Trainee Manual

INTRODUCTION TO INTEGRATED PEST MANAGEMENT

Brussels
October 2008

Revised January 2011

CropLife INTERNATIONAL

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1 INTRODUCTION

This handbook has been prepared by CropLife International as part of a training course on Integrated Pest Management (IPM). The objective of the course is to provide an overall understanding of the concepts of IPM, together with the principles for implementation in all crops. In this handbook, and during the course, it is assumed that participants are aware of IPM, but are not fully familiar with the concepts, and practical principles of implementation.

The handbook contains all the information that should be presented in the training course, together with some additional background information.

The main target groups of the course are pesticide retailers and agricultural extension officers, although farmers could also be included. With the understanding of IPM provided by the course, participants should be able to understand the practical implementation of IPM in actual farm and crop situations.

The overall concepts and principles of IPM are the same for all crops or pests.

However, IPM is not a fixed recipe of recommended practices.

Crops or pests in different locations may require different IPM practices to be implemented.

2 INTEGRATED PEST MANAGEMENT – WHAT? HOW?

This section outlines the reasons why we need to implement IPM in crop production, what is meant by IPM, and the strategies which can be used in an IPM programme. These outlines will be expanded in subsequent sections of the handbook.

What is a Pest?

Before defining IPM, we need to consider exactly what is a pest. There are many animals, plants and other organisms in the world, of which we may consider some to be of benefit, some to be pests, and some to be neutral. But what makes an animal, plant or other organism to be considered a pest? For example, bees produce honey and wax which are eaten and used by man, and so bees can be classed as beneficial. However, if bees make a nest close to a house and sting the people in the house, then in this situation they are a definite nuisance and are classed as a pest. Alternatively, one Striga plant in a field is not a problem, but if there are so many that the cultivated crop is affected then the Striga is classed as a pest or weed.

No organism, therefore, is inherently a pest, and to call something a pest is a subjective classification depending on the situation in which the organism occurs and in what numbers. A pest, disease or weed can be described as any organism that:

- Competes in any manner with humans, domestic animals or useful plants.
- Injures humans, domestic animals, useful plants, structures or possessions.
- Spreads disease to humans, animals or plants.
- Annoys humans or animals.

Put simply, a pest can be defined as:

Any organism which adversely affects man, his crops, his livestock, or anything that he considers to be of value.

The types of pests include:

• Insects	Aphids, beetles, caterpillars, mosquitoes, cockroaches etc.
• Insect-like organisms	Mites, spiders, ticks, etc
• Weeds	Any plant growing where it is not wanted
• Parasitic weeds	Orobanche, Striga, etc
• Molluscs	Slugs, snails, etc
• Vertebrates	Rats, mice, etc
• Nematodes	Root knot nematode, etc
• Micro-organisms	Bacteria, fungi, viruses

In this handbook, whenever the word “pest” is used, it implies any animal, plant or other organism which is harmful to crop growth or agricultural production.

What is IPM?

Pest control is a corrective measure, used when pests are already a problem. It mainly relies on pesticides, and often attempts to reduce pest populations to the lowest possible level or to eradicate them completely.

Pest management includes preventative methods as well as corrective measures, and manages the population of a pest so that it is below damaging levels.

Integrated pest management (IPM) uses all available pest management techniques in an overall crop / pest management programme which considers all the potential pests. Pesticides are applied only when absolutely necessary, and an important part of IPM is determining when pesticides are actually needed.

In some countries, the use of pest control based on pesticides in certain crops has resulted in the development of pest resistance to pesticides (see 5.6), pest resurgence, the development of secondary pests into major pests, an increase in pesticide use, an increase in production costs, and uneconomic crop production. These effects have resulted in production of those crops being abandoned, as well as the contamination of food, water and soil.

Integrated Pest Management provides a long term solution to these problems by employing as many pest management techniques as possible and by using pesticides rationally. IPM is not new – mechanical, cultural and biological techniques were used by farmers for hundreds of years before chemical pesticides became available. In addition, there are IPM techniques that have been developed more recently.

Integrated Pest Management has been defined in many different ways; the definition agreed by the UN's Food and Agriculture Organisation (FAO), NGOs, such as the Pesticide Action Network (PAN), and the pesticide industry, is:

An approach which "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 minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms."
(International Code of Conduct on the Distribution and Use of Pesticides, FAO, November 2002)

This definition incorporates the underlying concepts that IPM:

- is farmer based,
- is not a "package" but is location specific (even down to the field level or crop growth stage),
- is a combination of all suitable techniques,
- must be considered as an integral part of crop production together with all agronomic techniques (ie integrated crop management – ICM),
- considers the economics of pest management, and
- optimises pesticide use, eliminates unnecessary use of pesticide, and promotes safe handling and application for the protection of health and the environment – as little as possible, as much as necessary.

IPM is not a fixed package of recommendations for any crop.

Put simply:

"IPM is the combination of all appropriate practices into a single plan for crop and pest management that optimises input use to reduce pests and damage to an acceptable level, maximise yield, and minimise negative effects."

To take the concepts one by one:

IPM is farmer based as the farmer is the one who has to put the techniques into practice in his or her field. The farmer must, therefore, possess the knowledge and the resources required to do this.

IPM is not a package of fixed recommendations, such as variety, land preparation, time of planting, plant spacing, fertiliser or irrigation rates and timing, time of thinning, times of weeding etc. Each of these factors is largely fixed - for a particular crop the land should be prepared in a certain way, there is a best time for planting, there should be a particular spacing between the plants, etc.

IPM is not like this. There is no single "recipe" for IPM. Even within one crop there will be differences between locations, crop growth, yield potential, the attacks of the different pests, and the farmer's resources. It is impossible to give one package of recommendations that will adequately cope with all the combinations of these possibilities. The implementation of IPM, therefore, must be flexible, and adapt to local agronomic, pest, and farmer circumstances.

IPM is a combination of all suitable techniques which minimise pest numbers and damage. The actual techniques included in an IPM programme will vary, not only between crops, but also within the same crop grown in different locations, depending on the suitability of the different techniques for that situation and availability of tools and resources.

2 INTEGRATED PEST MANAGEMENT – WHAT? HOW?

IPM must be considered as an integral part of crop production together with all agronomic techniques (ie integrated crop management – ICM). Pest management cannot be considered on its own, it is a part of the overall production practice of a crop, which include seed/variety selection, land preparation, fertility and water management etc. Changes to production practices will affect pest management practices.

IPM considers the economics of pest management as the crop has to pay for all the input costs. If unnecessary inputs are used, such as unnecessary pesticide applications, profits and the farmer's income are reduced.

IPM optimises pesticide use, eliminates unnecessary use of pesticide, and promotes safe handling and application for the protection of health and the environment – as little as possible, as much as necessary.

These points will be covered in greater detail in later sections.

IPM practices are not new. Farmers used many of the practices that we now incorporate into IPM strategies for hundreds of years before synthetic pesticides were available, using their own knowledge of the crops and pests to minimise pest damage. These practices were largely abandoned when synthetic pesticides, which provided an easy answer to pest problems, were developed in the 1940s and then widely used in the 1950s. However, in the 1960s the above problems of pesticide use started to become acute. In consequence, pesticide use began to be rationalised in certain crops, particularly cotton. IPM has gradually developed since then, and modern IPM combines aspects of the old farmer knowledge with more recent technical advances.

IPM practices were used by farmers long before synthetic pesticides were available.

The advantages of using IPM are that:
- Use of inputs is optimised
- Unnecessary pesticide use is avoided
- Pest management costs are reduced
- Crop losses are reduced
- Pest resistance to pesticides is avoided
- Crop production is sustainable
- Biodiversity is sustained
- The risk of human, animal, food, wildlife and environmental contamination is reduced.

How is IPM Implemented?

As noted above, IPM uses all suitable techniques or strategies to keep pests below levels that cause unacceptable crop loss. These different strategies are usually placed under the main headings of Mechanical, Cultural, Sanitation, Biological, and Chemical methods of pest management.

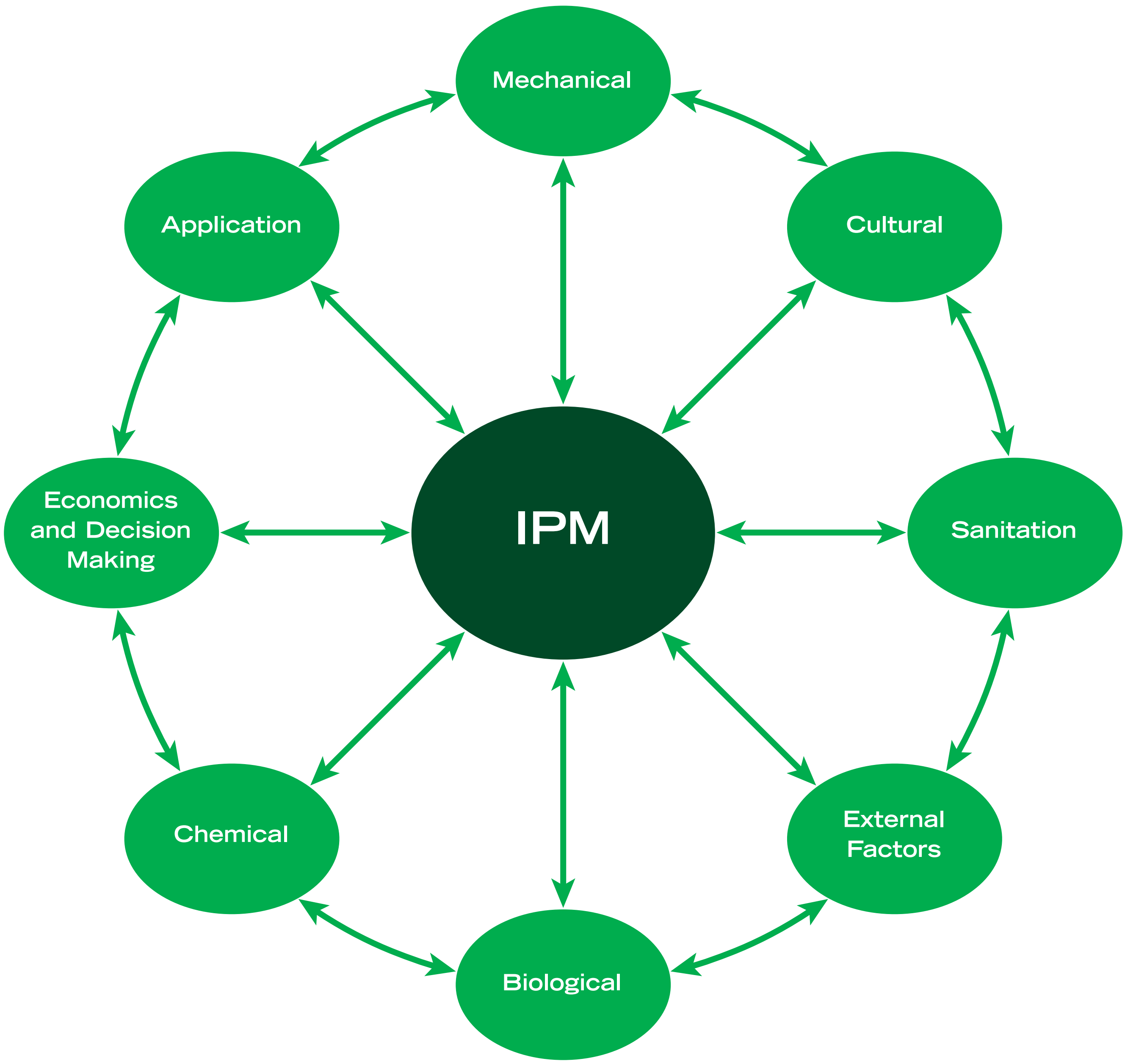
There are many individual methods under these headings which can be used in an IPM programme. Those which are actually used will depend on the crop and pest situation, and also to some extent on the infrastructure under which the crop is produced, as well as the availability of resources.

It is also important to remember that any crop is a dynamic system – it is constantly changing. It is changing within a season due to the natural growth stages of the crop (seedling, vegetative, reproductive stages), as a result of the farmers management practices (thinning, weeding, fertiliser application, irrigation etc), and as a result of changes in pest types and numbers. It also changes between seasons as one year may be generally hotter or cooler than another, or one year may have more rainfall than another. The implementation of pest management needs to take this dynamic situation into account.

A crop is dynamic and constantly changing.

Pest management must take this into account.

The Components of IPM – The IPM Circle



3 CROP MANAGEMENT

Pest management is only one aspect of overall crop production. It cannot be considered on its own as crop management affects pest management, and vice versa. The first requirement of IPM is to grow a healthy crop, which is more able to withstand the effects of pests than a weak crop or one under stress. A healthy crop also has a higher yield potential, and is more able to repay any costs of pest management.

The genetic makeup of the seed, together with crop management practices, determines the potential of a crop to produce a high yield. Pest management, good or bad, does not affect this potential, it only protects what the crop produces. For example, poor cotton seed and poor crop management may give a maximum yield potential of 300 kg per ha. Pest management, no matter how good, cannot increase this potential to 400 or 500 kg per ha.

Pest management does not increase the potential of a crop to produce a high yield.

It only protects the crop against yield losses.

The primary objective of crop production, and the foundation of IPM, is to use good seed and good crop management practices to grow a healthy crop with maximum yield potential. Such a crop is also more able to withstand pest attack and damage before yield loss occurs. Pest management is coordinated with these practices to obtain economic protection of the crop from pest injury or loss, while minimising hazards to human health, other crops, animals and the environment.

Understanding how a crop grows and develops, and its place in the cropping system, is essential to successful pest management. Without the knowledge of how pests and crop management practices interact to affect crop growth and development, it is not possible to apply effective and economic pest management techniques.

Furthermore, there are external factors which can affect the crop and make it more susceptible to pest attack or provide more suitable conditions for pest development, for example, dust settling on leaves, which attracts mites. Knowledge of these factors, their effects and prevention or treatment, is also essential to successful pest management.

Good Crop Management

Growing a strong, healthy crop depends on:

Quality of site and soil texture

The selection of a suitable site, particularly for perennial crops such as fruit trees, is most important. Stony areas or areas with shallow soils or poor soil texture should be avoided, as these are often associated with a hard pan, which prevents proper root development. Soils with poor drainage should also be avoided.

Crop rotation

Crop rotations and the previous crops can affect the growth of a crop. For example, nematodes can build up with repeated tomato crops in the same field; clover and legumes before another crop puts nitrogen into the soil, reducing the need for applied nitrogen in the following crop; crops such as maize and wheat can reduce the level of *Fusarium* in the soil.

Crop rotation helps to minimise the build-up of soil-borne pests, weeds and diseases, such as nematodes, weeds (eg *Orobanche* – broomrape), diseases (eg *Fusarium*, and root rots such as *Phytopthora* and *Pythium*).

Land preparation

Appropriate land preparation is important. Soil tillage of the field removes hard pans and allows roots to fully penetrate, while a correctly prepared seed bed allows seeds to germinate and grow quickly. Improved soil tilth and drainage can reduce nematode levels. Tillage can destroy the pupae and overwintering stages of many insect pests. However, the advantages of tillage should be weighed against other advantages gained through no-till agriculture (build-up of organic matter, water retention, soil conservation, lower labour etc).

Certified seed or root stock

Clean, certified seed/root stock is the essential foundation of a healthy crop with a high yield potential. No crop management practices are able to compensate for problems arising from poor quality seed or planting material. Clean and certified seed and root stock is free of any weed seeds, pests and diseases, for example virus-free tomato seed. Seed and root stock which is dressed will also protect against soil-borne diseases and early season sucking pests. When establishing an orchard, root stock should be obtained only from a certified nursery.

Transplanting
Seed beds should be insect pest, disease and nematode free so as to avoid transferring these pests to the field with the seedlings.

Time of planting
Planting at the correct time promotes healthy plant growth and avoids periods of attack by major pests, such as late planting of Faba bean to avoid infestation by aphid from other legumes, and early planting of cotton to avoid late season bollworm attack.

Plant spacing and density
Plants sown too close together are weaker and more susceptible to pest attack. Too close spacing also provides suitable micro-climatic conditions within the crop for the build-up of pests and diseases, such as aphids and whitefly in cotton, blight in tomatoes, downy mildew in cucumber, and aphids, mites, blight and mildew in apple.

Thinning of seedlings
When seedlings are not thinned or thinned too late, the plants are weaker and more susceptible to pest attack.

Weeding
Weeds compete with the crop for sunlight, nutrients, and water, resulting in a weak crop. Cotton, for example, is extremely susceptible to weed competition at the seedling and early growth stage. Weeds can also harbour or attract pests and diseases which then spread to the crop, such as fruitworm in tomato. However, weed species can also encourage populations of beneficial insects by acting as refuges, and are often left at the edges of fields, or as ‘strips’ through the field. Tall weeds in orchards can attract rodents, but a low cover of weeds or grass between trees avoids the dusty conditions which promote red spider mite.

Timing and amount of fertiliser
Ideally an integrated soil fertility management (ISFM) should be adopted. ISFM aims to replenish soil nutrient pools, maximize on-farm recycling of nutrients, reduce nutrient losses to the environment and improve the efficiency of external inputs of natural or artificial fertiliser. Wrongly timed or excess fertiliser can promote vegetative and dense plant growth which encourages pests such as aphids and whitefly. Excess nitrogen fertiliser weakens plants and makes them susceptible to pests such as aphids and whitefly, and diseases such as mildews and blights.

Origin, timing and amount of irrigation water

Similarly to fertiliser, wrongly timed or excess irrigation can promote vegetative plant growth which encourages pests and diseases such as aphids and whitefly in cotton, blight and *Orobanche* in tomatoes, root rot in citrus and Faba beans, and spider mite, aphids and blight in apple. The trunks of citrus trees should not come into contact with irrigation water in order to avoid gummosis. Irrigation water must also meet the necessary criteria of hygiene (not obtained from drainage or sewage canals) and salinity, must not contain harmful materials such as heavy metals.

(Dryland crops depend on rainfall, which is out of the control of the farmer, although crop management practices such as crop rotation, land preparation, mulching or no-till cultivation, time of sowing, and plant spacing can ensure the best use of available rainfall,).

Pruning of tree and vine crops

Correct shaping of fruit trees and regular pruning allows more air and light to enter, and lowers humidity so that diseases and pests are discouraged. Infested branches should be removed after harvesting.

Removal of infested plants/branches

Disease infested plants and branches provide a source of infestation to healthy plants. They should be removed and burnt to prevent the spread of disease. Plants infested with *Orobanche* or other parasitic weeds can also be treated in this way in low infestations.

Post-Harvest Sanitation

Crop residues left in the field can provide shelter for over-wintering insect pests, such as pink bollworm, cotton stainer, and codling moth, and for diseases such as blights and mildews. Crop residues, fallen fruit etc, should be ploughed-in, burnt, or buried.

General

One of the main problems caused to pest management by poor crop management (particularly by too close spacing, excess fertiliser or water) is the development of a vegetative, tall, or dense crop.

Such a crop has a climate inside it which promotes the development of pests such as aphid, jassid and whitefly, and diseases such as blight and mildews. In addition, chemical control is less effective as spray penetration and coverage of all the plant surfaces is poor, and it is difficult for the spray operator to walk through the crop. There is thus the double effect of encouraging pests and diseases while reducing the effectiveness of chemical control measures. As a result, pests and diseases are much more difficult to control effectively in crop which has grown dense through poor crop management.

External Factors

External factors act on the crop indirectly by creating conditions that encourage pest development, or weaken the plants so that they are more susceptible to attack. If these factors cannot be avoided, then suitable treatment must be applied to overcome or minimise the effects.

Examples of external factors are:

- The dust deposited on leaf surfaces by desert winds, which provides a suitable environment for the development of spider mites in many crops, particularly fruit and palm trees. The dust should be washed off with water and detergent if at all possible.
- Sun scorch of leaves of crops such as tomato and cucumber, particularly when grown in plastic tunnels, which facilitates infestations by diseases such as *Alternaria* (early blight) in tomatoes, and *Peronospora* (downy mildew) in cucumbers. Tomato fruits should be protected from the sun by covering with foliage or straw, and plastic tunnels should be opened for ventilation during the hours of strong sunshine.

Examples of other external factors which may be difficult to avoid, but which will affect crop growth and product quality are:

- Soil conditions such as pH, structure, hard pans, or water logging.
- Irrigation water quality, such as high salinity or toxic contents.
- Humidity after rain or sprinkler irrigation.
- Air pollution and dust, particularly downwind of heavy industries such as cement or brick factories.
- Mechanical damage by wind or agricultural machinery to branches, foliage and roots.
- Temperature during the crop growing season, which can affect both crop development and the development of pests and diseases.

The potential effects of external factors need to be considered in an IPM programme, and mitigated wherever possible.

4 THE PRINCIPLES OF PEST MANAGEMENT

Pests can occur in many situations – for example in crops, where they cause damage and loss to produce; in houses and buildings, where they cause damage and loss to food, structures and fabrics; in public health, where they spread disease; and as general nuisance organisms.

Often, the first reaction to a pest situation is to use a pesticide. However, chemical control is only one component of an IPM programme. This section outlines other methods of pest management, describes the place of pesticides in the overall pest management strategy, and gives the principles for effective and economic pesticide use. Although many of the examples given refer to crop protection, the underlying principles apply in almost any pest situation, be that in the field, a house, or wherever.

Methods of Pest Management

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

Mechanical control is sometimes called physical control, and involves the use of machines or other tools. Some of the practices were detailed in Section 3.1.

- Soil cultivation and tillage, which physically kills some pests, buries them, or exposes them to drying conditions on the soil surface or as food for birds or other predators.
- Soil cultivation also buries and kills weed seedlings, and buries potential food sources for insect pests.
- Traps, such as rat traps and sticky insect traps.
- Hand collection of insects, leaves/fruits that are diseased, with insect eggs, or infested with insect pests, etc.
- Hand weeding

Cultural control includes practices that optimise plant growing conditions, or produce unfavourable conditions for pests. Optimal growing conditions provide a healthy crop that is more able to resist pest attack. These crop management practices were detailed in Section 3.1.

- Quality of site and soil texture
- Crop rotation
- Land preparation
- Use of clean, certified seed and planting material
- Time of sowing
- Plant spacing
- Timing and amount of fertiliser
- Weeding
- Origin, timing and amount of irrigation water

Additional practices which can be included under cultural control are resistant crop varieties and trap crops.

Resistant crop varieties have in-built resistance or tolerance to attack by certain pests. The degree of resistance can vary from slight to almost complete. A resistant variety is resistant to some pests, but not all pests. Resistance mechanisms work in three main ways:

- Chemicals in the plant repel the pest, or prevent it from completing its life cycle.
- The plant is more vigorous or tolerant than other varieties, and thus suffers less damage from pest attack, or is not susceptible to the disease.
- The plant has physical characteristics that make it more difficult for the pest to attack it.

Examples are varieties of tomatoes tolerant to virus diseases and *Fusarium wilt*, and Faba beans tolerant to *Orobanche*. Genetically modified crops, such as Bt cotton, also fall under this category.

Trap crops attract pests away from the main crop, such as eggplant attracting spider mite. These crops are then either sprayed with pesticide, harvested, or destroyed.

Sanitation may be included in either mechanical or cultural control. Sanitation helps to prevent and suppress pests by removing or preventing access to sources of infection or sources of food and shelter. Practices include:

- Removal of infected crop material in fields and orchards.
- Ploughing-in or burning of crop residues.
- Removal of food sources such as seed and grain (after both planting and harvesting); cleanliness in the store, house or kitchen; good management of animal manure, etc.
- Using nets and screens in greenhouses; rodent proof grain stores, etc.

Biological control involves the use of natural enemies of pests – predators and parasites (also called beneficial insects) and disease causing organisms – and encouraging their development. Some pests or, in some cases, non-pest species, must always be available to provide a food supply, and there often is a time lag between the increase of a pest population and the increase of natural enemies. Biological control also includes methods by which the pest is biologically changed. More information on biological control is given in Section 4.3.

Chemical control is the use of chemical pesticides which kill pests, control their activity (this particular mode of action is often included under biological or 'bio-rational control, e.g. use of insect sex pheromones), or prevent them from causing damage.

Examples of Mechanical, Cultural, and Sanitary Control Practices

Examples of mechanical, cultural, and sanitation pest management practices for selected vegetable, field and orchard crops are presented in the Appendix. They indicate the wide range of practices which are available, most of which are good crop management techniques. Not all practices will be suitable for all areas, but, together with local information, the information shouldl help in the development of specific IPM cultural practices for individual crops in more localised areas.

The examples were compiled from a range of publications, largely in the Middle East, but also from the USA, Africa, Australia, the Far East, and FAO.

Enhancing Biological Control

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

The beneficial organisms are present in the crop itself, and also in neighbouring fields and crops, and the vegetation between fields and along canal banks, waste ground, and roadsides. However, this vegetation can also harbour pests which can spread into cultivated crop areas, and the importance of the surrounding vegetation in harbouring beneficial insects relative to pests should be assessed as part of the IPM programme.

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

- In many circumstances, natural enemies are extremely common in fields that have not been sprayed with a pesticide. When certain pesticides are used in a crop, the beneficial insects are also killed. Brown Planthopper in rice is, in many instances, only a problem as a result of the pesticides used also killing the beneficial insects.

- Natural enemies can be encouraged by using pesticides only when necessary, particularly early in the crop season so as to allow populations of natural enemies to build up. If an early season pesticide applications are often required, a seed dressing should be used instead of foliar sprays. Refuge habitats should be left around fields where natural enemies can shelter and find food. Spot spraying, timing of sprays when the pest is active but the natural enemies are inactive and sheltered, and accurate placement of chemical sprays can all help to preserve natural enemies if a pesticide has to be used.

- Pests also naturally suffer from diseases caused by viruses, bacteria, fungi, protozoa and nematodes, and which can reduce pest numbers. These diseases may be commercially formulated for application as pesticides, such as nucleopolyhedrosis virus and *Bacillus thuringiensis* (Bt).

- Pests can be biologically changed by the use of Insect Growth Regulators, which prevent the pest from developing from one stage to another, and by pheromone mating disruption, which prevents the adult pests from finding one another to mate. These methods are sometimes included under Chemical Control.

- Biological control can be enhanced by the mass rearing and release of beneficial insects. Those commonly used include *Trichogramma*, *Bracon*, and *Chrysopera*.

In certain circumstances, the numbers of natural enemies can also be enhanced by intercropping, border planting, and relay cropping.

Intercropping is the planting of strips of crops or plants, which are either habitats for natural enemies or which attract pests out of the main crop, between the main crop or next to it. Examples are lucerne in cotton, which encourages populations of natural enemies of aphids, although Spodoptera leafworms can also develop in lucerne.

Border planting is the establishment of refuge habitats of flowering plants around the edges of fields which attract natural enemies. Suitable plants are fennel, coriander, brassicas, crucifers, legumes and castor.

Relay cropping is the planting of short duration crops early in the season, into which the main crop is planted shortly before the harvesting of the relay crop. The natural enemies which develop in these crops will then move into the main crop when they are harvested. Examples are crucifers (eg cabbage), legumes (eg beans), or cucurbits (eg cucumber). However, the relay crops need to be selected with care, as the first crop may increase pest numbers in the following crop. Aphids can develop on cucurbits or tobacco, thrips is often present in large numbers on onions, and *Helicoverpa* bollworm on maize, sunflower, legumes and tomatoes.

Economic Principles of Pest Management

A farmer grows a crop as a food supply or to make money. In either case, he wants to maximise his yield or profit, and needs to consider both in economic terms.

- Crop production inputs cost the farmer money. The more he spends on inputs, the less profit he makes.
- Profit = Value of Harvested Crop – Production Costs – Transport/Marketing Costs.
- All inputs need to be used effectively and economically. In other words, the farmer should only use inputs when they will give an economic or other significant benefit.
- For pesticides, it is the cost over the season that must be considered, not the cost per litre. A pesticide that is cheap per litre may be more expensive over the season as a higher mixing rate may have to be used, or it may be less effective and so require more applications, than a pesticide that is more expensive per litre.
- If pests are at a high level, the value of the crop that will be lost will be greater than the cost of the pesticide application. The use of a pesticide in this case will give a RETURN on the farmers investment in pesticide use.
- If pests are at a low level, the value of the crop that will be lost is less than the cost of a pesticide application. In this case, the farmer will LOSE money by using a pesticide.

- Pests that cause indirect damage by transmitting virus diseases require a different economic evaluation, as although the numbers of the pests may be low, the crop losses caused by the disease may be very high. Similarly, fungal or bacterial diseases may need preventative sprays to be applied before disease symptoms are common, such as blight in potatoes.

- Crops are often able to withstand a certain amount of damage without any loss of yield. Some varieties of cotton can tolerate up to 50% leaf loss before flowering and rice can lose more than 25% of leaves before yield loss occurs. Cotton can also compensate for loss of fruiting bodies, and low levels of leaf or fruiting body loss can actually result in an increase in yield.

Pest Management Decision Making

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

The pest management decision making process is a continuous cycle that can be summarised as:

- **Detection**. Continual monitoring to see what pests and beneficial insects are present in the crop. This is usually called scouting, and is discussed in Section 5.2. Pests and diseases are detected before they cause economic loss, and spot treatments can possibly be made. If detection is too late, control will be less effective, more costly, and crop losses will occur.

- **Identification**. The organism must be identified to see if it is a pest, a beneficial insect, or of no importance. If the organism is an insect or weed pest, it is necessary to identify the stage in the life cycle so that control methods can be directed at the most vulnerable stage. For diseases, knowledge of the symptoms is needed for identification.

- **Economic significance**. Is the pest causing, or, if left uncontrolled, will it cause, economic damage or loss? As described earlier, economic damage is the amount of damage that justifies the costs of control. It must be determined, therefore, if the pest numbers or infected areas are high enough to warrant spending money on control. This is usually achieved by treatment thresholds, which are also discussed in Section 5.2. Crop growth stage and economic value also need to be taken into consideration. It should be noted that biological damage (for example, holes in leaves) often occurs without there being any yield or economic loss. The potential (controlling) impact of beneficial species also needs to be considered.

- **Decision**. If the pest level is below the threshold, then no pesticide treatment should be applied. If the pest level is above the threshold, then control treatment is required.

- **Selection of control method(s)**. The method of control must be effective, practical, economic, and safe. More than one control method may be involved for a single pest. For example the application of a pesticide spray to kill adult mosquitoes and remove the nuisance effect, while at the same time removing breeding sites (draining ponds, cleaning up old tins, bottles, tyres etc that contain water in which the larvae live) to prevent future infestations.

- **Evaluation**. The follow-up of the control method to evaluate the effectiveness. This is a continuation of the monitoring procedure at the beginning of the decision making process, and starts the decision making cycle again.

The Place of Pesticides in IPM

This Section, and Sections 6 and 7, discuss chemical control and pesticides in some detail. This reflects the need for rational and careful pesticide use. A thorough knowledge of the place of pesticides in IPM is required for effective implementation of practical IPM.

Efficient, effective and safe pest management is not a case of "See a pest – spray a pesticide". It is a case of using all available techniques, all of which play a part in keeping pests at levels below those which cause economic damage or loss – in other words, integrated pest management. Pesticides more often than not are an integral component of an IPM programme.

The advantages of pesticides are that they provide an effective and quick reduction of pests when numbers reach economically damaging levels, they can control several pests at the same time, and they are easy to use.

The disadvantages of pesticides are that they provide only a temporary solution, can be costly, involve a hazard in use and to the environment, can kill natural enemies of pests, can kill pollinators such as bees, can cause pest resurgence, excessive use can result in pest resistance, and there is a potential risk to users and others.

In IPM, therefore, pesticides are used only when pests are causing, or will cause economic loss or damage. Crop monitoring and application thresholds are used to determine pest numbers and to time applications at the most vulnerable pest stage. If a pesticide is used, it ideally should be selective, of low persistence and of low toxicity.

Normally pesticides are used when an examination of the crop shows that economically significant levels of the pest are present. However, there are situations where the preventative use of pesticides is desirable or essential, such as seed dressings against soil-borne pathogens and early season sucking pests, disease vector control to limit virus infections of crop plants, and crop fungal diseases.

No attempt should ever be made to eradicate a pest with pesticides, as this is almost impossible to achieve. In addition, small numbers of pests may be required to provide a food source for natural enemies, particularly parasites.

Following a pesticide application, pest numbers may be reduced for a short period but then rapidly increase to much higher levels than were present before the application. This is known as pest resurgence, and is due to the pesticide killing the natural enemies of the pest, as well as most, but not all, the pests. The removal of the natural control allows the pests to multiply to much higher levels than before.

In addition, pests may be present which are not normally a problem as their numbers are kept low by natural enemies. When a pesticide is applied, this control is removed as the natural enemies are killed, and the pests can develop from secondary pests to become major pests. Choosing a product with restricted activity or that is specific to the pest, or spot application to areas of the crop with high pest numbers, can help avoid these problems.

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Thresholds and Pest Scouting

Thresholds are the pest level at which a pesticide application is needed in order to prevent economic loss or damage. They are set at the level where, if the pest population continues at that level or increases, then the value of the economic loss or damage would be greater than the cost of control. In some cases the threshold is zero or very low – for example, late blight in potato, crop virus transmitting insects where the virus is a major crop problem such as whitefly transmitting virus disease in tomatoes, preventative treatments for late blight in potatoes or downy mildew on cucumbers grown in glasshouses. In other cases, it is set fairly high – for example aphids in cotton or stemborer in maize.

The **economic** threshold is calculated from a range of factors including the expected price for the produce, the expected yield, factors which may influence the yield and future pest attack (eg weather), and the anticipated cost of future control interventions. The economic threshold is thus dynamic, varying almost on a daily basis, and is thus difficult to apply in practice.

A **treatment**, or **spray**, threshold is largely used instead. This is derived from a series of research trials over several seasons, and is the pest level at which a pesticide treatment will give a return to the farmer in most seasons. Treatment thresholds can also vary during the season, based on such factors as crop growth stage, the damage or loss pests can cause at that stage, and the number of beneficial insects present. These variations are also derived from research trials, but the changes occur at pre-fixed intervals during the cropping season.

With insect pest thresholds, a pest population is usually allowed to exist in the crop, as the cost of control would be greater than the value of the crop saved from loss or damage.

Pest scouting is the term given to monitoring a crop for levels of insect pests, disease infestation, weeds, and beneficial insects, and the growth stages of the insects. It is done on a regular basis, the intervals depending on the crop and the pests of importance. Scouting also enables hot-spots of infestations such as aphids and mites to be identified and spot sprayed, rather than spraying the whole field.

Scouting provides the information on whether pest levels are above or below the treatment threshold, and so if an intervention is needed or not, and information on whether previous control actions have been successful.

Different crops and pests have different pest scouting methods and techniques. Also, the same crop and pest may have different methods in different areas or countries. As a result, the treatment thresholds will also be different.

Thresholds and pest scouting are one of the fundamental aspects of IPM and of the effective, efficient and economic use of pesticides.

Pesticide Selection

If it has been decided that a pesticide is necessary, the correct pesticide must be used. A pesticide only controls a certain range of pests, so one which is effective against the pest to be controlled must be selected. A pesticide should not be applied simply because it is a pesticide or is cheap – this is a waste of time and money if it is not effective against the pest.

If possible select a pesticide with a limited range of activity. Such a pesticide has the least effect on beneficial insects and reduces the risk of resistance in other pests. In the very early stages of an infestation, “mild” pesticides can be used, such as mineral oils against insects and mites, and micronised sulphur against mites and powdery mildew.

If there is more than one suitable pesticide, select the one that poses the least risk to humans, animals and the environment under the conditions in which it will be used. A pesticide which is safer in these respects is not less effective in killing the target pest.

A pesticide of the same chemical group classification (see Section 6.2) should not be used repeatedly in the same season against the same pest or range of pests. This increases the risk of pest resistance.

Only pesticides from a reputable manufacturer or source should be used, and purchased in unopened or undamaged containers with a complete and undamaged label. Similarly, users (farmers) should only purchase pesticides from reputable pesticide retailers, in unopened and undamaged containers with a complete and undamaged label, and with a full crop season remaining before the expiry date. Counterfeit products are becoming more of a problem – these can be ineffective, as well as possibly dangerous to humans, animals and the environment, as well as being illegal. Users should be vigilant to avoid being sold counterfeit products, and be suspicious if offered products that are priced below the normal retail rate.

Pesticide Dose Rate

Pesticide dose rates – the amount of pesticide applied per hectare - have been evaluated by research and the manufacturers. These dose rates are given on the container label and should be followed when applying a pesticide.

- If too low a dose rate is applied, not all the pests are killed. Crop losses are not prevented, the use of the pesticide is not effective, and costs of control are increased.

- If too high a dose rate is applied, the excess is wasted. More pesticide is not more effective at killing the pests and the costs of control are increased. Also the risk of the pests developing resistance to the pesticide is increased.

Dose rates are given on the container label either as the amount to apply per hectare, or as the amount to mix in so many litres of water at so many litres per hectare. Local measurements may also be used, such as feddan instead of hectares in Egypt and other Middle East countries, rai in Thailand and acres in North America.

Causes of Failure of Pesticide Applications

Sometimes a pesticide application fails to reduce the levels of a pest. Usually, the farmer blames either the pesticide for this (he says it is old or adulterated), or he thinks that the pests have developed resistance. However, the usual causes of poor results with an application of a genuine pesticide from a reputable source are:

- **Incorrect pesticide for the pest**. The pest has been correctly identified, but a pesticide has been selected and used which has no effect on the pest. This may be due to the farmer wanting to use a cheap pesticide, or having been given poor advice. Alternatively, the pest has been incorrectly identified, and, although the correct pesticide has been selected and used for the pest as identified, the pesticide has no effect on the actual pest that is present.

- **Incorrect timing of the application**. The pest population is not at a susceptible stage, or a disease infection is too far advanced. For example, an established disease infection or late stage caterpillars are much harder, or impossible, to kill with the recommended pesticide dose.

- **Incorrect dose rate**. A dose rate has been used which is too low to kill the pests. This may occur if the farmer is trying to save money by using less pesticide than recommended, or through poor application.

- **Incorrect application**. The pesticide has not been applied correctly, so that the pesticide is not applied to the right place where the pest is present (for example, whitefly and downy mildew under the leaves, with most of the pesticide applied to the top of the leaves), or has not been applied evenly over the crop, so that there are areas of over- and under-dosing. Other possibilities are poorly calibrated or badly maintained spray equipment that applies an incorrect dose rate, blocked nozzles, and adverse environmental conditions during or after application, e.g. strong winds or rain.

Less common causes of failure are:

- Substandard pesticide (although this may be common in certain regions), such as poor quality formulation, adulterated, counterfeit, or expired.
- Pest resistance to the pesticide.

A possible cause of failure with systemic pesticides (see Section 6.2) is that the plants are under stress so that there is little absorption or movement of the pesticide within the plant. This can apply to insecticides, herbicides and fungicides.

Causes of Pesticide Resistance in Pests

Pesticide resistance is the inherited ability to tolerate the toxic effects of a pesticide.

- Every pest or pathogen population contains a small proportion of individuals with this inherited ability.
- When a pesticide is applied, susceptible individuals are killed while the resistant individuals survive.
- The proportion of resistant individuals in the population is thus increased.
- This effect occurs each time a pesticide is applied, with the proportion of resistant individuals increasing every time.
- As the proportion of resistant individuals increases, the normal dose of pesticide is not enough for effective control, and higher doses or more frequent applications are required.
- Eventually the proportion of resistant individuals in the population is so large that it is impossible to control the pest or pathogen with the pesticide.

Individuals inherit various genetic characteristics from their parents, such as blond or brown hair in humans. In every population, be it human or pest, there is genetic variation, and each individual is different to every other individual. Depending on the environment in which the individual is living, these differences may be of little importance, they may give an advantage, or they may give a disadvantage. For example, dark skinned people have an advantage over those with light skin in tropical areas, as those with light skin are more susceptible to skin cancer from the strong sunlight. Even so, in the dark skinned population there are always some people born with no skin colour due to genetic variation.

Similarly, in every pest population there are some individuals that are naturally less susceptible or resistant to pesticides. This is a characteristic that is genetically inherited and enables the individual pest to withstand the toxic effect of a pesticide. The higher the proportion of resistant individuals in a population, the greater the chances of two resistant individuals mating and producing resistant offspring. The lower the proportion of resistant individuals, the lower are these chances.

If resistance develops, then that pesticide can no longer be used to control the pest. Furthermore, in many cases, resistance to one pesticide also gives cross-resistance to other pesticides that act on the pest in a similar way. For example, resistance to one organophosphate pesticide may confer resistance to other organophosphates. A whole range of pesticides thus become ineffective against that pest.

Because of this, it is in the interest of all who use pesticides to minimise the risks of resistance developing.

Factors which encourage the development of resistance in a pest population are:

- Using the same pesticide, or pesticides from the same chemical group, too frequently in the same seasoon. The pests are continually exposed to the pesticide, which eliminates the susceptible individuals much more rapidly.
- Using too high a dose of the pesticide. A greater proportion of the susceptible individuals are killed, so resistant individuals are more likely to mate or spread infective inoculum.
- Using a pesticide with a long persistence. The pests are continually exposed to the pesticide, which eliminates the susceptible individuals much more rapidly.
- The proportion of resistant individuals in the population before the pesticide is used. The higher the proportion to begin with, the faster resistance will develop.
- Exposure of a greater proportion of the pest population to the pesticide, such as with area-wide treatments.
- A short pest life cycle. Resistance can build up more quickly with pests that multiply rapidly.

Factors which minimise the development of resistance in a pest population are:

- Immigration of susceptible individuals from outside the pesticide treated area. These reduce the proportion of resistant individuals in the pest population.
- A long pest life cycle.
- Following IPM principles
- Applying pesticides only when necessary.
- Using pesticides from different groups during the season.
- Using the correct pesticide dose rate.
- Applying the pesticide effectively.
- Using less persistent pesticides.

6 PESTICIDES AND FORMULATIONS

A pesticide can be defined as any substance that is used to prevent or reduce loss or damage caused by pests, either by directly killing the pest, or by inhibiting its growth, or repelling it.

Pesticide Names

A pesticide may be referred to by several different names, which can cause confusion. The same pesticide may be referred to by a number of different names, or different pesticides may have similar names.

Active Ingredient. Only a certain component of a pesticide product has activity against pests. This component is called the **active ingredient**. There may be more than one active ingredient in a formulation.

Chemical name. Each active ingredient is given a chemical name that describes the actual chemical composition. This name is often long and complicated. It may appear on the label in brackets.

Common name. Each active ingredient is given an internationally recognised common chemical name that is much easier to use and remember than the chemical name. A specific common name always refers to the same active ingredient, regardless of the manufacturer of the product. Common names are always given on the label.

Product name. Manufacturers give their own name to their products containing a particular active ingredient. It is the product name that appears in large print on the label.

An example of pesticide names is:

Chemical name:
(RS)-α-cyano-3-phenoxybenzyl(1RS,3RS;1RS,3SR)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate

Common name: Cypermethrin

Product names: Arrivo, Basathrin, Cymbush, Cypersect, Ripcord, etc

Pesticide Classification

Pesticides may be classified in several ways, each way having its own special purpose. Examples of classification are:

A: Type of pest controlled

• Insecticides	Control insects.
• Fungicides	Control fungi.
• Herbicides	Control weeds.
• Acaricides	Control mites.
• Rodenticides	Control rodents (rats, mice).
• Molluscicides	Control snails.
• Nematicides	Control nematodes.

B: Chemical group

Insecticides

- **Inorganic**: Do not contain carbon. They commonly contain arsenic, copper, mercury, sulphur, tin or zinc. Most of these compounds are now banned throughout the world, or have severely limited uses.
- **Organic**: Contain carbon and which are synthetic in that they have been developed by man. They are the most commonly used pesticides, and include groups such as the organophosphates, carbamates, and pyrethroids.
- **Botanical**: Obtained from plant extracts, such as rotenone, neem, and pyrethrum.
- **Biological/Microbial**: Contain bacteria, fungi, protozoa or viruses, such as *Bacillus thuringiensis*, and Nucleopolyhedrosis Virus.

Herbicides

Herbicides have many different chemical groups, the most common of which include triazines, substituted ureas, and sulfonylureas.

Fungicides

As with herbicides, fungicides have many different chemical groups. Common groups are inorganic, dithiocarbamates, and triazoles.

C: Hazard/Toxicity

The measure of how poisonous the pesticide is to man. High toxicity to man does not necessarily mean that the pesticide is highly toxic to the pest. Formulations are usually less toxic than the pure active ingredient, although with some formulations one or more of the inert ingredients (for example, oil-based solvents) can be more toxic than the active ingredient. The World Health Organisation (WHO) classification is most commonly used, but there are other classifications, such as national systems:

- Class Ia "Extremely Hazardous"
- Class Ib "Highly Hazardous"
- Class II "Moderately Hazardous"
- Class III "Slightly Hazardous"
- [no class] "Unlikely to Present Acute Hazard in Normal Use"

The toxicity warning on the product label refers to the formulation, not the active ingredient.

D: Mode of action

The mode of action of a pesticide is how it works on the pest.

- **Contact**. The target pest is killed when it comes into direct contact with the pesticide. The pesticide is usually applied to a surface, such as leaves, but may be applied as aerial droplets, for example for flying mosquito or locust control. For a given volume of spray, the more droplets per square centimetre of treated surface, the better the effectiveness of the pesticide. Most insecticides are contact pesticides. Good under leaf cover is essential for the control of insect pests such as aphids, whiteflies and spider mites, while good overall plant cover is essential for control of weeds and diseases.

- **Stomach ingested**. Insect pests must eat the pesticide to be killed. Most insect contact pesticides are also stomach poisons.

- **Systemic**. A pesticide that is absorbed and moved within a plant. They are applied to leaf surfaces, or to the soil as a drench or granules. Within a leaf, movement is mainly from the upper to lower leaf surface. There is very little movement down the plant, so overall plant coverage is essential for pests in the lower parts of the crop. Absorption by the plant is reduced if the plants are under stress. Insect pests are killed when they feed on the plant. Herbicides are largely systemic pesticides, which kill the weed when they are absorbed.

- **Vapour action**. A pesticide in vapour or gas form in the air or soil, which the pest breathes in or which is absorbed through the cell wall of microbial pathogens. These are used as space treatments in enclosed areas such as greenhouses, houses etc, or for soil disinfection.

Pesticide Formulations

Active ingredients are rarely applied in a pure form. Instead, the manufacturer mixes the active ingredient with various other components to make a pesticide formulation. This is done in order to dilute the active ingredient, and to make the product safer and more effective, or easier to measure, mix and apply, or to improve storage. The other components are referred to as inert ingredients, as they have not effect on pests.

Some inert ingredients, such as petroleum based solvents may be more toxic to humans and crop plants than the active ingredient. More recent formulations, such as suspension concentrates (SC), water dispersible granules (WG), and microgranules (MG), have no hazardous inert ingredients, and also posses improved stability properties. The properties of a formulation, including the effectiveness of the active ingredient and safety, depend on the use of high quality ingredients and manufacturing processes.

The same active ingredient may be available in several different formulations. One formulation may be safer to handle or more suitable for a given situation than another formulation of the same active ingredient. Also, different formulations of the same active ingredient may be registered for use on different crops. For example, an emulsifiable concentrate formulation may be phytotoxic to certain crop while the wettable powder formulation is not.

The common types of formulations are:

Emulsifiable Concentrate (EC)

Liquid formulations where the active ingredient is dissolved in a petroleum solvent. The formulation is diluted with water to form a suspension for application. Usually contain 25 to 75 percent of active ingredient. ECs are among the most common pesticide formulations.

Advantages	Disadvantages
• Easy to handle, transport and store. • Easily measured and mixed with water. • Can be used with most types of application equipment. • Little agitation needed in spray tank, does not settle out. • Not abrasive to nozzles and pumps. • Do not block filters or nozzles.	• Usually high concentration in the formulation. • Due to high concentration, easy to make errors when mixing, and in application dose rates. • Mixers need more protective clothing than applicators. • May cause phytotoxicity to crops. • Easily absorbed through the skin. • Solvents may attack rubber, plastic, hoses, gaskets etc. • Flammable.

Wettable Powder (WP)

Dry formulations of fine, insoluble powders. The active ingredient is combined with an inert carrier such as clay or talc, together with wetting and/or dispersing agents. The formulation is diluted with water to form a suspension for application. Usually contain more than 50 percent active ingredient. WPs are among the most common pesticide formulations.

Advantages	Disadvantages
• Easy to handle, transport and store. • Can be used with most types of application equipment. • Easily mixed with water. • Usually less phytotoxic than ECs. • Absorbed less readily through the skin than ECs.	• Mixers need more protective clothing than applicators. • More difficult to accurately measure when mixing than ECs (WP weight vs EC volume). • Risk of inhaling powder during mixing. • Require constant agitation in the spray tank, or they quickly settle out. • Abrasive to nozzles and pumps. • Can clog filters and nozzles. • Inert carriers may leave a deposit on crops, which has to be removed before marketing.

Suspension Concentrate (SC)

Used for active ingredients that are not soluble in the more common solvents. They are mixed on a carrier, such as clay, and formulated with a liquid to form a thick, paste-like suspension. The formulation is diluted with water to form a suspension for application. They combine the advantages and disadvantages of both ECs and WPs.

Advantages	Disadvantages
• Easy to handle, transport and store. • Can be used with most types of application equipment. • Easily mixed with water. • Usually less phytotoxic than ECs. • Absorbed less readily through the skin than ECs.	• Mixers need more protective clothing than applicators. • Container must be shaken before use to remix formulation. • More difficult to accurately measure when mixing than ECs. • Require moderate agitation in the spray tank, or they settle out. • May be abrasive to nozzles and pumps. • May clog filters and nozzles. • Inert carriers may leave a deposit on crops, which has to be removed before marketing.

Seed Dressings (DS, ES, FS, LS, PS, SS, WS)

Dry or liquid formulations for application to seeds prior to planting. Dry formulations usually require no further dilution (SS formulations require dilution with water), liquid formulations usually, but not always, require dilution with water. PS formulations are pre-dressed seed.

Advantages	Disadvantages
• Depending on formulation, similar to EC, WP, SC formulations. • Can be applied to seed on-farm with simple equipment. • Help to avoid early season foliar sprays, and so protect beneficial insects.	• Depending on formulation, similar to EC, WP, SC formulations. • Bulk treatment of seed requires specialist treatment equipment. • Treated seed may be eaten by humans, domestic animals, wildlife.

Granule (G)

Dry formulation of relatively large and heavy inert material. The active ingredient may be coated on the outside or absorbed into the particles. They are applied without any further dilution, and usually contain 1 to 15 percent of active ingredient. They are most commonly used for soil application to control weeds, nematodes and soil living insects.

Advantages	Disadvantages
• Ready to use, no mixing needed. • Soil application – do not stick to foliage. • Slow release of pesticide gives extended protection. • Low risk of drift. • Little hazard in use to applicator. • Require only simple application equipment.	• Plant application – do not stick to foliage. • May need to be incorporated in soil. • Can be difficult to obtain even distribution over the target area. • Slow release of pesticide results in long persistence. • May be hazardous to non-target animals such as chickens and other birds who mistake granules for food grain.

Bait (B)

An active ingredient mixed with food or other attractant material. The bait may be sold pre-mixed, or the pesticide and bait material mixed by the user. Pests are killed by eating the pesticide contained in the bait, either in a single dose, or over time. The concentration of active material is low, usually less than 5 percent. Commonly used in indoor situations, but may be used in agriculture.

Advantages	Disadvantages
• May be ready to use. • Little pesticide needed – bait applied only where pests are present and pests are attracted to the pesticide.	• Can be attractive to non-target organisms (domestic animals, children etc). • Pests may prefer other food or crop to the bait. • Pests may avoid bait due to association with ill-effects (eg bait-shyness of rodents).

Fumigant (F)

Pesticides that form poisonous gases. May be a liquid under high pressure that changes to a gas when released, or a volatile liquid, or a solid that releases a gas under high humidity. Used for structural pest control, food and grain storage, soil sterilization, and greenhouses.

Advantages	Disadvantages
• Toxic to a wide range of pests. • Can penetrate cracks, wood, soil and grain. • Single treatment will usually kill most pests in the treated area.	• Target site must be covered and airtight to prevent the gas from escaping. • Most are highly toxic to humans and all other living organisms. • Need specialized protective clothing, including respirators. • Need specialized application equipment. • Fumigated premises must be well-aired before access by humans and animals is allowed.

"Mixing" means the preparation of a pesticide formulation for application, such as when a pesticide is "mixed" with water ready for spraying. It does NOT mean the mixing of two pesticide formulations to be applied together. This practice is not recommended because of potential adverse effects, particularly to the crop or to the spray mix, and should be avoided.

Pesticide Adjuvants

Adjuvants are chemicals incorporated in a pesticide formulation, or added to the tank mix, to increase effectiveness and safety. They generally have no effect on pests in themselves.

Emulsifiers:	Help emulsifiable concentrates mix better with water.
Wetting agents:	Help wettable powders mix better with water, and help formulations spread on water repellent surfaces.
Spreaders:	Help the pesticide spread evenly over the sprayed surface.
Stickers:	Help the pesticide stick to the sprayed surface.

The Pesticide Label

The label on the pesticide container is the primary source of information about a product. The label has all the basic information that is needed – the product name, the active ingredient, the concentration of active ingredient, the crops and pests for which the product is registered, the dose rates, the toxicity, the safety precautions, the pre-harvest intervals, the expiry date, the name of the manufacturer and importer. If you need information about a pesticide, do not rely on memory as it is very easy to make a mistake. Read the label every time before using a pesticide.

The lay-out of the pesticide label varies between countries. However, every label on a pesticide container from a reputable manufacturer or source will have the following information:

- The product name of the pesticide
- The name of the active ingredient(s) in the product.
- The percentage concentration of active ingredient in the product.
- The percentage concentration of inert materials in the product.
- The toxicity of the product.
- The crops and pests for which the product is registered for use.
- The dose or application rates to use.
- The safety precautions to follow when mixing and applying.
- The first aid measures and antidotes.
- The pre-harvest interval.
- The date of manufacture, batch number, and expiry date.
- The product registration number, and the name of the manufacturer or importer and contact details.

Also along the bottom of the label should be pictograms, which give information in a graphical format about the precautions to be taken when using the product, and which complement the statements in the label text.

Toxicity

The FAO Guidelines on Good Labelling Practice for Pesticides include a hazard statement, a symbol, and often a band colour for labels based on the WHO classification system. This system is supported by CropLife International, and followed in many countries for pesticide labels, although some countries follow other systems.

WHO Class (1)		Label		
		Hazard statement	Symbol	Band Colour (2)
Ia	Extremely Hazardous	Very Toxic		Red
Ib	Highly Hazardous	Toxic		Red
II	Moderately Hazardous	Harmful		Yellow
III	Slightly Hazardous	Caution	None	Blue
	Products unlikely to present a hazard in normal use	Caution	None	Green

(1) The hazard warning on the label refers to the formulation, not the active ingredient.

(2) This is the most commonly used colour scheme, but they may differ in some countries.

Pictograms

The pictograms on the label are intended to provide graphical advice and warnings concerning the product. They should be in a band across the bottom of the label, one section of the band being concerned with mixing, one with application, and one with general warnings and information. The meanings of the most common pictograms are as follows:

Storage

Keep locked away and out of reach of children

Activity

Handling liquid concentrate

Handling dry concentrate

Application

Advice

Wear gloves

Wear boots

Wear eye protection

Wear face shield

Wear mask

Wear respirator

Wear overalls

Wear apron

Wash after use

Warning

Dangerous to animals

Dangerous to fish and water

8 PESTICIDE APPLICATION

The effectiveness of a pesticide in controlling a pest depends on:

• Using the right pesticide for the target pest	(Selection)
• Applying the pesticide at the right time	(Pest Scouting/ Monitoring)
• Applying the pesticide in the right amount	(Mixing/Application)
• Applying the pesticide to the right place	(Application)

If any of these factors is wrong, the effectiveness of the pesticide application will be reduced, control of the pest will be poor, costs will be increased, and additional (probably also incorrect) applications will be applied. All too often, farmers complain that a pesticide did not work, blaming the pesticide itself, when one of the above factors was wrong.

Two of the factors are concerned with application, emphasising the need of correct application for a pesticide to be fully effective.

Objectives of Pesticide Application

The objectives of applying a pesticide are to:

- Protect the crop from economic damage or loss.
- To do this in the most effective and economic way. Pesticides cost money – they must be used effectively to give the farmer a return on his investment.

The final target for a pesticide is the pest. An intermediate target is often the plant surface. The pesticide must thus be taken from the container in which it was purchased and transmitted to the pest. This can be done in various ways, but the most common method in crops is by spray application.

Spray application involves:

- Mixing the pesticide with a carrier to dilute it and carry it to the target. The carrier is commonly water, or a mixture of water and air.
- Putting the spray mix into a sprayer.
- Using the sprayer to break the spray mix into droplets, usually by passing it through a nozzle.
- Using the energy of the droplets themselves, or natural or artificial air movement, to carry the droplets to the target.

For the pesticide to be most effective, there must be sufficient numbers of droplets containing the pesticide applied evenly over each plant in the target area or field. This gives the greatest opportunity for a mobile pest, such as leafworm to come into contact with the pesticide, for the pesticide to directly contact immobile pests such as aphid, or, in the case of systemic pesticides, to be translocated throughout the plant.

If the pesticide is not applied evenly:

- Areas on the plant and in the field will be under-dosed so that many of the pests are not killed. Crop losses will not be prevented, and costs of control are increased.

- Areas on the plant and in the field will be over-dosed so that excess pesticide is wasted. Costs of control are increased.

- Particularly with underleaf pests (aphid, whitefly, some diseases, etc) there must be good coverage of the lower leaf surface for contact pesticides to be effective.

- If the target area is limited, for example aphids only in parts of the field or application to young seedlings, then spot- and band-spraying can save pesticide, water, and time.

Plant Coverage, Droplet Size, and Volume of Water

The objective of spray application is to get the pesticide to the target pest, not to drown the pest with water. It is not necessary to use large volumes of water to evenly cover the plants and field, as “washing” the plants results in large amounts of pesticide running off to the ground, where it is wasted, is money thrown away, and causes environmental contamination.

The spray mix is broken into droplets by the sprayer. It is not the volume of water or spray mix that is important, but the number of droplets which are deposited per unit area on the plant. Providing there are sufficient droplets on the plant, each one of which contains pesticide, then effective plant coverage will be obtained and the pesticide will be effective in controlling the pest. If droplet size is halved, then eight times as many droplets will be produced from the same volume of spray mix.

It is the number of spray droplets per unit area on the plant which is important, *not* the volume of water used

Droplets can be large or small in size.

- If large droplets are produced by the sprayer, to achieve the required number on the plant a large volume of water is needed.
- If small droplets are produced by the sprayer, to achieve the required number on the plant only a small volume of water is needed.

Large droplets are usually used for the application of herbicides, so as to minimise drift, while small droplets are usually used for the application of insecticides, fungicides and acaricides to optimise crop penetration and underleaf cover.

Effectiveness of Spray Applications

Effective spray application is essential for the pesticide to have the greatest effect and to minimise costs.

To illustrate this, on average less than 1 per cent of the pesticide applied actually reaches the pest population.

- If, through poor application, only 0.5 per cent of the pesticide reaches the pest population, the effectiveness of the pesticide is halved, twice the amount is needed to obtain effective control, and the costs are doubled.

- If this can be increased to 2 per cent by more effective spray application, the effectiveness of the pesticide is doubled, only half the amount will be needed, and the costs are halved.

Small changes in the proportion of pesticide applied which actually reaches the pest population thus result in huge changes in effectiveness and costs.

Nozzles and Sprayer Calibration

Different types of nozzles are used for different purposes. The size of the droplets produced depends on the size of the hole in the nozzle and the spray pressure. For any type of nozzle, the larger the hole and the lower the pressure, the larger the size of the droplets produced. Nozzles are generally described by the shape of the spray pattern produced. The most common types are:

Full Cone/ Hollow cone 	• Produce a cone shaped spray from the nozzle. With a cone nozzle, the full area of the cone has spray droplets, with a hollow cone the droplets are only on the outside of the cone. • Full cone nozzles are usually fitted only to air-blast sprayers, hollow cone nozzles are used with hand operated knapsack equipment. • Droplet size tends to be small, and there is a risk of spray drift. • Used at higher pressures than flat fan or deflector nozzles. • Most commonly used for application of insecticides, acaricides and fungicides.

Flat fan / Even spray flat fan 	• Produce a fan shaped spray from the nozzle. • Droplet size tends to be large, with a low risk of spray drift. • Flat fan nozzles deposit most spray directly under the nozzle tip. They are thus used on tractor mounted boom sprayers, where several nozzles can overlap, producing an even spray pattern. Not suitable for single use with hand operated equipment. • "Even spray" flat fan nozzles produce an even deposit of spray across the fan, and are thus suitable for hand operated equipment. • Most commonly used for the application of herbicides. • May reduce the efficacy of insecticide, acaricide and fungicide application.

Deflector 	• **Also known as "flooding" or "anvil" nozzles.** • **Droplet size tends to be large, with a low risk of spray drift.** • **Give a relatively even deposit of spray across the fan.** • **Most commonly used for the application of herbicides.** • **May reduce the efficacy of insecticide, acaricide and fungicide application.**

Sprayer Calibration and Maintenance

Accurate calibration of a sprayer is essential to ensure that the correct amount of pesticide is applied to the target area. A sprayer which is not regularly calibrated will apply either too much or too little pesticide, resulting in waste or poor control of pests.

Calibration involves measuring the output of the sprayer, the width of the spray pattern produced, and the speed at which the spray operator walking or the tractor is moving. Once these factors are known, the amount of spray mix applied to the target area can be calculated. If necessary, adjustments can then be made to one or more of the controlling factors, or to the mixing rate of the pesticide in the water (or to the pressure), to ensure that the correct amount of pesticide is applied.

Regular sprayer maintenance is also essential to ensure that the sprayer is working correctly, and for safety by ensuring there are no leaks. Nozzles should be regularly replaced, at least at the beginning of the season, more often if the sprayer is used frequently or if abrasive formulations such as wettable powders are applied. Calibration of the sprayer with new nozzles fitted will give a base from which to determine when new nozzles should be fitted, as the output will gradually increase as the nozzles become worn.

Leaking sprayers are dangerous, and leaks should be repaired immediately. Seals should be inspected on a regular basis and replaced as necessary. A small toolkit (screwdriver, spanner) should be available in the field to effect immediate repairs. These tools, and some spare parts, may be provided with the sprayer on purchase.

Comparisons of Sprayer Types

Four types of hand held ground sprayers are commonly used by farmers – pressure sprayers, knapsack sprayers, motorised knapsack mistblowers, and ULV/CDA sprayers.

Pressure (Compression) Sprayers

In this type of sprayer, the spray liquid is pressurised by pumping air into the spray tank. Although very cheap, these sprayers are not recommended for agricultural use as the pressure rapidly drops as soon as spraying starts, with subsequent reduction in output and increase in droplet size. However, they are widely used in public health programmes, such as for mosquito control.

Manual Knapsack Sprayers

Manual knapsack sprayers are continually pumped by hand to maintain spray pressure. A regular rate of pumping should be maintained. The cost of these sprayers ranges from cheap to moderately expensive. The cheaper versions should be avoided as they have a very short working life, and are very prone to breakdowns and leaks.

Knapsack sprayers are widely used in field and vegetable crops. The most effective method of use of the hand lance provided with the sprayer is to spray sideways into the foliage, or “up and under” the leaf surfaces. For spot spraying in tall orchard trees, an extension can be fitted to the hand lance.

Motorised Knapsack Mistblowers

Mistblowers are petrol motor driven knapsack sprayers that produces droplets by air force. The droplets are carried to the crop by a combination of the air forces produced by the sprayer and by natural wind forces. These sprayers are expensive to purchase and run, but they have a greater work output than manual knapsack sprayers.

The drift spraying technique must be used as the natural wind forces are much stronger than those of the sprayer. The spray should be directed downwind over the top of the crop, and allowed to penetrate and settle by natural air movements. The spray should not be directed directly into the crop, as this gives massive overdosing on the plants closest to the sprayer, with very poor penetration into the crop and uneven spray coverage

Misblowers are widely used in field, vegetable and tree crops. However, they are not suitable for treating tall field or orchard crops, unless an additional pump is fitted to pump spray mix to the nozzle.

ULV and CDA Sprayers

Ultra Low Volume (ULV) and Controlled Droplet Application (CDA) sprayers use spinning discs to produce small sized droplets of similar size. The discs are driven by a battery powered motor. Pesticides may be applied undiluted or mixed with a small amount of water. Different sprayers are needed for the application of insecticides and fungicides, and for the application of herbicides.

For insecticides and fungicides, the drift spraying technique is used, the small droplets being carried into the crop by natural wind forces. Understanding how to use this technique is essential for good crop coverage and to avoid unwanted drift out of the target area/crop. With drift spraying, work rates are higher than with manual knapsack sprayers. CDA sprayers for applying herbicides produce larger droplets which fall under the influence of gravity, and drift is less of a problem.

Risk, Hazard, Toxicity, and Exposure

Pesticides are poisons that used to kill pests. Human beings have certain body systems similar to those of pests, and so pesticides can also kill people. Some pesticides are extremely toxic to humans and can cause severe adverse effects. Others are less toxic, but too much exposure can also cause adverse effects. The following formula will help determine the potential risks of handling or using a pesticide.

Risk = Hazard x Exposure

Hazard is the inherent property of a substance to cause adverse effects. **Exposure** is the amount of time a person is in contact with the substance, or how much they get in or on their body. The combination of these two factors gives the **Risk**.

Every time a pesticide is handled or used, there is an associated **Risk**. The amount of risk depends upon the level of hazard of the pesticide combined with the level of exposure during the conditions under which the pesticide is used. For example, applying a pesticide in windy conditions gives a greater chance of drift onto the operator, or to adjacent crops, livestock, or open water. Under these circumstances, the exposure is increased and so is the risk of adverse effects to the operator or in these adjacent areas.

A pesticide formulation has an inherent hazard. The primary consideration when using a pesticide is to avoid exposure and so reduce the risk.

How Pesticides Enter the Body

Pesticides enter the body in three main ways or routes:

Dermal exposure	–	Getting a pesticide on the skin, or in the eyes.
Inhalation exposure	–	Breathing a pesticide into the lungs through the nose and mouth.
Oral exposure	–	Swallowing a pesticide through the mouth.

In most pesticide handling situations, the skin is the most likely route of exposure. The amount of pesticide absorbed through the skin (and eyes) depends on:

- The pesticide itself and the dilution material. Oil based formulations (emulsifiable concentrates) are absorbed easily. Water based pesticides and dilutions (wettable powders) are absorbed less readily. Dry formulations (dusts, granules) are not absorbed as readily as liquid formulations.

- The part of the body that is exposed. The scalp, forehead and ears are highly absorptive. The genital area is the most absorptive part of the human body and the below-waist area is exposed to pesticide as an applicator walks through freshly sprayed crops.

- The condition of the skin. Cuts, abrasions and skin rashes allow the pesticide to penetrate more easily. Hot and sweaty skin absorbs pesticide more readily than cool, dry skin.

Common Ways of Pesticide Exposure

Dermal	Eyes	Inhalation	Oral
Not washing hands after handling pesticides or containers	Rubbing eyes or forehead with contaminated gloves or hands	Handling pesticides in confined or poorly ventilated areas	Not washing hands before eating, drinking or smoking
Splashing or spilling pesticide on the skin	Splashing pesticide in the eyes	Handling dusts or powders	Splashing pesticide into the mouth
Wearing contaminated clothing	Pouring dry formulations without wearing goggles	Using an inadequate or poorly fitting respirator	Storing pesticide in drink bottles
Being exposed to pesticide drift	Being exposed to pesticide drift	Being exposed to pesticide drift	Accidentally applying pesticide to food
Applying pesticides in windy weather	Applying pesticides in windy weather	Applying pesticides in windy weather	
Leaking sprayers			
Touching treated plants, livestock or soil			

The primary safety consideration is to avoid exposure to pesticides.

Exposure can be avoided by following an IPM programme to reduce pest numbers, and using pesticides only when indicated by pest scouting and threshold levels. If a pesticide has to be applied, the necessary safety precautions must be taken, with correct mixing, properly maintained and filled spray equipment, application of the correct dose, wearing suitable protective clothing, washing often when handling or using pesticides, and observing re-entry and pre-harvest intervals.

(See also CropLife International Guidelines for the safe and effective use of crop protection products: www.croplife.org)

Harmful Effects of Pesticides

Pesticides can cause three types of harmful effects – Acute, Delayed and Allergic. These effects are intensely studied by medical experts prior to product registration, particularly the first two (allergic effects often depend on an individual person's reaction to exposure). High doses, typically much greater than those that handlers and applicators may experience, are used with test animals to determine what possible short and long term effects might occur. These risks are accounted for when a product is registered, and, provided the label recommendations for the handling and use of the product are followed, the potential effects are not expected to occur.

Acute effects are those that occur immediately after the exposure, within minutes or hours. As well as the poisoning symptoms given in the next section, there can be physical effects on the body. The mouth, throat and stomach can be burned, making it difficult to eat and drink. The lungs can be burned, making it difficult to breath. The skin can itch, blister, or crack. The eyes can be burned, causing temporary or permanent blindness.

Delayed effects are illnesses or injuries that do not appear immediately and may take years to become apparent. They are caused by repeated exposure to a pesticide, pesticide group, or combination of pesticides over a long period of time, or by a single exposure to a pesticide which causes a harmful reaction that does not become apparent until much later. Delayed effects include cancer and other damage to internal organs. Similar risks exist from other substances such as coffee, tobacco and alcohol if exposures are high enough over time.

Allergic effects are reactions that some people, but not all, develop after exposure to pesticides. For example, some people suffer from hay fever due to pollen in the air, while others do not. Allergic effects usually require several exposures before they become apparent. Typical reactions are asthma (difficulty in breathing), skin irritation (rashes, blisters, open sores), or eye and nose irritation (itchy, watery eyes and sneezing).

General Symptoms and Signs of Acute Pesticide Poisoning

Pesticide poisoning occurs when a pesticide enters the body and interferes with the essential systems of the body. Many of the signs and symptoms of acute pesticide poisoning are similar to those of other illnesses, such as flu. Anyone who has been handling or using pesticides and then develops suspicious signs and symptoms should immediately see a doctor, taking the pesticide label or container with them.

Depending on the type of pesticide and degree of exposure, only some of the symptoms may be apparent, and individual symptoms may appear at different times after the exposure. Symptoms can start anything from 1/2 hour to 24 hours after exposure. The typical symptoms and signs of pesticide poisoning are:

Initial:

- Nausea, vomiting
- Headache, dizziness
- General weakness or tiredness
- Tightness in chest

Later:

- Excessive sweating, salivation
- Vomiting, diarrhoea
- Stomach cramps
- Muscle twitches, cramps, aches
- Blurred vision
- Confusion
- Fits or unconsciousness

First Aid

First aid is the initial treatment of a person suffering from a pesticide exposure, before seeking proper medical attention.

In a case of pesticide poisoning:

FOLLOW THE PRODUCT LABEL INSTRUCTIONS IF THEY ARE AVAILABLE

The **first action** is to remove the person from the source of the exposure by removing pesticide from the skin, removing contaminated clothing, or getting the person to fresh air. While doing this, be careful to avoid contaminating yourself.

Pesticide on the skin (follow label instructions if available):

- Drench skin and clothing with plenty of water.
- Remove contaminated clothing.
- Wash hair and skin with soap and water. If available, a shower is the best way to thoroughly wash and rinse the whole body.
- Dry the victim, and wrap in a blanket or any clean clothing. Do not allow the victim to become chilled or overheated.
- If the skin is burned, or otherwise injured, cover immediately with a loose, clean, dry, soft cloth or bandage.
- Do not apply ointments, greases or powders to burns or injured skin.

Pesticide in the eye (follow label instructions if available):

- Wash the eye(s) quickly but gently.
- Hold the eyelid open and wash with a gentle drip of water flowing across the eye rather than directly onto it. If a tap is not available, a tea pot, or similar, can be used.
- Rinse for 10 minutes or more.
- Do not use chemicals in the rinse water.

Pesticide inhaled (follow label instructions if available):

- Get the victim to fresh air immediately.
- Warn other people in the area of the danger.
- Loosen tight clothing that would restrict breathing.

Pesticide in mouth or swallowed (follow label instructions if available):

- Repeatedly rinse mouth with plenty of water.
- Do not induce vomiting if you can get the victim to a doctor within one hour.
- Never induce vomiting if the victim is unconscious or having convulsions
- Never induce vomiting if the victim has swallowed a corrosive poison, as it will burn the throat and mouth as severely coming up as it did going down. It may also get into the lungs and cause burning there. Similarly, never induce vomiting if an emulsifiable or oil solution has been swallowed, as these can cause death if inhaled during vomiting.

Apply artificial respiration if breathing has stopped or if the victim's skin is blue. If pesticide is on the victim's mouth or face, avoid direct contact during artificial respiration.

Following the first aid, the victim must be taken to a doctor as quickly as possible, with the pesticide container or label so that the doctor can identify the active ingredient.

Sources of advice on pesticide poisoning are given in Appendix 2.

Personal Protective Clothing

Protective clothing consists of clothing and devices that are worn to minimise exposure to pesticides and to keep pesticides away from the body. The minimum amount to wear for a specific pesticide formulation and activity is given on the label, either in the text or the pictograms.

Protective clothing only protects if the pesticide remains on the outside and does not come into contact with the body. If pesticide gets inside the protective clothing, it holds the pesticide next to the body. Contaminated clothing should be removed immediately. All protective clothing should be cleaned at the end of every use.

Body protection:

- Any time pesticides are handled, the minimum to wear is overalls. The collar should be fastened to protect the lower part of the neck.
- An alternative to overalls is a long sleeved shirt and long legged trousers. The shirt collar should be fastened to protect the lower part of the neck, the sleeves down and the cuffs buttoned.
- A wide brimmed, cotton or canvas hat can be worn during spraying to protect the head.
- All work clothes, including hats, should be washed after every days use.

Hand and foot protection:
- Rubber gloves and rubber boots should be worn when handling pesticide concentrates. They should be unlined, as fabric liners can trap pesticide and are impossible to clean adequately.
- Trousers should be worn outside the boots, and not tucked in.
- Gloves should be washed with soap and water before removal, turned inside out and the inside washed. Boots should also be washed inside and out after use.
- Do not use gloves with holes or tears, as the pesticide will get inside and be held next to the skin.

Eye and face protection:
- Non-fogging eyewear such as safety glasses and goggles should be worn when there is a chance of mists or dusts, for example during spraying or mixing dry formulations.
- Face shields should be worn when there is a risk of being splashed with insecticide, such as when mixing liquid formulations.
- An alternative is to use ordinary glasses or sunglasses. However, these give only minimal protection to the eyes.

Inhalation protection:
- Dust/mist masks are usually shaped filters that cover the nose and mouth to filter out dusts, mists and particles.
- Masks must be disposed of after each days use.
- For spraying operations only, an alternative is a cloth tied over the nose and mouth. This should be washed after every spraying operation.

- Respirators remove contaminants in the air by filtering dusts or mists, or by removing gases and vapours.
- Respirators are usually only needed in specialised operations, or when mixing or applying more toxic products.
- Respirators have a face piece with one or more cartridges attached. The cartridge may have either a dust/mist filtering material or a vapour and gas removing material. The specific cartridge must be fitted for each type of situation.
- Vapour removing cartridges should have a dust/mist pre-filter fitted. This will need to be changed more often than the vapour cartridge.
- Cartridges should be replaced when breathing becomes difficult. The maximum time of use of a cartridge is normally eight hours. During continual use, masks or cartridges may need to be replaced twice a day if there is a lot of dust or mist in the air.

(See alsoCropLife International Guidelines for personal protection when using crop protection products in hot climates: www. croplife.org)

10 ENVIRONMENTAL ASPECTS

What is the Environment

The environment is everything around us. It includes not only the "natural" elements such as soil, water and air, but also people, plants, animals, indoors/outdoors, fields, gardens, houses, offices, etc. We are dependent on the environment for our survival. If pesticides are used incorrectly or without due consideration, they can affect beneficial insects, birds, fish and domestic animals, they can contaminate sources of drinking and washing water, and they can contaminate our food and living and working areas.

It is the responsibility of everyone concerned with the handling or use of pesticides to use them correctly and to follow practices that minimise environmental contamination, such as following the principles of IPM. Careful transport, storage, handling and application, applying pesticides based on pest scouting and threshold levels, use of the correct dose rates, and use of application methods that both minimise the amounts used and ensure that the pesticide is only applied to the target area, will all minimise environmental contamination by pesticides.

Pesticide Sources of Environmental Contamination

Pesticides can get into the environment by several ways:

- Use at the site of application. Even a correct application puts a pesticide into the environment.
- Excess application leading to run-off from the plants or other treated surfaces.
- Drift during application, or application during windy weather.
- Spills during storage, transport, mixing and use, which are not cleaned up.
- Water used for personal washing and cleaning equipment and clothing.
- Improper disposal of excess spray mix
- Improper disposal of empty pesticide containers.

Pesticide Movement in the Environment

Once applied to the target area, and thus introduced into the environment, pesticides can move to other places in several different ways:

- Volatilisation from treated surfaces.
- Drift during application.
- Washing from the treated surface to the ground or soil by dew, rain, overhead irrigation, or other washing.
- Incorporation into the soil with treated crop residues.
- Removal from the field as residues on treated crop surfaces, such as vegetables, fodder and fuel.
- Carried across the field in surface irrigation water.
- Leached through the soil into ground water.

The persistence of a pesticide is a measure of how long it remains active before being degraded or broken down. A pesticide with long persistence will remain in the environment for a longer period and have more chance to move from the site where it was applied than a pesticide with short persistence.

Sensitive Areas

Some areas of the environment are more sensitive than others, as people, animals, plants, or other living organisms in such areas are more likely to be injured by a pesticide.

Indoors:

- Places where people – especially children, pregnant women, the elderly and the sick – live, work or are cared for.
- Places where food is processed, stored, prepared, or eaten.
- Places where domestic animals are kept, live and eat.

Outdoors:

- Areas near open or surface water, or where the ground water is close to the surface.
- Areas near schools, playgrounds, hospitals, gardens, or where food or fodder is processed.
- Areas where honey bees are active.
- Areas near non-target or harvested food or fodder crops.

Residues on Food Crops and Pre-Harvest Intervals

Pesticides are applied to food crops to protect them from pest damage or loss. However, they leave residues that may be eaten by people or animals. For this reason, a pre-harvest interval is needed between the time of the pesticide application and harvesting in order to allow time for the pesticide to degrade and for the crop to be safe to eat.

Pre-harvest intervals are given on the pesticide label as the number of days that must elapse between the pesticide application and harvesting of the crop. The length of the interval depends on the toxicity of the pesticide and its persistence. Pre-harvest intervals are longer for pesticides of high toxicity and long persistence.

When a food crop is close to harvest, the pre-harvest interval must always be considered when deciding if a pesticide spray is to be applied. If the crop will be harvested within the pre-harvest interval, either the spray should not be applied, a non-toxic (biological) pesticide should be used, or harvesting of the crop must be delayed until the relevant number of days have elapsed after the pesticide application.

Re-entry intervals are also indicated on the product label. These give the number of days which must elapse before a treated field can be entered.

Consumer Protection

Protection of consumers of agricultural produce is one of the farmer's responsibilities. The farmer should ensure that pesticide use is kept to a minimum on the crop he is producing, and that pre-harvest intervals are followed.

- Read the product label for any particular precautions to take.
- Use all appropriate practices to manage pests.
- Only pest scouting and treatment thresholds for pesticide applications.
- Use only the recommended pesticides at the correct dose for the crop/pest
- Apply pesticides effectively and efficiently
- Avoid pesticide drift when spraying so as to avoid contaminating other crops.
- Dispose of empty pesticide containers and left-over spray mix safely so as to avoid contaminating other crops.
- Observe the pre-harvest interval.
- FOLLOW THE PRINCIPLES OF IPM.

APPENDIX 1

Examples of Cultural, Mechanical and Sanitation Methods of Pest Management

All Crops	Practices and Management of:
	Implement optimum crop management practices to produce healthy and strong plants, which are more resistant/tolerant to insects, diseases and weeds.
Tomatoes	
Tolerant varieties	Nematodes, *Fusarium* wilt, *Verticillium* wilt, virus diseases, Early blight, Late blight, *Sclerotina*, Bacterial canker, Blossom end rot, Fruit cracking
Crop rotation	Do not grow tomatoes on the same land for at least 3 years. Rotate with wheat, barley, maize, rice, chillies
	Nematodes, *Fusarium* wilt, *Verticillium* wilt, Early blight, *Sclerotinia*
Rotation with cereal crops	Nematodes
Rotation with rice	*Sclerotinia*
Avoid infested fields	*Orobanche*, *Striga*
Use certified seed	Disease free, weed seed free
Seedbed sterilisation/ solarisation	Nematodes, all bacterial and fungal diseases
Establish seedbeds in light soil	Seedling wilt
Ensure seedbeds are free of nematodes and diseases to avoid transplanting infected plants into the field	All nematodes and diseases
Ensure good seedbed ventilation	All bacterial and fungal diseases

APPENDIX 1

Avoid excessive seedbed irrigation	Seedling wilt, Damping off, Root rot
Fallow before planting	Keep field free of weeds or cover crops for at least 10 days (3 weeks is best) before planting to minimise Cutworm
Deep ploughing of field	*Orabanche*, Cutworm
Avoid close plant spacing, which reduces ventilation and increases humidity	Plants growing too close together give an environment which encourages diseases and insects. All bacterial and fungal diseases, aphids, whitefly
Avoid damaging plants when transplanting	All diseases
Immediately gapfill cut seedlings after transplanting	Cutworm
Heavy irrigation/ flooding of field prior to sowing	Nematodes, Cutworm, *Sclerotinia*
Avoid insufficient or irregular irrigation	Fruit cracking, Blossom end rot
Avoid excessive irrigation	*Orabanche*, *Phytophthera* root rot (late blight), *Sclerotinia*
Ensure balanced fertilisation	Diseases and insect pests
Nitrogen	Excess encourages Blossom end rot, Blight, Powdery Mildew, Aphids, Whitefly (which transmit virus diseases, causes delay in maturity and reduced yield
Potassium	Correct rate increases tolerance to diseases, essential for fruit formation
Sterilise manure/ compost	*Orabanche*, other weeds, Nematodes, fungal and bacterial diseases
Increase organic matter of soil	Nematodes

Control weeds	Virus diseases, Fruit worm
Plough crop residues under, as soon as harvesting completed	Late blight
Remove and burn crop residues	All diseases
Clean all equipment and feet before leaving field to avoid spreading pests and diseases	Nematodes, *Verticillium* wilt, *Fusarium* wilt, many diseases

Haricot/Faba Beans

Tolerant varieties	*Orobanche*
Crop rotation	Root rots, *Orabanche*
Late planting	Avoids infestation by Aphids (and Necrotic Yellows) from other legumes
Irrigation	Avoid excess humidity in the soil and in the plant's direct environment to reduce risk of disease such as root rot
Ensure balanced fertiliser	Excess nitrogen makes plants susceptible to diseases (Chocolate Spot) and insects (aphids = indirectly virus diseases) Correct rate of K increases tolerance to diseases.
Roguing	Reduces number of virus infected plants, and so spread of virus. Can also be applied to *Orobanche* if infestation is low.
Weeding	Removes potential hosts of aphids and virus.

APPENDIX 1

Vegetables general

Site selection	Use land without a history of disease or weed pressure
Crop rotation	3 year crop rotation best for vegetables. At least one cereal crop before cultivating the same vegetable crop, or fallow for several months Nematodes, diseases
Use certified seed	Disease free, weed seed free
Seedlings	Produce in greenhouse or tunnel to avoid insect infestations
Tunnels/plastic sheets	Ventilate to reduce humidity and incidence of disease and insect pests
Ensure balanced fertiliser	Excess nitrogen makes plants susceptible to pests and diseases. Correct rate of potassium increases tolerance to diseases, and essential for fruit formation
Fallow before planting	Keep field free of weeds or cover crops for at least 10 days (3 weeks is best) before planting to minimise cutworm
Ensure balanced irrigation	Diseases
Remove and burn infested plants	All diseases
Remove and burn crop residues	All diseases
Clean all equipment and feet before leaving field to avoid spreading pests and diseases	Nematodes, *Verticillium* wilt, *Fusarium* wilt, many diseases, Red spider mite
Clean and disinfect all equipment at the end of the season	Avoids carry-over, spreading, to the following season. *Verticillium* wilt, *Fusarium* wilt, many diseases

APPENDIX 1

Cotton

Rotation with cereals	*Fusarium* wilt, Bacterial blight, seedling diseases.
Rotation with soyabean	Bacterial blight, Root knot nematode.
Adjacent crops	Avoid growing cotton close to wheat, melon, cucumber, pumpkins, onion. Aphid, Thrips, Whitefly
Land preparation	Kills and exposes pests such as Cutworm, Bollworm. Fine seedbed allows plants to germinate and grow strongly, increasing tolerance to pest attack
Resistant varieties	Jassid, Mites, Bollworm, Aphid, Whitefly, Bacterial blight, *Fusarium* wilt
Certified, acid delinted seed	Bacterial blight free, weed seed free
Fallow before planting	Keep field free of weeds or cover crops for at least 10 days (3 weeks is best) before planting to minimise cutworm
Early planting	Avoids late season Bollworm, Pink bollworm, Aphid, Whitefly
Short season varieties	Pink bollworm, Bollworm, Aphid, Whitefly
Avoid planting seed too deeply	Seedling diseases (Damping off, Root rot, etc)
Avoid planting into cold, wet, soil	Seedling diseases (Damping off, Root rot, etc)
Avoid too close plant spacing	Close spacing makes plants weak, and gives an environment which encourages Aphids, Whitefly, Bollworms
Early thinning	Allows plants to grow strongly, increasing tolerance to pest attack
Ensure balanced fertiliser	Excess Nitrogen makes plants attractive or susceptible to Aphid, Jassid, Whitefly, Bollworm, and encourages *Fusarium* wilt
Ensure balanced irrigation	Excess irrigation encourages Aphid, Whitefly, Bollworm

Weeding	Seedlings are very susceptible to weed competition. Weeds in the crop encourage Aphid, Whitefly, Spider mite.
Avoid plant stress (water, fertiliser, weeds)	Spider mites and other sucking pests
Remove and burn crop residues	Pink bollworm, Cotton stainer, Stem weevil, Whitefly, all diseases
Plough after harvest	Bollworm

Rice

Certified seed	No weed seeds
Resistant varieties	Brown plant hopper, Rice leaf roller
Early maturing varieties	Brown plant hopper, Rice gall midge
Early planting	Rice leaf roller
Avoid damaging plants when transplanting	Bacterial blight
Avoid excess nitrogen	Bacterial blight, Rice blast, Rice leaf roller
Avoid pesticide use	Brown plant hopper (and other hoppers)
Weeding	Rice gall midge
Weed free bunds	Rice bug
Land preparation and flooding after harvest	Stem borer

Mango

Pruning	After harvest. Enhances aeration within the tree, reducing risk and spread of disease
Removal of malformed flowers	Reduces spread of flower malformation
Others	As for Citrus

APPENDIX 1

Apple

Improve soil tilth and drainage	Nematodes
Do not plant apple orchards within 2km of cedar trees	Cedar apple rust
Do not plant apple with pear	Fire blight
Resistant varieties	Woolly apple aphid, apple scab, cedar apple rust, fire blight, Powdery mildew
Certified, virus-free seedlings	Apple leaf spot virus, Apple mosaic virus
Avoid close spacing of trees when establishing orchard, so as to ensure adequate ventilation and light	Aphids, Mites, Apple scab, Branch wilt, Fire blight, Powdery mildew
Ensure balanced irrigation	Red spider mite, Nematodes, Branch wilt
Avoid over-irrigation	Fire blight
Balanced fertilisation	Nematodes
Avoid over-fertilisation with nitrogen	Aphids, Fire blight
Open tree to improve ventilation	Pruning in late winter, early spring. Aphids, Apple scab, Powdery mildew
Remove infested, dead, diseased wood, cankers, mummified fruits	Stemborer, Woolly apple aphid, Apple scab, Fire blight, Powdery mildew
Summer pruning of water sprouts	Green apple aphid
Avoid excessive pruning	Fire blight
Ensure area around base of trunk is free of grass and weeds	Rodents, Stemborer

Keep grass and weeds between trees cut short	Rodents
Remove and bury/ burn all fallen fruit	Codling moth, Rodents, Apple scab
Remove and burn/ compost fallen leaves at the end of the season	Codling moth, Apple scab
Avoid dusty conditions	Keep low cover of grass and weeds between trees. Red spider mite

Citrus

Certified planting material	Disease and virus free
Circle trunk with soil	Avoids infection and spread of *Phytophthora*.
Ensure balanced fertiliser	Diseases and insect pests
Ensure balanced irrigation	Diseases and pests
Pruning to enhance aeration and reduce humidity	All diseases, many insect pests. Navels and mandarins should be pruned immediately after harvest in January to induce early spring flush that avoids leaf miner attack
Collect and bury dropped fruit	Mediterranean fruit fly

APPENDIX 2

Date Palm

Ensure planting material and enclosing soil is disease free	Bayoud (*Fusarium*) (This is the means of transmission of the disease to new areas, and adequate quarantine measures are absolutely essential)
Resistant Varieties	Old world mite, Bayoud (*Fusarium*), Black rot, Inflorescence rot, *Graphiola* leaf spot
Well-spaced trees to increase ventilation and reduce humidity	Approx 120 trees/ha, 9-10m between trees in both directions. Dubas bug, Fruit stalk borer, Green scale, White scale, Inflorescence rot, *Graphiola* leaf spot, Fruit rot
Ensure balanced irrigation	Fig moth, Fruit stalk borer, Green scale, Lesser date moth, Palm stem borer, Black rot, Inflorescence rot
Avoid excessive irrigation	Dubas bug
Avoid use of surface irrigation	Bayoud (*Fusarium*)
Ensure good drainage	Fig moth, Lesser date moth, Black rot, Inflorescence rot
Ensure balanced fertilisation	Fig moth, Fruit stalk borer, Green scale, Lesser date moth, Palm stem borer, Black rot, Inflorescence rot
Prune dead, old leaves to lower level of fruit bunches to reduce humidity	Dubas bug, Fruit stalk borer, Green scale, White scale, Inflorescence rot, *Graphiola* leaf spot, Fruit rot
Keep plantation free of weeds	Fig moth, Lesser date moth, termites
Remove and burn/ bury all old and fallen fruits, old bunches, spathes, dry leaves, dead trunks, fronds	Dubas bug, Fig moth, Fruit stalk borer, Lesser date moth, Palm stem borer, Black rot, Inflorescence rot, *Graphiola* leaf spot
Remove and burn/ bury infected material	Green scale, Red scale, White scale, Black rot, inflorescence rot, *Graphiola* leaf spot

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Do not use pollen from infected trees	Inflorescence rot
Protect date bunches with nets, shade cloth or paper bags	Greater date moth, Lesser date moth, Oriental wasp. (Reduction in pesticide use against these pests by bunch protection also enhances natural control of Date palm scale, Green scale, Mealy bug, Red scale). Fruit rot
Fruit thinning	Fruit rot
Light Traps	Fruit stalk borer, Palm stem borer

Sources of IPM Information:

IPM in General

World Bank Pest Management Guidebook:
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/EXTPESTMGMT/0,,contentMDK:20631409~menuPK:586795~pagePK:64168445~piPK:64168309~theSitePK:584320,00.html

FAO Plant Production and Protection Division:
http://www.fao.org/ag/AGP/Default.htm

FAO Global IPM Facility:
http://www.fao.org/ag/AGP/AGPP/IPM/gipmf/index.htm

IPM in Various Crops

Aglearn.net (Asia):
http://www.aglearn.net

Community IPM Program (FAO):
http://www.communityipm.org/index.html

Cornell University (USA):
http://www.nysaes.cornell.edu/hp/commodity.html

Crop Protection Programme, UK:
http://www.cpp.uk.com/outputs.asp?step=3

National Sustainable Agriculture Information Service (USA):
http://attra.ncat.org/

Online Information Service for Non-Chemical Pest Management in the Tropics – PAN Germany (wide range of crops):
http://www.oisat.org/

University of California:
http://www.ipm.ucdavis.edu/

West Virginia University (fruit trees):
http://www.caf.wvu.edu/kearneysville/wvufarm1.html

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Pesticides

FAO:
http://www.fao.org/ag/AGP/AGPP/Pesticid/Default.htm

Pesticide Action Network (PAN):
http://www.pesticideinfo.org/Index.html

UK Health and Safety Directorate
http://www.pesticides.gov.uk

Pesticide Information
http://pesticideinformation.eu

US Environment Protection Agency
http://www.epa.gov/pesticides

Information/advice on pesticide poisoning:

The container label

The pesticide manufacturing / importing company (information on the label)

Local emergency phone numbers – doctors, hospitals, etc

Local poison control centres.
Worldwide poison centre locations can be found at the WHO website:
http://www.who.int/ipcs/poisons/centre/directory/en/index.html

Pesticide poisoning diagnostic tool (to identify pesticide from poisoning symptoms): http://www.pesticideinfo.org/Search_Poisoning.jsp#Identify

WHO training manuals on pesticide poisoning (intended for medical staff): http://www.who.int/ipcs/poisons/training_manual/en/index.html

US EPA Recognition and management of pesticide poisoning:
http://www.epa.govv?opp00001/healthcare/handbook/handbook.htm

Specific medical treatment for individual pesticides:
http://www.intox.org/databank/pages/chemical.html
http://www.inchem.org/pages/pims.html

Guidelines

Guidelines – Roadmap for establishing a container management programme for collection and disposal of empty pesticide containers (01/12/2009)

The overall aim of stewardship is to maximise benefits and minimise any risks from the use of crop protection products. This is a summary of the most relevant aspects of a successful programme for handling empty pesticide containers.

http://www.croplife.org/files/documentspublished/1/en-us/PUB-GL/840_PUB-GL_2009_12_01_Guidelines_-_Roadmap_for_establishing_a_container_management_programme_for_collection_and_disposal_of_empty_pesticide_containers.pdf

Guidelines for the safe warehousing of crop protection products (26/09/2007)

These guidelines deal with the safe warehousing of packaged crop protection products in quantities of 10 tonnes or more. However, it is recommended that the basic principles should be followed, if smaller amounts are stored.

http://www.croplife.org/files/documentspublished/1/en-us/PUB-GL/275_PUB-GL_2007_09_26_Guidelines_for_the_safe_warehousing_of_crop_protection_products.pdf

Guidelines for the safe transport of crop protection products (25/07/2006)

These Guidelines deal with the transport of packaged crop protection products in quantities ranging from full factory loads to single package. The advice given in this booklet will help to ensure that crop protection products are transported safely.

http://www.croplife.org/files/documentspublished/1/en-us/PUB-GL/274_PUB-GL_2006_07_25_Guidelines_for_the_safe_transport_of_crop_protection_products.pdf

Guidelines for the safe and effective use of crop protection products (25/07/2006)

To be used safely and effectively, crop protection products must be handled and used in accordance with the manufacturer's recommendations. If not used according to their label instructions, they may be harmful to people, animals and the environment.

http://www.croplife.org/files/documentspublished/1/en-us/PUB-GL/279_PUB-GL_2006_07_25_Guidelines_for_the_safe_and_effective_use_of_crop_protection_products.pdf

Guidelines for personal protection when using crop protection products in hot climates (14/02/2005)

Guidelines for trainers, extension officers, farmers and other agricultural workers using crop protection products in tropical conditions and complement the CropLife International Guidelines for safe and effective use of crop protection products.

http://www.croplife.org/files/documentspublished/1/en-us/PUB-GL/278_PUB-GL_2005_02_14_Guidelines_for_personal_protection_when_using_crop_protection_products_in_hot_climates.pdf