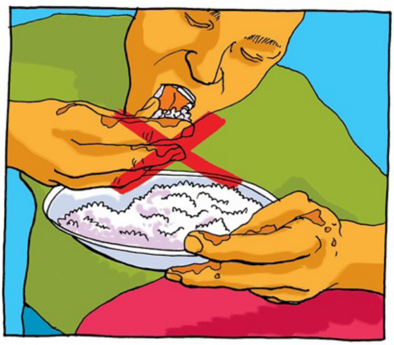
How do pesticides enter the body?

Pesticides enter the body through three main routes:

- Through the skin – many pesticides are designed to move from the surface of the pest to its interior, and it is similar for humans, so they can be absorbed through a person's skin or eyes.



- Through the mouth – by swallowing or by the pesticide coming into contact with a person's mouth.



- Through the lungs, if the person breathes in dusts and vapours.

Although ingesting or breathing in pesticides are the most dangerous routes to poisoning, the highest risk of contamination during normal use is through the skin.

Risk

The risk of using a pesticide is determined by two factors: hazard and exposure.

$$Risk = Hazard\ (how\ poisonous\ the\ product\ is\ \times Exposure\ (user\ contamination)$$

Handling and using pesticides safely reduces the risk from all products. Risk is also reduced by using less hazardous pesticides. The riskiest step in pesticide use is mixing and loading the pesticide to the sprayer because the concentrated pesticide is being handled.

Risk reduction through responsible handling and use

The nine steps of responsible use are shown in Figure 11.

Figure 11: The nine steps of responsible use

Complete Activity 3.1 in your workbook.

Session 3.2: Read and understand pesticide labels

Session outcomes

After completing this session, you should be able to:
1. Understand the content of a pesticide label
2. Understand its importance for effective use and handling and application safety.

Introduction

The pesticide label contains important information on:
- The nature of the pesticide,
- What it should be used for, and
- Its proper and effective use, including:
  - The basic requirements for handling the product safely, and
  - The basic requirements for using the product safely.

Not all pesticides are the same, so the label must be consulted every time a pesticide is used. If a farmer cannot read or understand the label, they must ask someone who can (like the pesticide retailer) to explain the instructions.

Label content

Most labels include the following information, but the actual content depends on the regulations in each country:
- Product name: The commercial name. It must also state what type of pesticide it is, such as an insecticide, herbicide or fungicide.
- Active ingredient: The common name of the chemical that is effective against the pest.
- Concentration of active ingredient and inert material: The amount (weight) of active ingredient and amount of inert

ingredients or % active ingredient in the inert liquid carrier, given as grams per litre. Different products with the same active ingredient have different concentrations of active ingredient. This will affect the hazard that the product presents and how it is used.

- Crops and pests the pesticide is registered for: A list of crops and pests the product can be used on. The recommended dose varies with each crop/pest combination.
- Dose rates and application volume: The amount of the concentrated product that must be added to the spray solution, for example 100ml/10 litres of water. This will be in ml for liquids, or grams per litre for wettable powders/ granules. It can also provide information on the volume to be applied, which can be a figure, like 400 litres per hectare, or a qualitative statement, for example "Apply at high volume, full cover spray".
- Toxicity and hazard warnings (which normally includes a colour hazard band): Different pesticides have different potential impacts on humans and the environment. In most countries, an indication of the acute human toxicity is included on the label (in future chronic toxicity and environmental impact will also be included). This information is given in the form of hazard symbols and as a coloured band and normally is based on classifications determined by the World Health Organisation.
- Safety precautions, including pictograms: Safety precautions that must be followed to avoid poisoning or environmental contamination. Pictograms are a visual guide to what safety precautions must be followed, normally divided into precautions for handling the concentrated product during mixing and loading and precautions when applying the product.

General safety advice can be provided. The meaning of the common pictograms is shown in Figure 12. Advice pictograms show precautions that should be followed.

	Hazard class				
	Class Ia *Extremely hazardous*	Class Ib *Highly hazardous*	Class II *Moderately hazardous*	Class III *Slightly hazardous*	Class U *Unlikely to present acute hazard in normal use*
Hazard symbol				*No symbol*	*No symbol*
Signal word	Very toxic	Toxic	Harmful	Caution	*No signal word*
Colour band	PMS red 199 C	PMS red 199 C	PMS Yellow C	PMS Blue 293 C	PMS Green 347 C

Figure 12: Common pictograms

Pictograms on pesticide labels

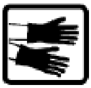
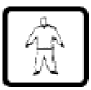
Type	Pictogram and message		
Storage pictograms	 Keep locked away and out of reach of children		
Activity pictograms	 When handling liquid concentrate ...	 When handling dry concentrate ...	 When applying pesticide ...
Advice pictograms	 Wear gloves	 Wear eye protection	 Wear rubber boots
	 Wear protection over nose and mouth	 Wear respirator	
	 Wear overalls	 Wear apron	 Wash after use
Warning pictograms	 Dangerous/harmful to animals	 Dangerous/harmful to fish – do not contaminate lakes, rivers, ponds or streams	

Figure 13: Safety pictograms

On the label, pictograms distinguish between protection for mixing and loading the pesticide and applying the pesticide:

Figure 14: Pesticide label

The following are commonly found on labels:

- Pre-harvest interval (PHI): The minimum number of days between the last pesticide application and crop harvest. This is based on field testing (good agriculture practice – GAP) and ensures that the pesticide residue levels are within acceptable limits. GAP trials determine the maximum pesticide residue level allowed on food crops at harvest. The PHI makes sure the residue levels are below this level.
- Manufacture/release and/or expiry date: The date the product was manufactured or released into the supply chain, and the date until which the product is guaranteed to be within the registered specification and after which it should not be used.
- Registration number: The unique number assigned by the government pesticide registration department when the product has been registered for use. Products without a

registration number should not be used.

- Name of manufacturer: The manufacturer of the product. Sometimes this will also show the importer of the product.
- Note for a physician: Important information for a medic in case of poisoning, which may include the antidote.
- First aid: Emergency first aid that should be carried out immediately if contamination or poisoning occurs.

A number or letter code designating the mode of action (MoA) may also be included. To avoid resistance development, products with a different codes (modes of action) should be used when repeated applications are needed.

Generally, but not always, directions of use are on the left of the label, general information in the centre and safety precautions on the right. This is illustrated below.

Layout of information on a typical pesticide label:

<table>
<tr><td colspan="2">FASTACT EC</td><td>Group 1A Insecticide</td></tr>
<tr><td>Directions for Use
Tomato, Potatoes, cabbage use 100 ml/ha in 100 litre water
Semi-looper
All sprays to be based on scouting,</td><td>Emulsifiable Concentrate

Insecticide Group 3

good insecticide......150g/l</td><td rowspan="4">Precautions:
Handle with care
Wear rubber gloves when mixing and handling
Avoid spray drift
Prevent contamination of food and water
Keep out of reach of children
Wash with soap and water after use or accidental contact
Dangerous to fish
Do not enter treated area within 1 day after treatment unless wearing protective clothing</td></tr>
<tr><td>Pre-Harvest Interval
WITHHOLDING PERIOD: THE FOLLOWING MINIMUM NUMBER OF DAYS BETWEEN LAST APPLICATION AND HARVEST MUST BE ADHERED TO:
Tomato.................5 days
Crucifers (cabbage, broccoli).................3 days</td><td>An emulsifiable concentrate stomach and contact insecticide for the control of various insect pests in vegetable crops</td></tr>
<tr><td>Symptoms of Poisoning
Can cause eye damage
Skin irritation</td><td>Imported and Distributed by:
The Good Pesticide Co Ltd
Sunny Hill Road
Nairobi, Kenya</td></tr>
<tr><td>First Aid
Remove patient from source of poisoning
Keep patient calm, warm and comfortable
In case of eye contact wash with plenty of water and seek medical advice
In case of skin contact wash with soap and water for 15 minutes
In case of ingestion do not induce vomiting.
Administer 1 – 2 glasses of water, and if possible 30 – 50g activated charcoal.</td><td>1 litre</td></tr>
<tr><td>Advice to Physician
No known antidote
Consider gastric lavage avoiding aspiration. Do not give ephedrine or related drugs.</td><td>Manufactured: 12/2018
Expire: 12/2020
Lot: A1956</td><td>Registration no. 12345/2015</td></tr>
<tr><td colspan="3">Pictograms X Pictograms

Harmful</td></tr>
</table>

Everyone who uses the pesticide must read and understand the label, which should be written in the language(s) used locally, to make sure that the correct product is being used for the target pest and that the product is used correctly and safely. If the label instructions are not followed, the product may not work and could be risky to use. In all cases, only genuine, locally registered products can be used. Products with poor quality labels, labels that contain spelling mistakes or bottles that are refilled are more likely to be fake and must not be used.

Complete Activity 3.2 in your workbook.

Session 3.3: Application equipment

Session outcomes

After completing this session, you should be able to:

1. Understand how to choose, maintain and use application equipment, with an emphasis on safety for both users and the environment.

Introduction

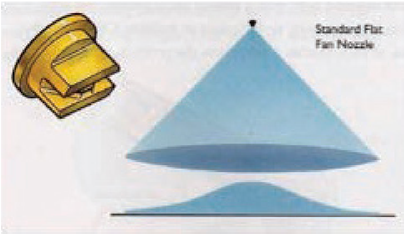
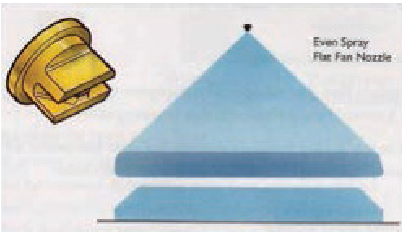
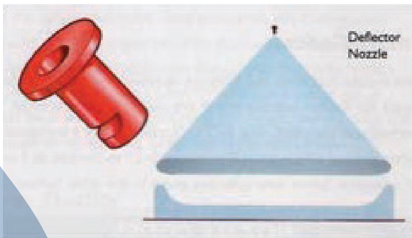
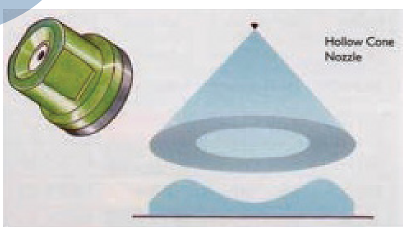
Smallholder farmers are likely to use hand-operated or motorised backpack sprayers. These may leak, which is a major source of contamination for both the user and the environment. Leaking can result from poor maintenance, or poor sprayer design or production. The equipment must be checked for leakage before purchasing. For backpack sprayers, a simple test is to half fill the sprayer with water and turn it upside down. If water leaks out, the spray mixture will also leak out when walking through the field. The sprayer should also be tested when pressurised for spraying and a test spray with water to check the hoses and trigger valve do not leak. Buy or use a sprayer that does not leak.

Choose the correct nozzle

The nozzle determines the shape of the spray cloud and the size of the droplets. Larger droplets drift less and so there is less chance of contamination, but these droplets may provide poorer coverage of the target.

Main types of nozzle for applying pesticides are shown in Table 3.

Table 3: Types of nozzle

Nozzle type	Description
	Flat fan nozzle: Used on boom sprayers where spray from one nozzle overlaps with spray from adjacent nozzles to provide uniform coverage across the boom.
	Even spray flat fan nozzle: Used as a single nozzle on a knapsack sprayer. Provides uniform deposit of spray.
	Deflector (flood jet) nozzle: Used on backpack sprayers. Provides wide coverage and produces large droplets. Appropriate for herbicide application because drift is less likely.
	Hollow cone nozzle: Can be used on a knapsack or boom sprayer. Produces a fine spray.

Recommended nozzles for different pesticide types are given below. In general, the fan nozzle provides a compromise suitable for most situations, but can lead to uneven coverage with backpack sprayers. Nozzles should be replaced when they are damaged or at least once per season. Nozzles are usually sold by the pesticide retailer. Investing in the right, undamaged nozzle helps to ensure good pest control, avoid spray drift out of the crop and to ensure pesticide is not wasted. It therefore saves money in the long-term and minimizes unintended environmental contamination.

Table 4: Nozzle types and uses (recommended pressure is shown in brackets)

Type of nozzle	Herbicide (1 bar)	Insecticide (3 bar)	Fungicide (3 bar)
Cone (small to medium sized drops)	*	***	***
Fan (medium-sized drops)	**	**	**
Deflector(large drops)	***	*	*

*unsuitable

**acceptable

***most acceptable

Sprayer maintenance

Leaking sprayers are a major contamination risk. Leaking is mostly caused by poor quality sprayers that leak from poor seals on the lance, lid and elsewhere. This can saturate protective clothing and result in pesticide coming into contact with the skin, which is a major source of contamination. This can be avoided by:

- Buying good quality sprayers, and
- Maintaining the sprayer properly, including checking and replacing seals

Always check for leaks, as follows:

- Fill the sprayer with water and spray.
- Look for leaks.
- If leaks are found, check or replace the seals, if spares are available.
- Do this on each day of spraying.

Sprayers must undergo a full maintenance at least every season. Maintenance for knapsack sprayer is explained below. For motorised sprayers, maintenance must be carried out by a professional.

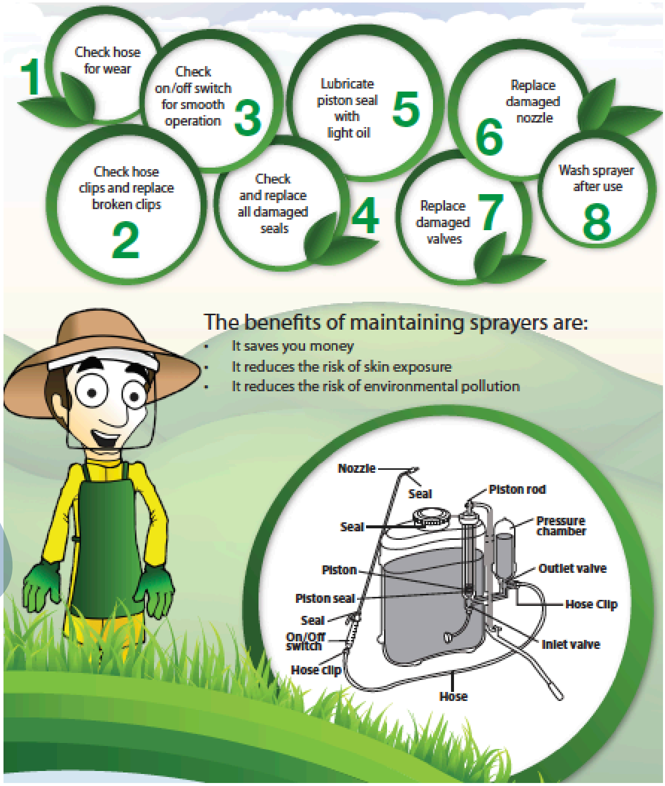


Figure 14: Maintenance of sprayers (Source: Crop Life International)

Calibration

For effective pest control and to reduce the risk of environmental contamination, it is important to apply the right amount of product. Normally, the concentrated product is diluted by mixing it with water and then it is sprayed onto the crop. The amount of diluted spray liquid applied per hectare is called the volume rate. For back sprayer application to field crops, the optimum volume rates are shown Table 5.

Table 5: General Volume Rate for knapsack sprayers

Target type	Volume Rate (litres/hectare, l/ha)
Bare soil and small plants, e.g. Herbicide application to soil or small weeds; or insecticide or fungicide application to young crops	150 – 200 l/ha
Medium sized weeds/crop	200 – 250 l/ha
Dense crop	300 l/ha
Tree crops	300 – 2000 l/ha depending and size and nature of the crop

Note: The pesticide label may recommend what volume rate to use.

The volume rate is determined by:

- The type of sprayer,
- The type of spray nozzle,
- The pressure at which the spray is applied,
- The width of the spray, and
- The speed that the sprayer/spray operator passes through the crop.

The sprayer is calibrated under the conditions that it is going to be used, which will account for all of the above. The simplest way to do this is:

- Spray a known volume of water into the target (either crop or weed) and measure the area it covers, or
- Have a known target area and measure how much water is necessary to cover it.

The application volume (litres per hectare) is the calculated as:

$$\frac{10\,000\ (one\ hectare\ in\ square\ metres)\ \times number\ of\ litres\ sprayed}{Area\ sprayed}$$

If the volume is very different from the amounts shown in the table, either change the nozzle or adjust your walking speed.

The applicator can determine the volume required to spray the area to be treated:

$$Application\ volume\ (l/ha) \times area\ to\ be\ treated\ (ha)$$

The number of sprayer loads required:

$$\frac{Volume\ to\ treat\ required\ area}{Sprayer\ capacity}$$

The amount of formulated product to be added to each sprayer load will be calculated according to the product label and may be in millilitres per hectare, from which the amount per sprayer load can be calculated.

$$\frac{Amount\ formulated\ product\ (ml/ha)}{Number\ of\ sprayer\ loads}$$

Alternatively, the amount or percentage of formulated product to be added to a litre of water may be given.

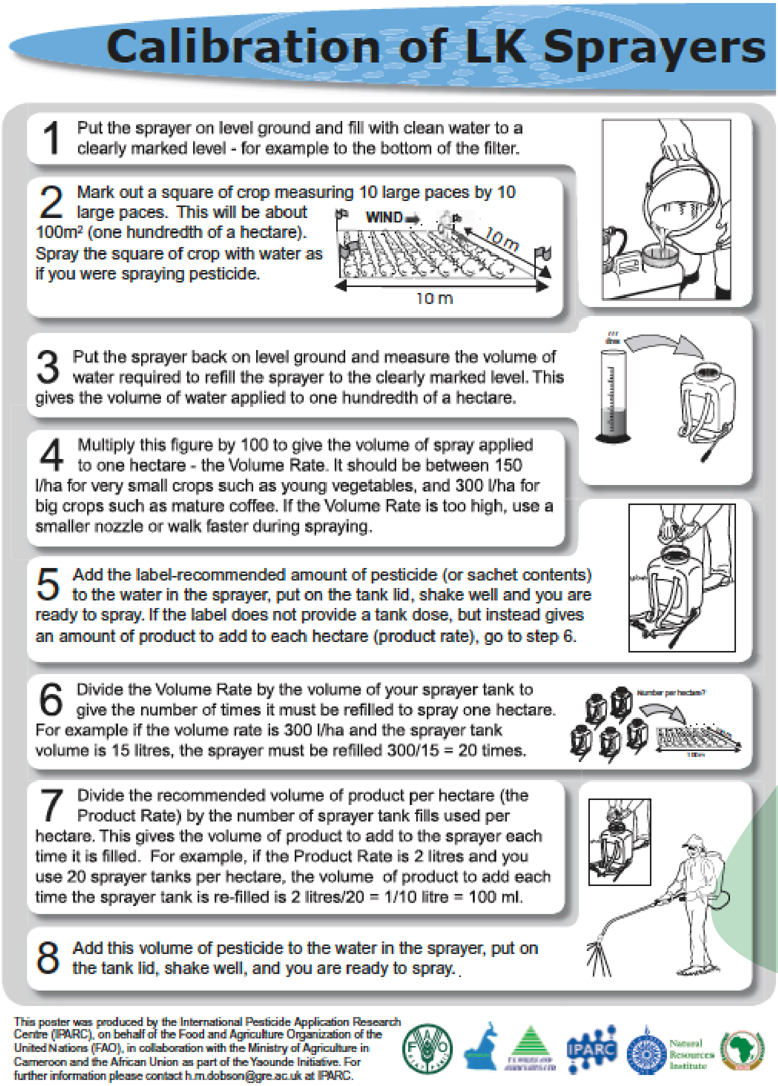


Figure 15: Illustration of calibration.

Handling pesticides safely

All pesticides must be handled with care. Pesticides should be transported and stored separately from other items, especially food, and stored out of reach of children in a well-ventilated locked room, cupboard or box. Recommended personal protective equipment (PPE) should always be worn when handling and applying pesticides and handling contaminated equipment. During handling and application, the user must not eat, drink or smoke.

Mixing and loading

The pesticide should be prepared for application according to the label instructions and just before it is applied. The following guidelines should be followed:

- Always use the recommended dose according to the label. Using too much will not produce a better result and using too little will be ineffective. Using the wrong dose could promote resistance development in the target organism.
- Take extra care when mixing because the risk of contamination when handling undiluted product is higher than when handling the spray (diluted) mixture.
    - Follow the correct measurement and preparation methods, which vary according to the product. Ready-to-use products, such as dusts and granules, can be tipped or scooped directly into the hopper of the application equipment. Ultra low volume formulations can be poured directly into the container.
    - Follow best practices when mixing the product with water. For example:
        - A specific amount of product can be poured into a sprayer that has been partially filled with water.
        - A specific amount of product is poured into a bucket half-filled with water.
        - Wettable powders should be pre-mixed with a small amount of water.
- Use clean or filtered water. If the water contains grit or soil, sprayer nozzles can be damaged or blocked.

- Mix with a stick or similar object, never with your hands.
- Add more water after the product has been mixed and added to the sprayer if the mixture does not reach the required level, and then mix again. If a pesticide container is emptied, it must be properly rinsed and the rinse water added to the spray tank before the sprayer is finally filled.
- Do not overfill the sprayer or it may leak. Clean splash from the sprayer to avoid contamination.
- Prepare only enough spray mixture that can be used during the same day.

Application

General rules to follow are:

- Do not spray in strong winds or when it is raining.
- Spray in the early morning or in the evening when it is cooler. This more comfortable for the applicator, and in hot sunny conditions when there is little or no wind, convection carries the spray upwards increasing the risk of contamination and drift
- Do not spray in areas where the spray is likely to drift into water bodies, sensitive areas or habitations.
- Spray to the side and walk upwind so the spray blows away from you. Do not wave the spray lance in front because this will cause contamination when you walk into the spray cloud and into foliage wetted by the spray.

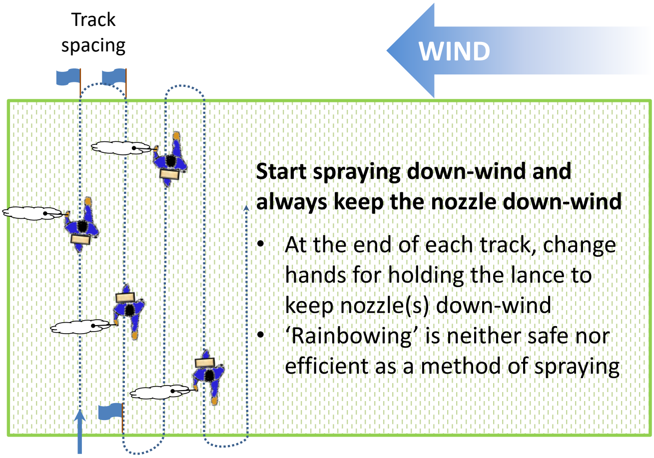


Figure 16: Safe pesticide application

Other application techniques

Small holders may use tractors for application. Generally, much of the safety and equipment advice is the same as or similar to the above. Unmanned aerial vehicles (drones) are also being used. These are normally provided and operated by a professional who must have training and certification in both flying drones and applying pesticides.

After application

After application, all contaminated equipment must be washed in clean water and away from water sources such as streams. Like empty pesticide containers, the sprayer should be triple rinsed (see Session 5.1). This must be done before removing PPE. Then the PPE must be removed and washed, dried and stored separately from other clothing. People who have handled or applied pesticide must also wash themselves thoroughly. Wash water must be disposed of in a designated area, the crop or on waste land, and away from water sources.

Complete Activity 3.3 in your workbook.

Session 3.4: Personal Protective Equipment (PPE)

Session outcomes

After completing this session, you should be able to:

1. Describe the minimum requirements of PPE and how it should be worn and maintained.

Introduction

PPE is essential to reduce the risk of contamination from pesticides. It is the last line of defence. Good handling, proper sprayer maintenance and proper application techniques are the first line of defence.

Minimum requirements

The minimum requirement for all types of pesticide operations is clothing and equipment that covers most of the body to protect the wearer from absorbing the pesticide through the skin, ingesting it through the mouth and sometimes breathing the product in. General PPE items are:

- Gloves to protect hands,
- Shoes or boots to protect feet,
- Long-sleeved cotton shirt to protect upper body and arms, made from thick material that is still comfortable to wear while working,
- Long trousers to protect legs, made of thick material that is still comfortable to wear while working, or overalls,
- Goggles or a visor to protect eyes, for mixing/loading, washing sprayer and overhead spraying,
- Apron, for mixing/loading and washing sprayer,

- Masks for dry formulations to prevent the product being ingested or inhaled or if stated on the label (for example for when mixing), and
- Hat to protect the head when spraying overhead.

Always consult the pesticide label, which states which PPE should be worn.

Figure 17: PPE

Gloves

Gloves must be made of chemically-resistant material, such as nitrile or neoprene, and should be worn over the shirt sleeves (unless the gloves are short). Gloves should not be lined, because the lining could absorb pesticide. General household gloves do not provide chemical protection.

Figure 18: Gloves

Boots

Shoes or boots must be sturdy and water-resistant. Trousers must be worn over the boots

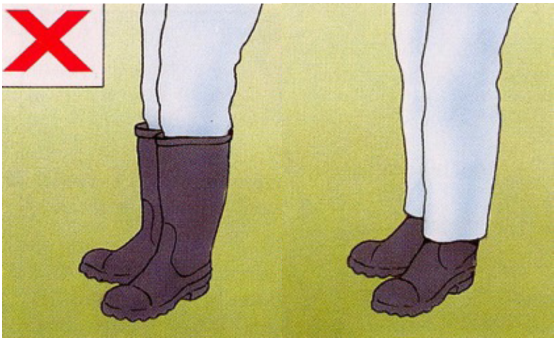


Figure 19: Boots and shoes

Visor/Safety glasses

A visor, safety glasses or googles should be worn, especially when handling the concentrated product during mixing.

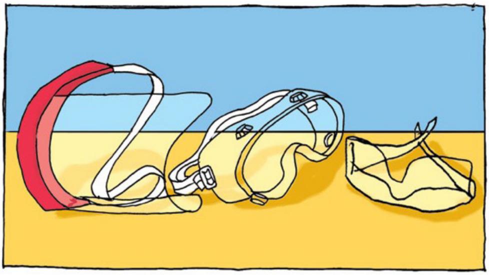


Figure 20: Visor and safety glasses

Respirator/mask

A respirator or disposable mask should be worn when recommended on the pesticide label. Respirators are normally used when spraying overhead, or at high volumes in an enclosed area like a greenhouse. A mask must be changed if it is contaminated. Disposable masks should not be used more than once.

Figure 21: Face mask

A trainer can take the farmers through the process of making locally produced PPE equipment.

Figure 22: PPE required for different operations

Although long-sleeved shirt and long trousers (or overalls) is ideal, local national dress may be appropriate if it covers the whole body, including the arms and legs. Face protection is only required during mixing and loading and under certain conditions like spraying plants that are shoulder high and above. When spraying overhead, a hat must be worn.

See: https://croplife.org/wp-content/uploads/2014/05/Personal-Protective-Video.mp4

Complete Activity 3.4 in your workbook.

Summary

This unit has shown you the major elements underlying the responsible use of pesticides. Most of these relates protecting the pesticide user, but also (particularly with application) also protecting the environment. All the elements are important and you must not only rely on one of these methods, because the methods work together to minimise contamination. These, along with choice of pesticide, reduces overall risk. If the safety rules are not followed, it is also likely that the pesticide is used poorly and wasted, leading to poor pest control, unnecessary user and bystander risk and negative environmental impact.

Complete the summative assessment in your workbook.

Study Unit 4: Pesticide Resistance Management

Study unit outcomes

After completing this study unit, you should be able to:

1. Describe what pesticide resistance is
2. Describe the negative effects of pesticide resistance,
3. Explain how pesticide resistance develops in pest populations
4. Explain The different mechanisms of resistance.
5. Describe how to manage pesticide resistance
6. Explain practices that encourage resistance development

Unit introduction

In this unit, you will learn about how to manage and slow resistance development. While the focus is on resistance to chemical pesticides, resistance to some biological pesticides can develop, such as bacteria and virus-based microbial insecticides. The development and management of resistance in insect-resistant, genetically modified (transgenic) crops are also discussed.

The development of resistance by pests can happen with all classes of pesticides (fungicides, herbicides, insecticides, rodenticides, and so on) and BT toxins expressed by insect-resistant transgenic crops. This makes pesticides less effective, and the resulting loss of pest control can mean that farmers must increase the dosage or spray more frequently, which can increase resistance, which will lead to control failure. In addition, this can lead to high pesticide residues, and application costs. This is why it is important to understand and manage resistance.

Session 4.1: Pesticide resistance development

Session outcomes

After completing this session, you should be able to:

1. Explain how resistance develops in a pest population
2. Differentiate between resistance mechanisms
3. Explain practices that can promote or delay resistance

Introduction

Pesticide resistance is the genetic ability of some individuals in a pest population to survive a pesticide application. This develops when pesticides that work in the same way (mode or site of action) are used over several generations of the pest.

Mode of Action (MoA)

You need to know the MoA of a product you want to apply. This is represented by a letter or number code on the product container label and each MoA has a different code. If there is no MoA label, check the active ingredient listed on product label and look up the MoA on the lists/ posters shown on CropLife International Resistance Action Committees' websites:

- Fungicide Resistance Action Committee (FRAC: www.frac.info)
- Insecticide Resistance Action Committee (IRAC: www.irac-online.org)
- Herbicide Resistance Action Committee (HRAC: www.hracglobal.com)

- Rodenticide Resistance Action Committee (RRAC: www.rrac.info)

A good retailer should have access to these lists/posters and keep them up to date. Local pesticide company representatives should also be able to help. Figure 23 shows the different sites where different insecticides affect an insect.

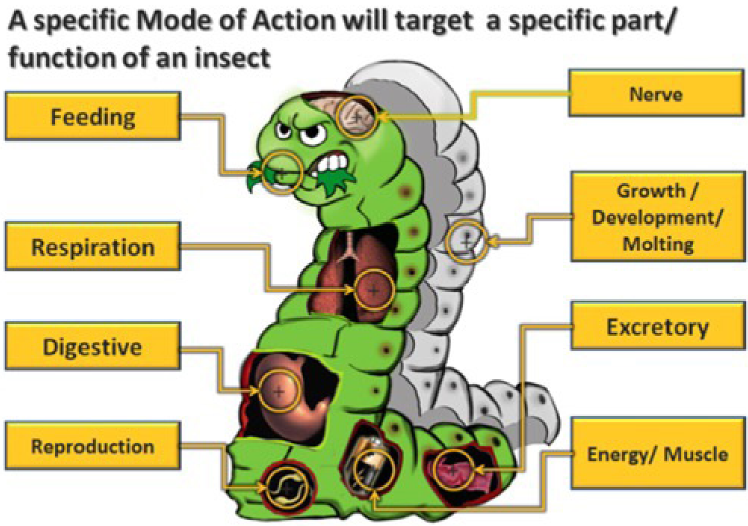


Figure 23: MoA targets

Pesticide resistance and the mode of action

Pesticide resistance is when a particular pest is no longer affected by pesticide. It is an inherited trait. What this means is that individual pests within a pest population are less sensitive to a certain MoA, based on natural mutation, so these individuals will survive a pesticide application. When pesticides with that same MoA are repeatedly applied, the proportion of resistant individuals in a pest population will increase because they survive at a greater rate than the average (susceptible) population. How resistance develops in insects is illustrated in Figure 24 but the principle is the same for other pests.

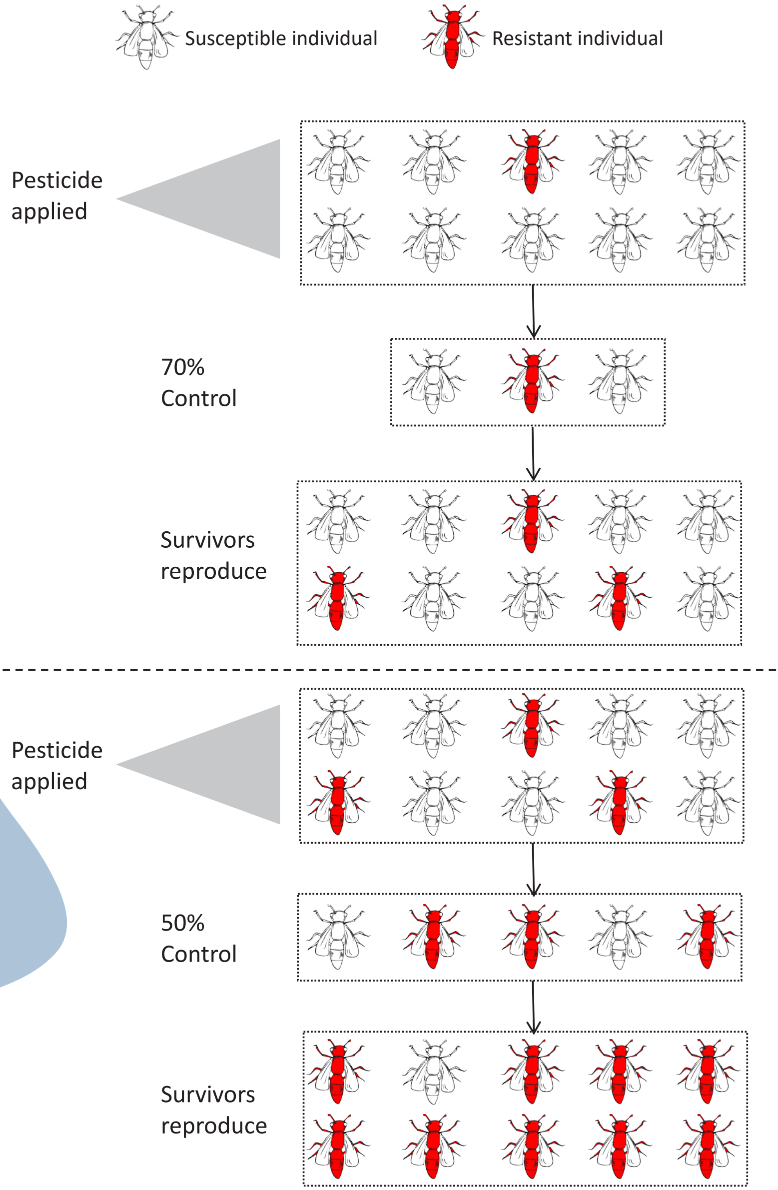


Figure 24: How resistance develops in a population

Cross resistance and multiple resistance

Cross resistance is resistance to two or more insecticides delivered by a single mechanism of resistance. Cross resistance occurs in most cases because resistance to one insecticide also creates resistance to other insecticides of the same MoA (IRAC group). In rare cases, there can also be cross resistance between insecticides that do not have the same MoA (IRAC group), but have similar molecular structural components, which may be metabolised by a single enzyme. Insects that over express that enzyme may therefore be resistant to all the insecticides metabolised by the enzyme.

Multiple resistance is resistance to two or more insecticides delivered via multiple mechanisms of resistance in a single insect. It is often confused for cross resistance.

This means that you cannot assume that a rotation of products with different MoAs contributes to good resistance management. You can check this by referring to the label or relevant online information on mode of action.

Resistance mechanisms

There are several different mechanisms of resistance to pesticides, the main ones are as follows:

- Metabolic resistance
    - Most commonly found in insects, less common in diseases, becoming more common in weeds.
    - Based on enzymes that insects have developed to detoxify toxins that occur naturally in their host plants or other food sources.
    - Insects can become resistant to insecticides when the enzymes that break down unwanted molecules are either significantly increased or modified to become more efficient at breaking down the molecule.
    - The level of resistance can range from low to high and differs between pesticides and crop-pest combinations.

- Target site resistance
  - Pesticides generally have a specific site of action within a pest organism, usually a receptor protein. When a mutation occurs in the genetic code for the receptor protein, it can modify the protein in a way that prevents or alters the pesticide interaction at the site of action, reducing toxicity, and this confers resistance. This type of mutation is called target site resistance.
  - Target site resistance is a common mechanism in weeds, fungi and insects.
- Reduced penetration
  - Slows the penetration of the pesticide through the cuticles of resistant insects.
  - This mechanism produces low levels of resistance, but greatly increases the effect of other resistance mechanisms.
- Sequestration (separation or isolation)
  - In plant cells, the pesticide is removed from sensitive parts to a tolerant site, such as a vacuole.
  - In insects, toxic molecules are sequestered and combined with an enhanced metabolism, preventing them from reaching the site of action.
    - Behavioural resistance
      - Occurs only in insects, mites, and rodents.
      - Individuals change their behaviour to avoid ingesting or coming into contact with the pesticide.

Complete Activity 4.1 in your workbook.

Session 4.2: Resistance Management Strategies

Session outcomes

After completing this session, you should be able to:

1. Know how to manage resistance development effectively in a pest population, both with normally applied pesticides and with pest resistant crops.

Introduction

There are several agronomic, cultural, chemical, and biological practices that can be employed to manage pests and contribute to managing resistance

Integrated Pest Management (IPM)

Adopting IPM helps to reduce the chances of pesticide resistance because IPM can include

- Cultural practices like crop rotation,
- Using pest-resistant varieties, and
- Maintaining naturally occurring predators, parasites and other beneficial organisms.

These practices help keep pest populations low and avoid the need to use control measures. If pest control is needed, a range of practices can be used including

- Mechanical control,
- Biological pesticides, and
- Chemical pesticides.

The result is that pesticides are only used when necessary and not used continuously. Pesticides should always be used within an IPM strategy.

Use the correct pesticide dose

When pesticides are needed to help manage a pest population, they must be applied according to the label requirements and guidelines to ensure good coverage and efficacy. Using less than the recommended dose increases the chances of resistant individuals surviving the application. Using more than the recommended dose may not provide more pest control, and add unnecessary chemicals to the environment. Therefore, always use the recommended pesticide rates on the pesticide label.

Use good quality, genuine pesticides

Using illegal or counterfeit pesticides can result in applying an unknown amount of the active ingredient or an active ingredient not declared on the label. This can result in:

- Illegal residues,
- Poor control, and
- Threaten the success of IPM and resistant management strategies.

Never use illegal or counterfeit pesticides.

Calibrate and maintain the application equipment

Poorly calibrated and maintained equipment results in uneven coverage and pesticide deposits on the crop. This can lead to variable and unacceptable pest control. Always calibrate application equipment before use and keep the equipment properly maintained. Follow the recommendations for the

- Nozzle types,
- Water volume, and
- Sprayer parameters.

Good application practices

A pesticide must be accurately applied to the target. This is done by:

- Directing pesticide application to the pest target location, such as
    - The under-surface of leaves,
    - The base of the stem,
    - The fruiting structure, or
    - Flowers.
- Calibrating the sprayer and choosing correct nozzles, pump pressure, and spray system configuration to deliver the optimized droplet size, maximizing crop coverage and minimizing drift.
- Using the correct volume of water to optimize coverage and avoid run-off
- Not spraying in poor conditions, such as when windy, prior to rain, or under extreme heat conditions and during the hottest time of the day in hot climates.

Incorrect application causes variable pest control and can accelerate resistance. Always use the recommended application techniques.

Double-hit (sequential application) strategy

If the pest survives the pesticide application, you can apply a different control technique to kill survivors. This is a useful strategy for surviving weeds, but in small plots, single surviving weeds can be removed by hand. Control technique should be done before seeding. Do not apply a pesticide dose that is higher than recommended on the label.

Mode of action (MoA) rotation, windows approach

In some cases, there may be several pesticide products available to control pests. Many of them share the same mode of action, act in the same way at the same target site in or on the pest. There may be a very limited number of pesticide modes of action available in a specific country that will be effective against a specific pest in a given crop.

If successive multiple pesticide applications are necessary to control a pest population, pesticides must be chosen carefully, because applications to sequential pest generations should be made with pesticides with different MoAs. This is called rotation. Continually using products with the same MoA across multiple pest generations will result in resistance development. For example, with insecticides, IRAC recommends segregating insecticide applications into MoA windows of application. IRAC recommends using a 30-day window (approximately) for most pests, but an 15-day window (approximately) for short cycle pests like aphids and mites. An example of how this works for insecticides is shown in Figure 25.

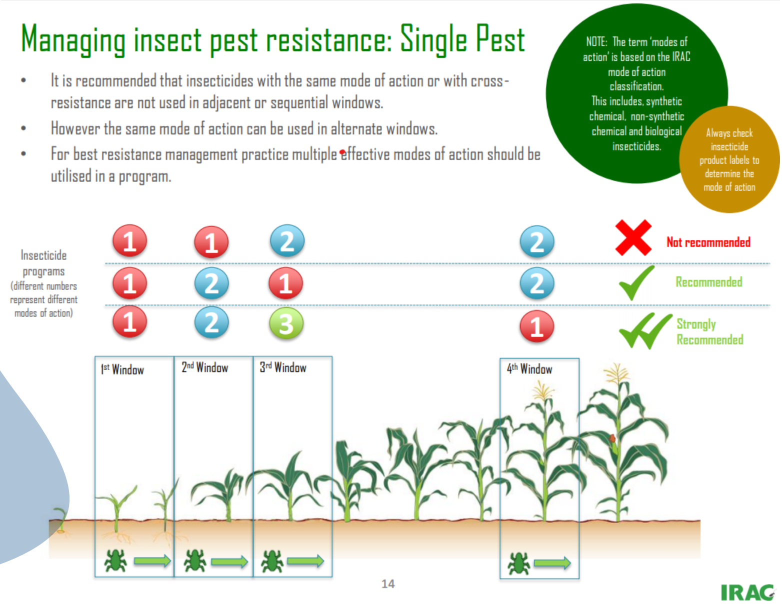


Figure 25: Managing pest resistance

The MoA classification is typically shown on the label of the pesticide bottle or in the technical leaflet. If not, look up the active ingredient on lists provided by the Resistance Action Committees (IRAC, FRAC; HRAC).

Mixtures

In some cases, good pest control can be obtained by applying mixtures of pesticides with different MoAs. Using mixtures is the preferred method of resistance management for some fungicides and many herbicides. If tank mixtures are sprayed, use the recommended label dose for each of the pesticides in the mixture. Mixtures do not replace rotation. If repeated applications of chemical pesticides are necessary, rotate the MoAs so that a MoA contained in a mixture is not used in a successive application window

Resistance management in insect-protected genetically modified crops

A GM crop, such as Bt corn (maize), Bt cotton, Bt soy or Bt brinjal (aubergine), is a crop that has been genetically modified to produce an insecticidal molecule to control certain insects that feed on the crop. Today, insect-protected GM crops mostly express a gene derived from the common soil bacterium *Bacillus thuringiensis* (Bt), to produce a protein that is toxic to a specific range of pest insects. Bt crops have been successfully used as part of IPM systems in several countries. Unlike crops sprayed with pesticides, Bt crops continually produce one or several Bt toxins for a very long time, which can lead to continuous selection of resistant insects. The development of a resistant population can be delayed through planting part of the crop area with a variety that does not contain a Bt gene, or surrounding the area with other plants that do not express the Bt gene for the insects feed on. This area is called a refuge. Susceptible insects from the refuge breed with resistant insects from the area planted with the Bt crop, which reduces the number of resistant insects that survive to the next generation. In many countries, this strategy is stipulated by national law. The concept of refuge is illustrated in Figure 26.

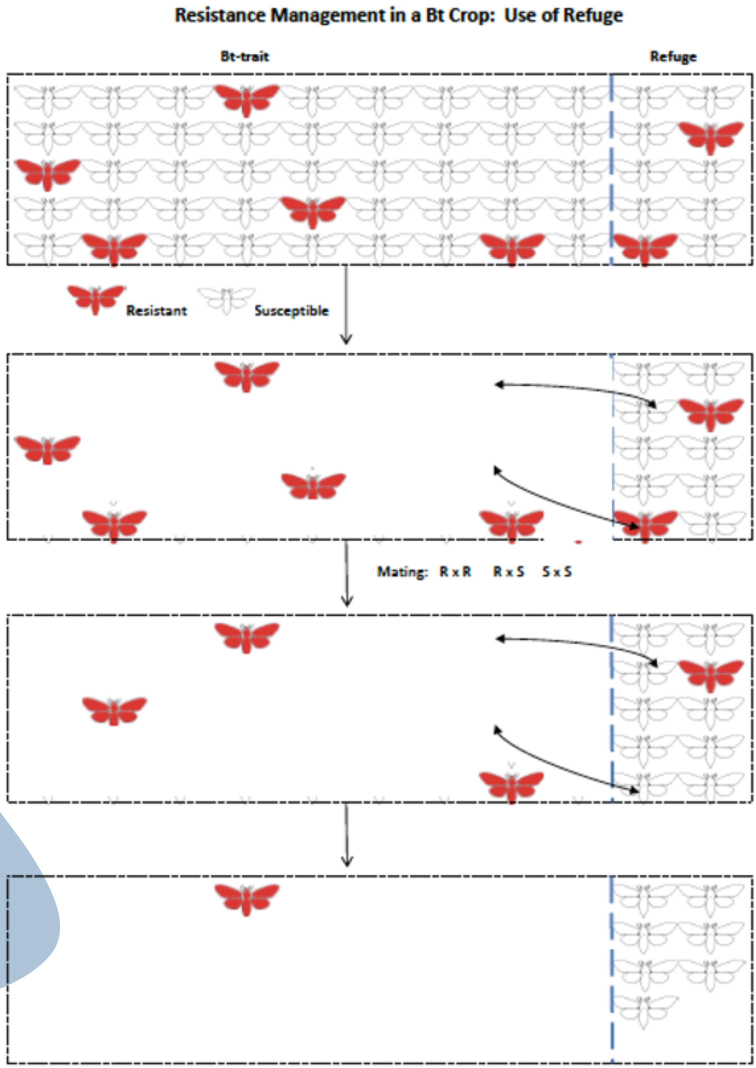


Figure 26: Pest management refuge

Complete Activity 4.2 in your workbook.

Summary

Resistance management is an important part of IPM and adopting IPM helps to manage resistance development. Without effective resistance management, which is an important and sometimes the only effective tool for pest control, maintaining a sustainable crop is not possible. Many of the practices described in this unit will help to manage resistance and improve pest management in general. Some are essential, such as rotating different MoAs, and are worth the effort because they help to provide sustainable crop yields and save money over time.

The two links below provide summaries of resistance management for insecticides and fungicides.

- Insecticides: https://www.youtube.com/watch?v=xrX5MmS2vuo
- Fungicides: https://www.youtube.com/watch?v=Fw8VXz2SUGs

Complete the summative assessment in your workbook.

Study Unit 5: IPM in Action

Study unit outcomes

After completing this study unit, you should be able to:

1. Describe practical aspects of IPM that ensure food safety
2. Explain how to make sure that IPM is not undermined by the use of illegal and counterfeit pesticides.
3. Understand examples of successful IPM strategies that have been used to illustrate different approaches that have been used.
4. Understand the cost benefits of IPM adoption.

Introduction

Now that you understand the principles of IPM, you know that there are many different options that can be employed, depending on the particular situation you face. Using the right methods in the right way provides both financial and environmental benefits. Incorrect choices can be detrimental, as described with development and management of pesticide resistance in the previous unit. You will now learn about some further threats and outcomes of IPM, the costs of implementing IPM, and the role of specific technologies and approaches. Training approaches and impact verification of IPM are also discussed. Finally, examples of IPM in practice shows how strategies can be developed and what actions are involved.

Session 5.1 Threats and outcomes

Session outcomes

After completing this session, you should be able to:

1. Understand how IPM helps to maintain food safety
2. Understand how pesticide waste can threaten human health and the environment.
3. Explain the dangers of illegal and counterfeit pesticides pose and how to avoid them.
4. Explain the impact on costs will be discussed.
5. Understand how genetically-engineered crops can be incorporated in an IPM strategy
6. Understand how area-wide pest management can be implemented.
7. Describe what training approaches have been shown to be successful and how impacts are verified.

Introduction

When a pesticide is used, some of the pesticide remains on the crop and in used containers. Certain procedures must be followed to make sure that they do not negatively impact people's health and the environment. Using illegal and counterfeit pesticides increases the risks, as the content of these products is unknown or has not been locally approved for use. These all impact the cost of implementing IPM. Some IPM strategies can involve specific new technologies or approaches.

Re-entry and pre-harvest interval

Following pesticide application, there is normally time that you must wait before workers and others can re-enter the crop. This is called the re-entry interval and prevents the risk of contamination by walking through or handling the treated crop, weeds and so on. The re-entry period is often on the pesticide label. If not, a re-entry period of at least 24 hours is recommended.

The pre-harvest interval is the period between applying the pesticide and the crop harvest. This is most relevant to food crops and it ensures that pesticide residue on the harvested crop is within acceptable limits. If relevant, the pre-harvest interval is shown on the pesticide label.

IPM and food safety

It is important to consider food safety when managing pests. This includes ensuring pesticide residue levels are within acceptable limits.

Residues are the traces of pesticides left in treated products. As part of the registration process, the risk of the pesticide harming consumers is determined, based on the following

- No observed adverse effect level (NOAEL), or
- No observed effect level (NOEL).

These are used to calculate the acceptable daily intake (ADI), which is the maximum amount of a substance that can be consumed every day for a lifetime without harm, and the acute reference dose (ARfD), which is the maximum amount of a substance that can be ingested in a single day without any harm. Both are set at a level about 100 times less than the NOAEL. The level of residue that is likely to remain on a crop at harvest must not exceed the ADI or ARfD.

During registration, a maximum residue level (MRL) is determined. This is the highest level of pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly, as determined by good agricultural practice (GAP). MRLs are not toxicological safety limits, but commercial standards that indicate the legally allowed maximum amount of an active ingredient that may be present as a residue in or on an unprocessed raw product, and they indicate whether a crop protection product has been correctly applied or not. They facilitate the trade in agricultural produce. The MRL is set at a level below the ADI and ARfD so that produce within the MRL is well within safety limits. Exceeding the MRL does not necessarily imply a risk to health, but it does indicate that a pesticide has been incorrectly used. Food products with residues exceeding MRL cannot be placed on the market. An MRL is determined by including a pre-harvest interval (PHI), which is the time between the last pesticide application and crop harvest, during which time the pesticide will degrade. The PHI is normally shown on the pesticide label, and pesticide must not be applied during the PHI to be sure that the residues will remain below the MRL.

Following GAP, including the PHI, is integral to IPM and is achieved by following the instructions on the pesticide label.

Waste disposal

Empty containers that contained pesticides must be disposed of responsibly. For plastic, aluminium or glass bottles (the most common containers), the first step is to properly rinse the containers. For smallholders this is done by triple rinsing, following these steps:

- The container is filled to one-third with clean water,
- The cap is put on tightly, and
- The bottle is shaken and turned upside down several times.
- Pour the water into the sprayer (if the sprayer is not filled)
- Repeat this process two more times.

Triple rinsing removes 99,9% of pesticide from the bottle. The bottle must then be punctured so it cannot be used again. Empty pesticide bottles must never be used to store other materials, especially not food or water because even though the vast majority of pesticide has been removed by rinsing, a small amount is in the plastic itself, so the bottle is not completely pesticide-free. The bottle must then be returned to a local container management collection scheme, if one is available. If there is no container management scheme, the containers must be sent to a hazardous waste disposal scheme. If this is also not available (and only if there is no alternative) they must be buried in a specified location that is fenced off and free from flooding. They must never be randomly discarded in the environment or burnt.

Other contaminated packs, such as foil and plastic bags, cardboard, and seed treatment containers, must be sent to a hazardous waste disposal scheme. Uncontaminated packaging can be disposed of via a normal waste collection scheme.

See: https://www.youtube.com/watch?v=HAWbSIh0ZFI&feature=youtu.be

Illegal and counterfeit pesticides

A serious problem in many countries is counterfeit and illegal pesticides:

- Counterfeits are illegal copies of legally registered products. They normally (but not always) have good looking packaging and their labels may look identical to original, legal products. The contents of the container may contain a variety of active ingredients of varying quality.
- Illegal products do not copy an authentic product. They have basic or incomplete labels. These products may or may not contain the ingredients named on the label of the container and their quality may be dangerous to human health and the environment.

Neither counterfeits nor illegal products are registered for use in a country. They are often made by criminal organisations and it is illegal and potentially dangerous to use them. As the content and quality of counterfeit and illegal products is unknown, be aware of the following:

- You do not know how toxic they are, and do not know what risk they pose to human health and the environment.
- They may not work, and may even damage the crop. There are examples of counterfeit insecticides being sold as that are actually herbicides.
- They can result in unknown and illegal residues.
- They may promote resistance, as the amount of active ingredient is unknown.

This means they undermine IPM and should never be purchased or used. It can be difficult to recognise counterfeit/illegal pesticides, but the following general rules should be followed:
- Only buy from known, licenced and reputable retailers.
- Do not buy products with poor quality or misspelt labels.
- Beware of products that are cheaper than normal.
- Only buy products that are in original and unopened containers.

Many genuine products have a phone number that can be used to check whether they are legitimate

Role of genetically engineered crops

Genetic engineering provides a way to develop crops with beneficial traits that:
- Is more targeted,
- Presents greater options, and
- Is more rapid than traditional plant breeding.

From an IPM standpoint, the technology creates potential for new varieties that are more adapted to climatic or other environmental conditions, and are therefore likely to produce a healthier crop that is resistant to pest attack or tolerant of herbicides. Varieties that have been developed are either resistant to pest attack, mainly crops such as maize or aubergine (brinjal), that have been engineered to incorporate the toxin gene from *Bacillus thuringiensis* (Bt), or crops, such as papaya resistant to ring spot. With Bt maize there is a considerable reduction in the need to use chemical pesticides.

It is an IPM solution currently being promoted in the battle against Fall Armyworm, an invasive pest originating from the Americas that threatens maize and other crops in Africa and Asia. Genetically modified (GM) papayas saved the papaya industry in Hawaii, as ring spot makes the fruit unmarketable and eventually kills the trees.

Herbicide tolerance is the other main approach that has been commercialized. A genetically engineered (GE) crop is tolerant to a broad spectrum herbicide, which facilitates efficient weed control. Crops such as soybeans, cotton and maize have been engineered to be both herbicide tolerant and insect resistant. In soybeans in particular, herbicide tolerance has helped to facilitate no-till agriculture by providing a cost-effective method of weed control.

Though the number of commercially available GE crops is limited, there are some, such as aubergines, cotton and maize, that are important to smallholder farmers and provide effective pest management options. An example of this is Bt cotton in India. The number and type of GE crops available to farmers is likely to increase in the future.

Potential for area-wide pest management

Area-wide or area-based pest management (AWPM) is when a pest management strategy is implemented in large, defined areas. It can cover several farms and it is often targeted against a single pest. Its advantage is that it prevents re-invasion of a pest from an untreated field to a treated field, and invasion from non-host plants. For some intervention strategies, like releasing biological control agents that need to establish over a large area, it the favoured approach. This approach requires agreement and co-ordination between farmers and is often managed by a public or private organisation, like the government extension service or a commodity organisation/buyer.

A second approach to AWPM is where pest management services are provided to farmers by a local individual or organisation. This can provide access to services that individual farmers cannot afford, such as pest monitoring, but are affordable to a farmer group. Examples of this approach are Spray Service Providers, who are contracted by farmers to advise on and undertake pest management practices, including applying pesticides. This approach has been widely promoted by CropLife Africa Middle East in several African countries, and spray teams have been supported by the public and private sector in Vietnam.

Costs of IPM

Farmers tend to only adopt new practices, such as IPM, if they are demonstrated to be beneficial to them.

Financially, farmers can gain by improving yields, which is often achieved by improving the agronomic practices that are part of an IPM strategy and better pest management. Adopting IPM can reduce input costs by eliminating unnecessary pesticide or fertiliser application. This balances the increased costs of non-chemical interventions. Increased income can result from improved access to markets, which may include a price premium, as IPM adoption is normally a requirement for the secondary standards increasingly demanded by buyers. IPM adoption also helps to ensure that pesticide residue levels are below MRLs.

Furthermore, the adoption of IPM, including responsible pesticide use, helps to eliminate or reduce the negative external, environmental or health impacts that may result from pesticide use. However, the negative impacts must also be considered for any alternative to pesticides, so a balance must be found.

Farmers need to be aware of the benefits of adopting IPM. To achieve this, they need to keep accurate records of the costs and income.

Record keeping

Accurate record keeping serves a number of functions, including:

- Facilitating decision making. The numbers and type of pests and beneficial organisms, crop damage and trends must be recorded to determine whether the action threshold has been reached and, if intervention is needed, what can be used and when different interventions should be integrated.
- Recording the type and costs of inputs and other agronomic practices to determine the action threshold, and to demonstrate the cost and benefits of IPM to the farmer.
- Recording the yield to show the impacts of adopting IPM.
- Recording the income from the crop to calculate the financial benefits of adopting IPM.
- Being able to be certified under a sustainability scheme, such as GlobalGap, as these are a major part of the independent auditing process.

There are tools to facilitate data collection. Two examples of this are GeoFarmer (https://blog.ciat.cgiar.org/app-enables-smallholder-farmers-to-be-community-influencers-and-citizen-scientists/) developed by the CGIAR, and the commercially-available Smallholder (http://www.smallholdr.com), both of which help farmers to make decisions. These tools are becoming more commonly available, but the majority of smallholder farmers will still rely on traditional pen and paper methods, such as a farmer field book, where planned and executed actions are recorded and the data obtained. Information obtained can also be summarised in a cropping calendar.

Activity	Details	Expected date	Actual date
1. Major operation			

Example of a written crop calendar

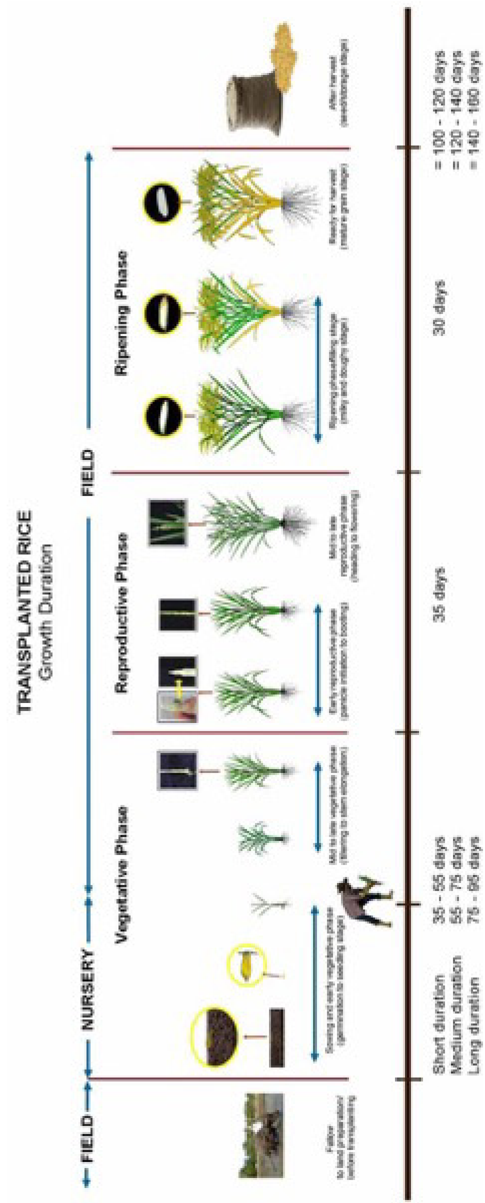


Figure 27: Example of a visual calendar (Source: IRRI knowledge bank)

Farm operations are listed along the time-line as the season progresses, such as pest management interventions.

How to train and support farmers in IPM

Farmer capacity building is essential for adopting IPM. Farmers need to understand the principles and benefits of IPM and how it is implemented. This requires training that results in behaviour change.

Experience has shown that approaches where farmers get hands-on experience are the most effective. This involves

- Demonstration plots,
- Practical field activities, and
- Interactive lectures that use the farmers' knowledge and experience.

Comparing IPM and non-IPM fields can demonstrate the impact of adopting IPM. The most well-known programme that has adopted this approach is the farmer field school (FFS).

FFS was developed and has been widely promoted by the FAO and partners, initially in rice farming in South East Asia. It is described as follows:

> *"…a group-based learning process. During an FFS, farmers carried out experiential learning activities that helped them understand the ecology of their fields. These activities involve simple experiments, regular field observations and group analysis. The knowledge gained from these activities enables participants to make their own locally specific decisions about crop management practices."*

The basic features of a typical IPM Farmer Field School are as follows:

- Field based
- Lasts for a full cropping season.
- Meet once a week throughout the season.

- Consists of 25 – 30 farmers (normally split into smaller groups during practical activities, like field monitoring and analysis)
- The primary learning material is the (crop) field.
- Meetings are held close to the demonstration plots, often in a farmer's home, local facility or in a shaded outdoor area.
- In each meeting there is agro-ecosystem analysis and information on a specific topic such as biopesticides, PPE, or group learning activities. Data collected from the field is summarised, analysed and discussed. Based on this, the group makes decisions on what agronomic or pest management interventions are needed.
- Participants conduct a study comparing IPM with non-IPM treated plots.
- Several additional field-based studies can be included, depending on local field problems, like irrigation practices or the impact of beneficial organisms.

The overall aim is to empower farmers to make their own decisions, in particular on IPM. Pre- and post-testing is normally included.

Figure 28: Agro-ecosystem analysis

FFS has been criticised for being too costly, so attempts have been made to reduce costs by reducing the number of sessions or promoting farmer-to-farmer learning (for an example, see https://croplife.org/partnering-for-a-new-training-model-sharing-knowledge-responsibility-and-benefits-in-the-adoni-region/), but the basic model remains the same. The Training for Farmers video in the following link provides more information on the different training approaches used. https://croplife.org/trainingthroughlocalpartnerships/#overview

Whatever training model is adopted, it must be reinforced through continued follow-up if IPM is to be sustained, because IPM is not a fixed set of actions, but is based on underlying principles that can result in different and changing actions. Follow-up advice must be available to address new challenges and make sure the newly adopted strategy is maintained. This is less intensive than the training itself, but does require regular interaction or visits by extension agents. This can be supplemented or replaced by new technologies, such as smart phone apps that can:

- Remind farmers to perform certain tasks as needed during the season,
- Warn of possible pest attack,
- Aid in identifying pests and beneficial organisms, and
- Remind famers of safety precautions.

Apps can also supplement training with new information and approaches. However, it is unlikely that apps or other communication tools will completely replace face-to-face.

Complete Activity 5.1 in your workbook.

Session 5.2: Examples of IPM in the field

Session outcomes

After completing this session, you should be able to:

1. Understand some of the different strategies that are used in IPM.

Introduction

The overall concepts and principles of IPM are the same for all crops, pests or locations. However, IPM is not a fixed set of practices, but differs depending on the agroecology, climate, type of pest, availability of tools and so on. The following case studies illustrate some of the different approaches to IPM that can be taken. As will be seen, although IPM is often described as knowledge intensive, the approaches taken can be simple. In all cases, general good agronomic practices have been used to grow a healthy crop and the need for intervention is based on crop and pest observations to determine if the action threshold has been reached.

Rice IPM in Vietnam

This project was initiated to address poor pest management, especially for planthoppers and rice blast, and overuse of chemical pesticides. The approach was to adopt an adapted FFS training approach, which included farmer to farmer training. The IPM elements adopted were:

- Prevention:
  - Flowers were planted on borders of fields to attract beneficial insects.
  - Fertilizer use was optimised as leafy growth due to high fertilizer use attracted insect pests.

- Monitoring:
    - Weekly scouting and group assessment were conducted to assess health of plant and whether threshold had been reached.
- Intervention:
    - The choice and application technique of chemical pesticides were optimized. No biological options were commercially available.

The outcomes were:

- Understanding of natural enemies (at least 3 species): 47 – 89%
- Understanding of Mode of Action: 66 – 80%
- Understand Label: up to 99%
- Using PPE: 52 – 99%
- Number of pesticide sprays reduced by 30% – these were not needed
- Net income increase: 14 – 17%

In summary

Problem	Poor pest control: resistance, resurgence User and Environmental Contamination
Identified Cause	Poor understanding of pest and pesticide management, Poor advice from retailer Poor pesticide application
Solution	Training in IPM (user and retailer)
Result	Change in Behaviour • Adoption of IPM • Proper Handling and Application of pesticides • Reduction in unnecessary pesticide use
Verification	User Surveys Reduction in pest outbreaks Increase in farmer income

See also: https://www.asean-agrifood.org/integrated-pest-management-in-rice-demonstrates-promising-results-in-vietnam/

These videos illustrate how the training was provided:

https://www.youtube.com/watch?v=ZBScC_cfGeg&list=PL2Q0araWBagCrlsK1g_A7_PHxrbXx8ypY&index=2

Chilli in India

Smallholder chilli farmers in Andhra Pradesh were unable to sell their crop to the Indian Spice Export Board due to high levels of pesticide residue. This was due to poor pest management and unnecessary pesticide use. The solution was to adopt IPM, including improved application of pesticides.

IPM practices adopted included:

- Prevention:
  - Bird perches installed as birds eat some insect pests
  - Border crops planted to attract beneficial insects
  - Trap crops planted as insect pests preferentially go to these
- Monitoring:
  - Scouting to assess whether threshold has been reached
  - Pheromone traps to assess presence of pest moths
- Intervention:
  - Mechanical control to remove diseased leaves and pest insects

- Botanical pesticides such as neem used
- Biological/ microbial pesticides used
- Chemical pesticides used

This is summarised in the Figure 29.

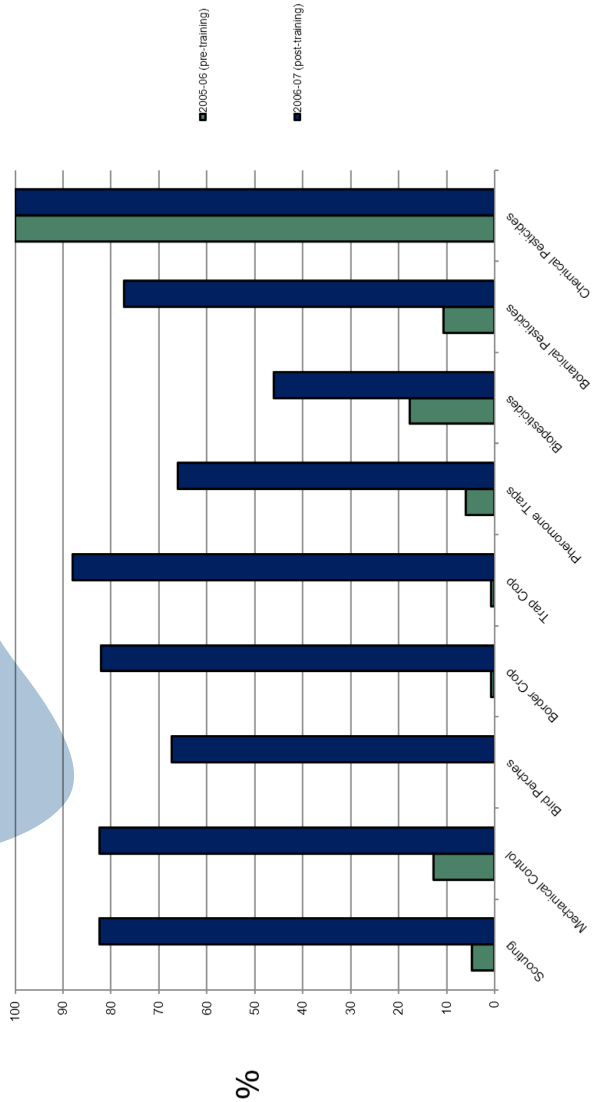


Figure 29: Results

The net results were:

- Pesticide applications reduced from 30 to 15 per season
- Residue levels were within the MRL
- Farmers able to sell their produce to the Spice Board
- 52% increase in net income

The farmers now pay for the training, having recognised its benefits.

In summary

Problem	User/environmental contamination Excess residues on produce
Identified Cause	Lack of knowledge; Poor decision making; Poor handling of pesticides
Solution	Training in Good Agricultural Practices including IPM
Result	Safe and efficient pest and pesticide management Residues within MRL requirement No use of pesticides that are restricted by importing authorities
Verification	User surveys; Number of product rejections

Vegetables in Sri Lanka

This programme adopted an FFS approach to introduce IPM to vegetable growers (aubergine, chilli and potato) in Sri Lanka. Adoption of improved cultivation and pest management practices, including using selective rather than broad spectrum insecticides resulted in improved yields and income.

IPM practices adopted included:

- Prevention:
  - Using good quality seed
  - Proper land preparation, fertilisation and irrigation

- Monitoring:
  - Scouting to assess whether threshold has been reached – mainly for podborers
- Intervention:
  - Mechanical control by removing fallen and infested fruits, and hand weeding
  - Use of selective rather than broad spectrum insecticides

Outcome
- Higher yield (7% – 44% increase)
- Reduction in pesticide application and costs by two-thirds
- Higher income (12% – 129% increase)

In summary

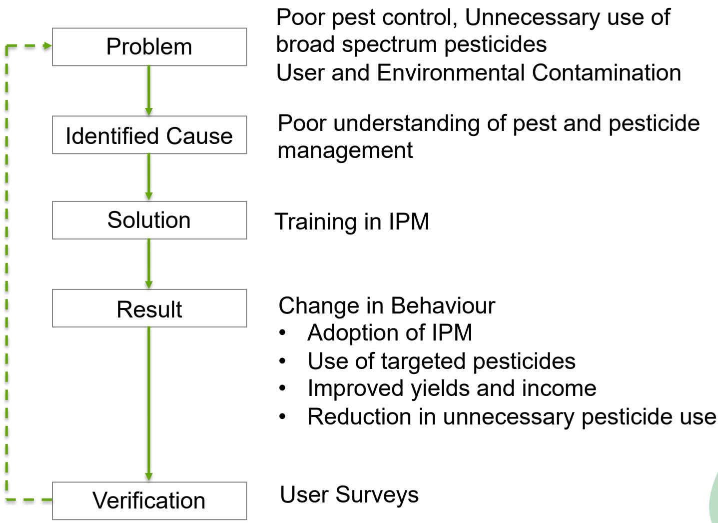
Problem	Yield losses due to uncontrolled potato blight
Identified Cause	Disease established before control measures undertaken as not apparent in early stages
Solution	Intervention based on modelling – rainfall and temperature
Result	• Effective control of potato blight through targeted fungicide application • Improved yields and income • Reduction in unnecessary pesticide use
Verification	User Surveys

Potato blight in Europe

This is an example of modelling being used to predict pest infestation and timing of targeted chemical application.

Late blight is a major fungal disease of potato that can result in total yield loss if not effectively managed. It was the cause of the Irish potato famine in the mid-nineteenth century. Breeding for resistance has had limited success, so other than reducing sources of inoculum by using certified, clean seed potatoes, the use of fungicides is the most effective management tool. Early stages of infection can easily be missed and spreads rapidly under warm, wet conditions (temperatures above 10 °C and humidity over 75 – 80%). Thus fungicide application is triggered by weather conditions, such as when the weather conditions have been suitable for disease transmission for at least two days. Forecasting systems, such as BLITECAST, are available to help the farmer decide when to treat the crop (https://www.cabi.org/isc/abstract/19751318878).

In summary



Oranges in Indonesia

The fruit fly is a major pest of many fruit crops, including oranges, where they reduce yield and quality of the fruit. IPM interventions include removing and destroying fallen fruit, but can also include mass trapping of the adult flies. A programme in North Sumatra, run by the German aid agency GIZ and the Indonesian Directorates of Horticulture and Horticulture Protection promoted an area-wide mass trapping programme covering over 10 000 ha of orange farms and involving 20 000 smallholder farmers. Traps, baited with a fruit fly attractant, methyl-eugonol (ME), which attracts male flies, were placed at a density of around 16 per ha by hanging them on tree branches 1.5 – 2 metres above ground level covering both the orange crop and other crops and areas, which can act as refuge areas. Water in the bottom of the trap catches the flies. Trapped flies are disposed of regularly by washing the traps. ME bait is replaced according to the manufacturer's instructions (every 1 – 3 months). The impact is assessed by designated monitoring traps, which are the same as the other traps, every 20 ha. The damage to oranges was reduced by approximately 50%, with yield increases from an average of 3 tonnes/ha to up to 15 tonnes/ha. Such an approach required commitment and collaboration from all stakeholders involved.

IPM practices adopted included:

- Prevention:
  - Removing infested and fallen fruit
- Monitoring:
  - ME traps used to assess the fruit fly population, including when to initiate mass trapping
- Intervention:
  - Mass trapping

In summary

Problem	Yield losses due to fruit fly
Identified Cause	Poor pest management, invasion of of fruitfly from non-treated fields
Solution	Area-wide management based on mass-trapping
Result	Effective control of fruit fly resulting in reduced damage and increased yields
Verification	User Surveys Damage and Yield assessments

Cocoa in West Africa

Pest management in cocoa in West Africa relied on smallholders applying pesticides to trees, which had a high potential for user and environmental contamination. To address this problem, CropLife Africa Middle East, in partnership with the Word Cocoa Foundation, promoted the concept of Spray Service Providers. These are local people, often farmers themselves, who sell pest management services to other farmers. Potential SSPs undertake a training programme in pest and pesticide management, covering

- Responsible use of pesticides, including using protective equipment, disposal of empty pesticide containers, transport, storage, and so on
- Application, including calibration, dosage, residues, and so on
- IPM, including proper fertilisation, proper tree pruning for disease control and stronger growth
- Business skills

After they have completed their training, participants must pass written and practical tests. They are then provided with a full set of PPE, an ID card and a ledger for record keeping, and they receive assistance in purchasing good quality application equipment. They are linked to input providers that make sure they use good quality, registered pesticides. Each trained SSP provides services to 25 – 30 farmers, who pay for these services. Approximately 40 000 cocoa farmers are now using SSPs, resulting in:

- Professional decision making,
- Agronomic and pest management advice,
- Eliminating unnecessary sprays,
- Improved and safer application, for both human health and the environment,
- Improved yields,
- Proper management of empty containers,
- Reduced chance of obsolete pesticide stocks, and
- Less use of counterfeit or illegal products.

- Prevention:
  - Improved fertilizer use, resulting in healthier trees
  - Proper pruning, resulting in healthier trees
- Monitoring:
  - Scouting to assess health of plant and whether threshold has been reached

- Intervention:
  - Mechanical control by pruning diseased branches
  - Chemical pesticide use optimised through product choice and application technique

In Summary

Problem	User/environmental contamination and household risk
Identified Cause	Lack of knowledge; Poor decision making; Poor handling of pesticides
Solution	Establish professionals to advice on pesticide management and provide application
Result	Safe and efficient pest and pesticide management, including:- • Timing and choice of intervention • Spray application • Container management • Safe storage
Verification	Uptake of SSPs; User surveys

This video shows how SSPs are used in Cocoa in Ghana and their impacts: https://www.youtube.com/watch?v=HjQh9JT7rgs

This video shows the how SSPs are being used in Ethiopia on vegetables and their impacts: https://www.facebook.com/CropLifeIntl/videos/273525386816388

Complete Activity 5.2 in your workbook.

Summary

Implementing IPM improves food safety, reduces environmental contamination and can increase income, thereby improving livelihoods. This video, from a project in Honduras, summarises some of these impacts and outcomes: https://croplife.org/trainingthroughlocalpartnerships/honduras/.

These impacts and outcomes can be easily achieved by adopting and improving good agricultural practices, but strategies can also use novel technologies and approaches. Getting farmers to change behaviour and adopt IPM requires effective, participatory training, which needs to be sustained over time. It is also important to demonstrate the benefits of IPM through accurate record taking and impact assessment.

There are many different activities that can be included in an IPM strategy. All strategies involve prevention, monitoring and intervention. If intervention occurs, it is applied responsibly in a way that minimises risks. The strategy can be developed by properly analysing:

- The problem,
- The causes of the problem, and
- How to address the problem.

Properly measuring impact checks that the proposed solutions are producing the required impacts and reduces or avoids unwanted impacts, and demonstrates which adjustments may need to be made. Impacts and adjustments may occur within a season or over several seasons. IPM is a dynamic rather than a static approach.

It is important to understand that IPM is not carried out in isolation, but as part of managing the farm as a whole. The following exercise (the coffee game) illustrates this in a fun way, using smallholder coffee production as an example, placing pest management as part of sustainable and profitable farming.

The instruction for playing the game is given below.

Summary of the game

The aim of the game is to promote the adoption of sustainable agricultural practices to enhance productivity levels that could lead to an improvement in smallholders' livelihoods. In addition, we intend to provide extension agents with an innovative tool to engage with producers about production techniques. The set up in a glance:

- Game is moderated by an extension agent. The Game was not designed to be played "solo" by farmers
- 2 – 5 teams with maximum 5 players in each team
- Each team has a laptop. Alternatively, if only one laptop is available, the moderator plays the game motivating farmers around her/him to participate in the decisions
- 30 – 60 minutes of playtime

In this game each player is a coffee farmer trying to make the right agronomic decisions to advance and become a "Sustainable Coffee Farmer" by learning more about the three pillars of sustainability, economy, environment and society.

In the Menu (upper right corner), the extension agent finds support information to play the game by clicking "Help" and "Rules of the Game". "Help" describes each of the "cards" indicating an agronomic practice and economic/social choices and includes messages that the moderator can communicate to smallholders to help them to select the proper activity in the farm.

Objectives

To win the game players must reach 100% in the "Asset" and "Welfare" indexes. The overall objective is for players to gain greater insight about sustainable coffee farming. The specific objectives are:

1. Provide an interactive educational tool for smallholders to implement Best Agricultural Practices with a focus on IPM and responsible use of Crop Protection Inputs

2. Provide a simple decision simulator about Best Management Practices (Economical and Social decisions).
3. Deliver essential and easy to understand sustainability messages (i.e. Soil health)

Setup

The game is divided in 3 Rounds and each of them consist of 3 Stages. In each Round, we communicate different messages and prioritize specific agricultural, economic and social practices. The first Stage is related to Agricultural practices and the second one encompasses the Economic and Social decisions. Depending on the choices of players, they will follow a specific path that will lead them to the export market or the local market at the end of the game.

The game is found here: http://sustainability-farm.basf.jedermann.de/demo/docs-coffee-0.22.0-en

✎ Complete the coffee farmer game with your facilitator.

✎ Complete the summative assessment in your workbook.

Further sources of information

- IPM training Manual (CropLife International) https://croplife.org/wp-content/uploads/pdf_files/IPM-Facilitators-Manual.pdf
- Responsible Use Training Manual (CropLife International) https://croplife.org/wp-content/uploads/2016/04/Responsible-Use-Manual.pdf
- Pocket Book of Integrated Pest Management for Vegetable Growers, Natural Resources Institute, University of Greenwich, UK. ISBN: 0 85954 572 5
- Integrated Vegetable Pest Management. ISBN: 0 85954 536 9. https://www.gov.uk/research-for-development-outputs/integrated-vegetable-pest-managementCABI PlantWise https://www.plantwise.org

Complete the post-assessment in your workbook.

Global Forum for Rural Advisory Services (GFRAS) is about enhancing the performance of advisory services so that they can better serve farm families and rural producers, thus contributing to improved livelihoods in rural areas and the sustainable reduction of hunger and poverty. Rural advisory services help to empower farmers and better integrate them in systems of agricultural innovations.

gfras
global forum for rural advisory services
forum mondial pour le conseil rural
foro global para los servicios de asesoría rural

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