ACIAR HORT/2016/185: Responding to emerging pest and disease threats to horticulture in the Pacific Islands

PLANT HEALTH CLINICS

A training manual for Plant Health Doctors in Pacific Island countries

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Dedication

We dedicate this manual to the memory of Unaisi Turaganivalu from Fiji who tragically lost her life from malaria during its production. Una was a keen member of the SPC team and a strong advocate and champion of plant health clinics. She was instrumental in their design, as well as in the writing of this manual, and was keenly looking forward to using it as a member of the regional team of trainers. Una was taken from us far too soon. We miss her enthusiasm, hard work and cheerfulness and we grieve at her untimely passing.

Foreword

Plant health clinics were progressively incorporated into the extension strategies of ministries of agriculture during the sub-regional Integrated Pest Management (IPM) project: *Strengthening integrated crop management research in the Pacific Islands in support of sustainable intensification of high-value crop production.* With support from SPC, ACIAR and University of Queensland, the Solomon Islands hosted a pilot clinic programme during the project, and based on the evaluation of this programme, Fiji, Samoa and Tonga also began activities.

The concept of plant health clinics has proven to be appealing. Extension staff, backed by research personnel, are trained as plant health doctors, and meet regularly with farmers to diagnose their pest and disease problems and give timely advice. Importantly, the solutions promoted are based on IPM, stressing the use of cultural control practices, and encouraging and protecting natural enemies, rather than a reliance solely on pesticides. That the clinics are held at places where both men and women farmers usually come together, such as markets, farmer organisations and agricultural shows, is a departure from normal practice as extension staff are effectively put into contact with many people at one time. We know from anecdotal evidence that farmers like this approach!

However, we realised that if the programme was to achieve sustainable change in our respective countries, a shared approach is necessary, with each country assisting where there is a need. This was discussed at the first meeting of the second phase of the sub-regional IPM project *Responding to emerging pest and disease threats to horticulture in the Pacific islands* held at Sigatoka Research Station, Fiji in April 2018.

Representatives from Fiji, Samoa, Solomon Islands and Tonga agreed that the way ahead was to strengthen collaboration and partnership by creating a pool of experienced regional trainers, members of which would be on-hand to assist national trainers in training extension staff. To promote consistency in the training approach, it was agreed that a training Manual was required.

The contents of this manual were agreed at a formulation and writer workshop in Fiji (August 2018) and then tested with regional and national trainers in Samoa (October 2018), Tonga (November 2018), and the Solomon Islands (May 2019). We are pleased that this manual has come to fruition. It contains a wealth of technical information, in addition to many exercises and quizzes designed to build knowledge, skills and confidence in describing, diagnosing and managing crop pests and diseases.

Congratulations to the authors and all those who reviewed and tested this manual - we are proud to note that it has been written by Pacific islanders for Pacific islanders. We wish our trainers every success in putting this Manual to good use to meet the needs of our farmers.

Permanent Secretary for Agriculture, Fiji

Chief Executive Officer for Agriculture, Samoa

Permanent Secretary for Agriculture, Solomon Islands

Chief Executive Officer for Agriculture, Tonga

April 2021

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
Bt	*Bacillus thuringiensis*
DBM	Diamondback moth
ICM	Integrated Crop Management
IPM	Integrated Pest Management
IPDM	Integrated Pest and Disease Management
MoA	Mode of action (of pesticides)
NGO	Non-Government Organisations
PHC	Plant health clinic
PHS	Plant health system
PNG	Papua New Guinea
SPC	Pacific Community

Units of measurement

Volume
- L: litre
- ml: millilitre
- Liquids are often measured using bottle tops (lids):
    - Coca-Cola top = 5 ml
    - beer top = 4 ml

Weight
- g: gram
- kg: kilogram

Length/area
- m: metre
- m^2: square metre
- Ha: hectare (1 Ha = 10,000 m^2)

Acknowledgements

This manual was produced with support from ACIAR HORT/2016/185: *Responding to emerging pest and disease threats to horticulture in the Pacific islands.* We thank the many farmers in Fiji, Samoa, Solomon Islands and Tonga who have contributed to the testing and of this manual. We acknowledge the work and inspiration of CABI Plantwise in developing plant health clinics worldwide.

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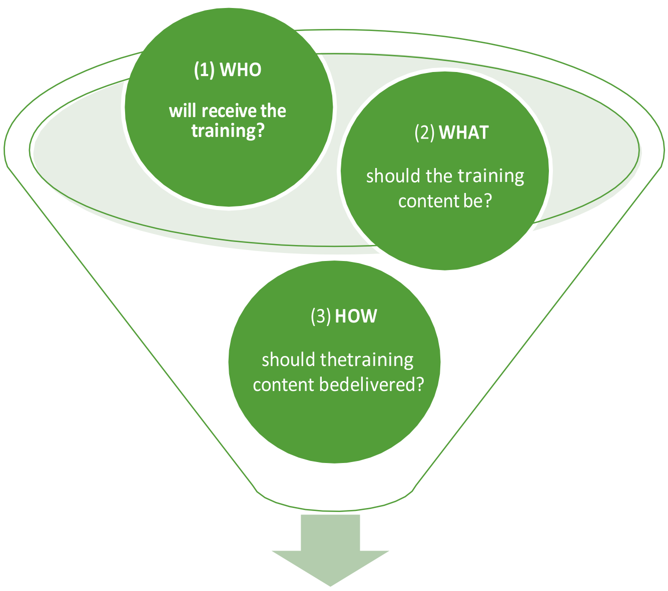
About this manual

This manual has been developed for trainers to assist in the training of agriculture extension staff in Pacific island countries to become plant health doctors. The doctors will be responsible for the development and running of plant health clinics (PHC).

The manual was conceived in April 2018 at the first meeting of Phase II of *Responding to emerging pest and disease threats to horticulture in the Pacific islands* implemented by the University of Queensland in partnership with the Governments of Fiji, Papua New Guinea, Samoa, Solomon Islands and Tonga, and the Pacific Community (SPC). Based on a successful trial in Solomon Islands during the first phase of the project, the partners at the meeting requested expansion of PHCs to other countries. Further, and in keeping with the concern to create sustainability, a regional approach was suggested whereby a team of trainers from the four countries would be available to train in-country trainers. This was an essential strategy of Phase II as, in most countries, agricultural training sections no longer existed. Thus, in some countries, regional trainers would have a double role as both regional and national trainers.

A training manual was deemed an essential component of the regional training, and it was considered important that the regional trainers should develop it. Too often, training manuals are developed for people by others, not by the people who actually use them. The content and structure of the manual was decided at a meeting the same year. Regional trainers from each country were appointed and met to develop the first draft of the manual. Working in small groups, the trainers drew on their expertise and knowledge of the needs of their extension staff and farmers, as well as a wide range of literature from other parts of the world.

The manual was designed with three elements in mind:



PHC training manual design

After initial editing, the regional trainers met again in Samoa 2018 to test the manual, and to begin the training of Samoan extension staff. Revisions and amendments were once again made. This was followed by workshops in Tonga and Solomon Islands, by the end of which, the revised manual was ready to be finalised and printed.

Layout of the manual

The manual consists of eight chapters and an appendix. It is written for trainers and aims to scaffold plant health doctor training from the plant health clinic concept (Chapter 1), pest and disease identification and diagnosis (Chapters 2 & 3) to management (Chapters 4 & 5) and the planning and running a plant health clinic (Chapter 6). Each of these chapters contains a list of materials that trainers will need, technical information, and a range of exercises and quizzes designed to facilitate learning.

Chapter 7 contains information for trainers on effective teaching strategies and practices. Chapter 8 contains the answers to the exercises and quizzes. The appendix contains forms and other resources for trainers.

CHAPTER 1

Plant Health Clinics

1.1 Introduction

Agricultural research and development are changing globally, and so education, training and research need to become more relevant to the needs of farmers and the extension staff who work closely with them. This means that the usual practice of experts generating and transferring agricultural information to farmers has to change to be more participatory, with farmers as part of a learning process.

In Pacific island countries, historically, technical support services for farmers with pest and disease problems have often been ineffective, with farmers often left without advice and having to tackle pests and diseases as best they can. This may result in nothing being done and the problems spreading, or inappropriate control measures being used. It has also been challenging to create effective collaboration between research, extension, biosecurity, and regulatory organisations, education and the private sector. This is now changing. There is now more emphasis in Pacific island countries on traded commodities, with value chain analyses pulling together different aspects of production and sale. Control of pests – insects, pathogens and weeds in particular - is an important aspect of this production and increasingly so due to climate change.

Plant health clinics (PHCs), initially developed in South America[1], are a practical approach to providing the information that farmers need to protect their crops. This manual forms part of a PHC program that trains Extension staff (and others) to identify pests and diseases and to give advice to the farmers in a local context. Once trained, the staff are recognised as plant health doctors who hold PHCs regularly at farmer-friendly places, especially markets, with the farmers bringing samples to assist problem identification. During these clinics, the plant health doctors are helped by links to research and biosecurity organisations, both within outside their country. Their role is to identify so-called unknowns, which may be unusual or new pests, as well as to give more advanced technical information. This collaboration is deemed necessary if an effective PHC program is to be established and flourish.

[1] For example, see Boa, E. (2009). How the Global Plant Clinic began. *Outlooks on Pest Management 20*(3):112-116.

1.2 A plant health system approach to pests and diseases

Plant health clinics form an important part of an integrated plant health system (PHS) approach to protect crops from pests and diseases.

Researchers of plant health clinics in Africa have developed a definition of a PHS that is based on the World Health Organization's concept of a health system for human beings:

A [plant] health system consists of all organizations, people and actions whose primary intent is to promote, restore or maintain plant health[2]

To develop the collaboration that is required for an effective PHS, different models have been considered, and the one used by medical services is an obvious candidate. After all, such services contain practices that are just as appropriate to plant health as they are to human health, such as stressing improvement of health through prevention, diagnosis and treatment of illness (Fig. 1.1).

In agriculture, good practice means the production of healthy crops with minimal negative impact to the environment and the farming community, and tailoring solutions to individual farmers' situations. We want to build a PHS that is underpinned by plant health clinics, supported by farmers, extension services, regulatory bodies, education and research institutions, and agricultural input and information suppliers. We want to be able to monitor pest outbreaks and forecast any threats to come, and we want to do this in partnership with relevant organisations.

[2] See https://www.who.int/healthsystems/strategy/everybodys_business.pdf

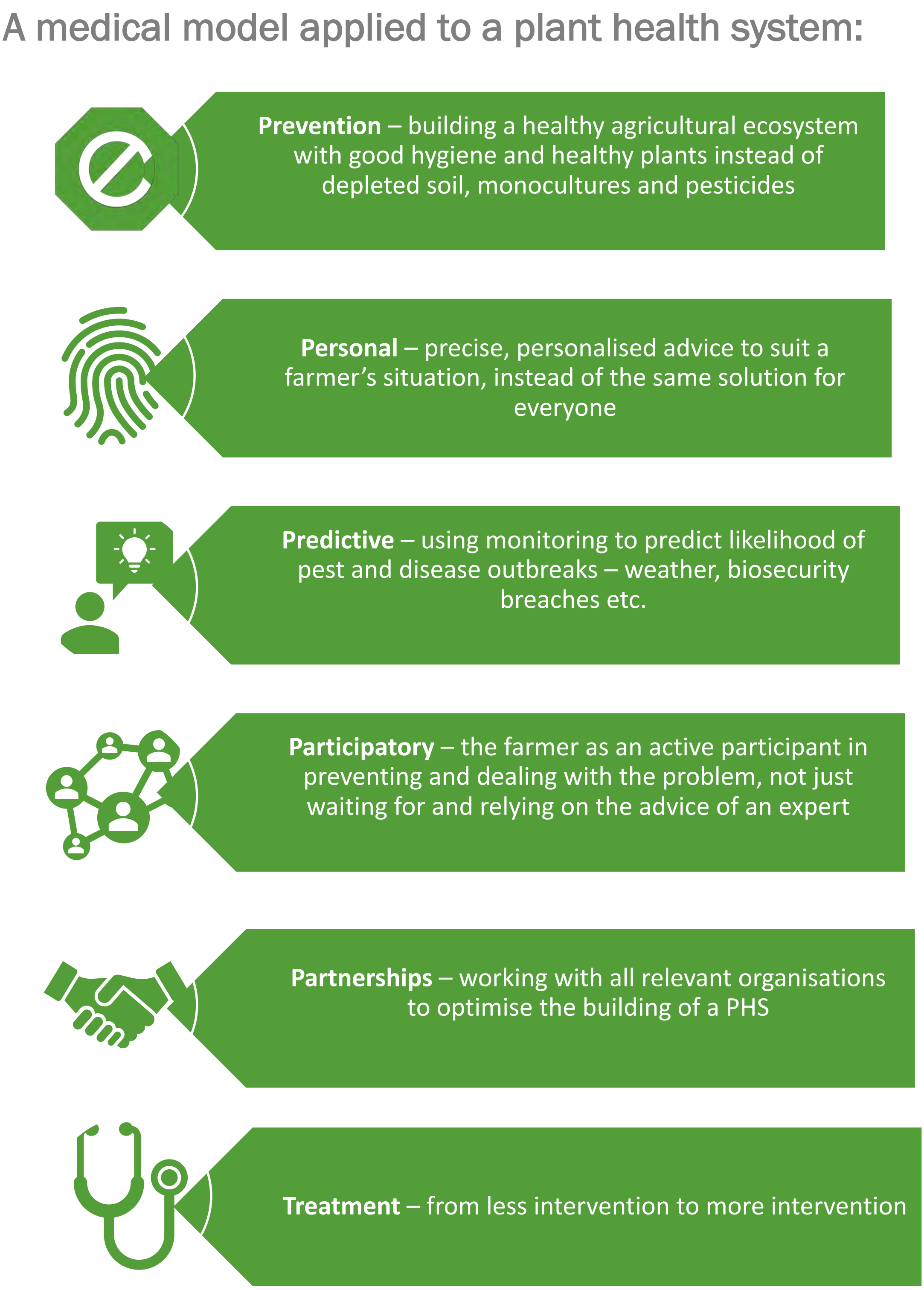


Fig. 1.1 A medical model applied to plant health systems.

1.3 Plant health clinics in the Pacific islands

The plant health clinic (PHC) program in Pacific island countries began as a pilot phase in Solomon Islands in 2012, with the support of Phase I of the ACIAR ICM/IPM project (PC/2010/090)[3]. A former member of the CABI Global Plant Clinic conducted the initial training, bringing experience in establishing PHCs in South and Central America, Asia, and across Africa. Subsequently, more than 20 clinics were held in Solomon Islands on the islands of Guadalcanal and Malaita, followed by an evaluation after 16 months.

The pilot phase showed that farmers and extension workers face challenges in managing plant health problems. Biotic (pests and diseases) and abiotic (non-biological) causes lead to regular and often significant losses in crop production and quality. Diagnosis is difficult because of the diversity of symptoms and possible causes, meaning that choosing the best management options needs skill and careful consideration. The pilot phase also showed that there was high farmer satisfaction with the PHCs, and the plant health doctors' knowledge and confidence improved substantially over the period.

Recommendations from the evaluation suggested that there should be pilot phases in other project countries for 18 to 24 months before widespread establishment of a PHC program. Importantly, a 'champion' with enthusiasm and commitment to the clinics should be selected within each country, and more pest and disease fact sheets should be written. Further, the sustainability of PHCs beyond the funding period should be a consideration at the outset, with clinics incorporated into department policies and work plans, as well as being part of Extension staff terms of reference.

Overall, the pilot phase was considered a success. Clinics continued in Solomon Islands, and Fiji and Samoa, both of which had sent representatives to the first workshop in 2012, began PHC programs in 2015 and 2016, respectively, and in Tonga a start was made in 2018.

[3]Strengthening integrated crop management research in the Pacific islands in support of sustainable intensification of high-value crop production, implemented by the University of Queensland and the Pacific Community.

CHAPTER 2

Identification and Diagnosis of Plant Pests and Diseases

In this chapter you will learn the meaning of biotic and abiotic (and what may confuse you), what a pest is, how insects (and mites) can be good or bad, the life cycles they have, and consider the symptoms that help to identify them. You will also learn about plant pathogens, the diseases they cause, and their symptoms.

What equipment do I need?

- ✓ **Pre-prepared PowerPoint presentation to cover Sections 2.3-2.8**
- ✓ **Plastic bags**
- ✓ **Marking pens**
- ✓ **Hand lenses**
- ✓ **Samples of pests and diseases, enough for one per trainee**
- ✓ **Laminated pictures of plant pests and diseases:**
  - **A, B & C**
- ✓ **Pacific Pests, Pathogens & Weeds app:**
  - **fact sheets**
  - **mini fact sheets**
- ✓ **3 tables marked A, B & C**
- ✓ **Brown or butchers' paper**
- ✓ **Sticky tape**

2.1 Introduction to identification and diagnosis

Many farmers and extension staff find it hard to identify pests and diseases that attack crops[4]. However, without knowing the cause of the damage seen in the field, it is difficult to know what to do for the best. Often, damage from disease is mistaken for damage from insects, and vice versa. Sometimes the cause is not even a pest or disease, but an abiotic factor. Without good identification and diagnosis, guesses may be made which can result in the wrong management being suggested, such as too much pesticide or the wrong pesticide. Sometimes, nothing is done because of the confusion.

The damage to crops caused by pests and diseases and other factors appear as **symptoms** (or **signs**). These are very important as they help identify the cause of problems

So, what can we do? We can get an idea of the cause of crop pest and disease problems by looking at the damage – the **symptoms or signs** on the plant. This is exactly what the doctor does when you go to a clinic. The doctor examines you, looks at the symptoms and asks questions. In a similar way, a plant health doctor has to find the cause of a problem by examining the plant, looking at the symptoms and asking questions. Obviously, in this case the farmer answers the questions as the plants cannot speak for themselves!

To become proficient plant health doctors, trainees need to spend a lot of time becoming familiar with the plant pests and diseases in their countries. ***There is no substitute for experience!*** The trainees need to know how to examine plants carefully with the help of a hand lens, recognise symptoms, and make use of resources, such as the Pacific Pest, Pathogens & Weeds app.

[4] Sometimes the terms 'pest', 'disease' and 'pathogen' are confused or used interchangeably. Diseases in plants are caused by pathogens (infectious organisms), as well as environmental conditions (abiotic or physiological factors). Pests, such as insects and mites, affect plant health by chewing or sucking. Weeds are also sometimes included as 'pests'. *In this manual we use the word 'pest' to include insects, mites, other animals and weeds, and the word 'disease' to include pathogens, i.e. fungi, oomycetes, bacteria, viruses, nematodes, phytoplasmas and viroids.*

2.2 Field diagnosis of plant pests and diseases – A, B or C[5]

Identification and diagnosis of problems during farm visits and at plant health clinics have to be done without the use of specialised equipment like that used in a laboratory. How can it be done and what is involved?

First, trainees need to sort the problems that can occur in the field into different categories. One way of doing that is to sort them into causes that are: (i) non-living; (ii) living; and (iii) not sure or confused. We can call these Abiotic (A), Biotic (B) and Confused (C), or A, B and C, respectively (Table 2.1 and Figs. 2.1 & 2.2).

Abiotic factors are non-biological. Like people and animals, plants get sick, not just from pests and diseases but also from non-biological factors; these we call 'abiotic'. For plants, these can include unhealthy environments such as poor soil, devasting weather, chemical poisons, or damage during cultivation. Sometimes it is difficult to differentiate between abiotic and biotic damage, as the symptoms can look quite similar. Also, a variegated but healthy leaf can be diagnosed as having a disease or a nutrient deficiency, whereas variegation is a genetic condition where chlorophyll is absent from part of the leaf.

Table 2.1 shows the main abiotic factors that can cause problems in plants. Of these, perhaps the most important are poor soil structure and composition, and nutrient deficiencies.

Table 2.1 Different categories that make up abiotic and biotic causes. 'Confused' can be when there could be more than one cause, or you don't know what it is.

Abiotic – non-biological causes	Biotic – biological causes
Nutrient deficiencies	Insects
Drought (water stress)	Mites
Waterlogging	Birds
Root damage from ploughing, hilling up, etc.	Snails and slugs
Fertiliser burn	Rats and mice
Herbicide damage	Parasitic plants, e.g. *Cuscuta* (dodder), mistletoe
Salt spray	Weeds
Lightning Frost, e.g. in the highlands of PNG Sunscald Very hot weather Senescence (old age)	Pathogens: • fungi • oomycetes • bacteria • nematodes • phytoplasmas • viruses and viroids

[5] This exercise is adapted from Plantwise PHC course Module One. The examples in the manual have been adapted to the Pacific context. See https://blog.plantwise.org/2017/10/25/using-the-plantwise-training-modules-and-approach-to-strengthen-the-curriculum-at-ucatse/

2.2.1 Abiotic causes

Poor structure and composition of soil

While plants have different soil requirements, there are some basic needs for optimum growth. In general, what we call ‘healthy soil’, is soil that can hold water and air, is not too fine or too coarse so it avoids waterlogging or drying-out too quickly, and contains a good amount of organic matter and some clay to hold nutrients. It also has a large number of macro- and micro-organisms, such as earthworms, bacteria, fungi and nematodes to keep it aerated and help nutrients became available to plants. Healthy soil has a pH of around 6 to 7, which is best for most plants, although many require a lower or higher pH. Just as humans are less likely to get ill if they have a healthy diet and lifestyle, plants growing in healthy soil are less likely to be attacked by pests and diseases.

Nutrition

Although they make their food (sugars) through photosynthesis from carbon dioxide and water, in order to be healthy, plants also need a range of other nutrients which they must get from the soil though their roots. If some of these nutrients are missing, the plant will show nutrient deficiency symptoms. Too much of a nutrient may also cause problems. Nutrient deficiency symptoms can be confusing; usually they appear as yellowing or discoloured patches on the leaf. The veins might also be discoloured or the fruit might be small, misshapen or fail to ripen. Sometimes there are no symptoms at all except a reduction in yield. In general, nutrient deficiency symptoms on the leaf form a pattern that is evenly spread, whereas disease symptoms tend to be patchy.

The most common nutrient deficiencies in Pacific islands are lack of nitrogen, potassium, sulphur, phosphorus, calcium, magnesium and chlorine. These are the macronutrients - needed in quite large amounts. Manganese, boron, zinc, cobalt, iron and copper are micronutrients, needed in smaller amounts. Sometimes it is difficult to know if the problem is a lack of the mineral in the soil or the plant is under stress and cannot take up the mineral properly, even if it is present. This is the case in blossom end rot of tomato and zucchini, as the disease is especially common when rapidly developing fruits are exposed to drought. The roots cannot transport enough water and the fruits rot from the flower end.

If possible, have a soil test done to find out what is missing in the soil. Then fertilisers can be applied that add the missing nutrients. Some governments (e.g. Fiji) provide soil analysis if farmers make requests through the extension service.

Abiotic

Fig. 2.1 Some abiotic conditions on common crops in Pacific island countries.

2.2.2 Biotic causes

The biotic group is very large, so we split it into smaller groups in the hope that the **symptoms (signs)** we see in the field will give us clues to the type of organisms that are causing the damage. For instance, insects can be split into those that chew, those that suck, and those that pierce (see Table 2.2 and Figs. 2.5.1-2.5.3).

Pathogens can be split into those that cause spots, blights, rusts, wilts, mildews, and more (Figs. 2.79-2.90). The idea is to match the symptoms we see with the damage we associate with different types of organisms as closely as possible.

Of course, we must have some idea about the different symptoms these groups cause in the first place, and that comes down to experience and practice. The manual sections 2.4 (Insect life cycles), 2.5 (Symptoms of insect and mites), 2.6 (What is a plant disease?), and 2.7 (Symptoms of pathogens), will help you by providing information, and 2.9 (Making a diagnosis: symptoms, possibilities, and probabilities) will give you the opportunity to put the learning into practice.

Once we have identified the likely cause of the damage, we say we have made a **diagnosis**. Then we can go on to recommend a treatment.

2.2.3 Confused

But what do we do if we are confused? A plant health doctor might be confused because the farmer presents a plant with symptoms that: (i) may be caused by more than one pest or disease; (ii) the doctor is unsure of; or (iii) are new to the doctor (Fig. 2.2).

It takes a lot of time and experience to become good at diagnosing symptoms, and even experts do not always know the cause of a plant problem. There are a lot of resources to help, and this manual will help your trainees to become familiar with:

- Using a WhatsApp group
- Pacific Pests, Pathogens & Weeds app - Full and Mini fact sheets
- PestNet Community

If the problem is still confusing or unknown, samples will need to be sent to the agencies in each country that deal with pest and disease identification, i.e. research or biosecurity. It may even mean that samples (or photographs of samples) need to be sent overseas for examination. Further information on these aspects is given in Chapters 3 and 6.

Fig. 2.2 When symptoms suggest the damage is caused by more than one pest or pathogen, or is something new to the plant health doctor or seen in the country for the first time, it is called "confused or unknown".

EXERCISE 1: A, B, C?

This exercise helps your trainees to begin to apply their learning to describe plant damage as abiotic (A), biotic (B) or confused (C) - either a mixture of symptoms or unknown.

In groups, allocate one or two sets of photo sheets of Pacific island pests and diseases. For each photo, trainees should decide whether the damage is caused by **abiotic** (A) or **biotic** (B) factors, or if unsure, **confused** (C).

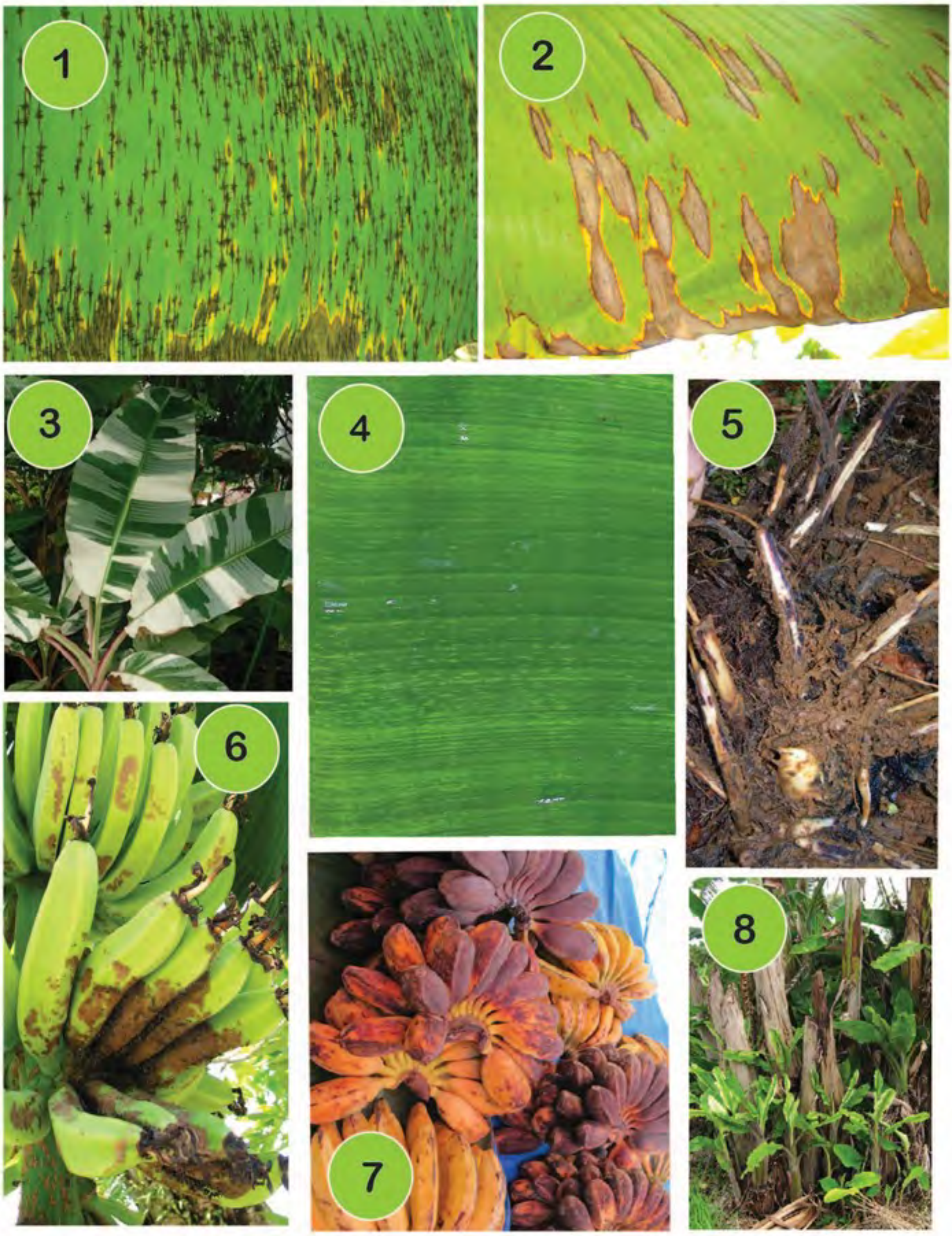
Fill in the table for the A, B, C photosheets. Trainees will need to draw a separate table for each photosheet. Trainees should give reasons and present their answers to the rest of the class. *Go through the answers first before asking them to fill in the last column.*

Your answers

Crop	Photo	A, B or C?	Reasons	Correct answer (fill in after class discussion)
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			

BANANA

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?



BELE

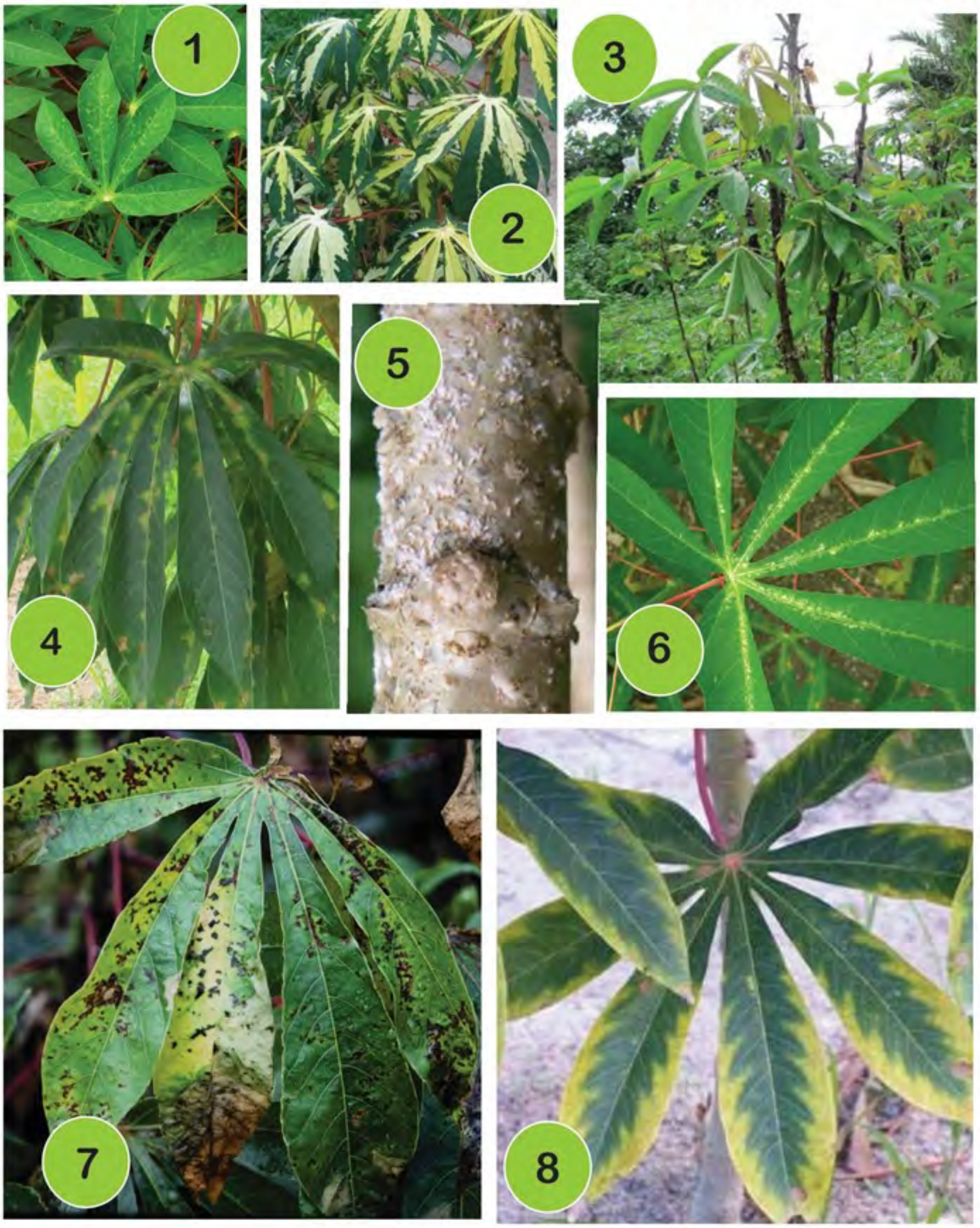
Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?

CABBAGE

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?

CASSAVA

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?

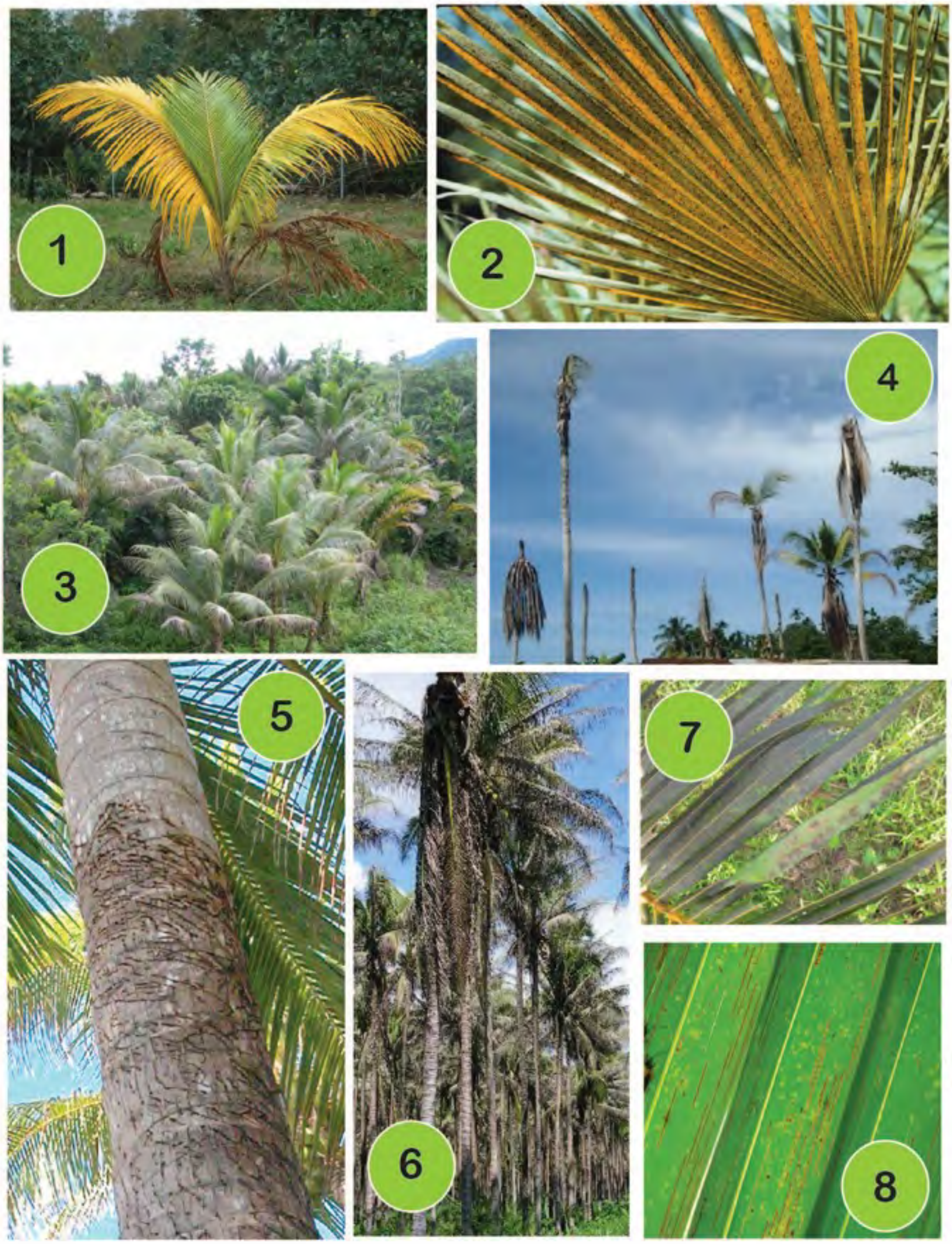


CITRUS

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?

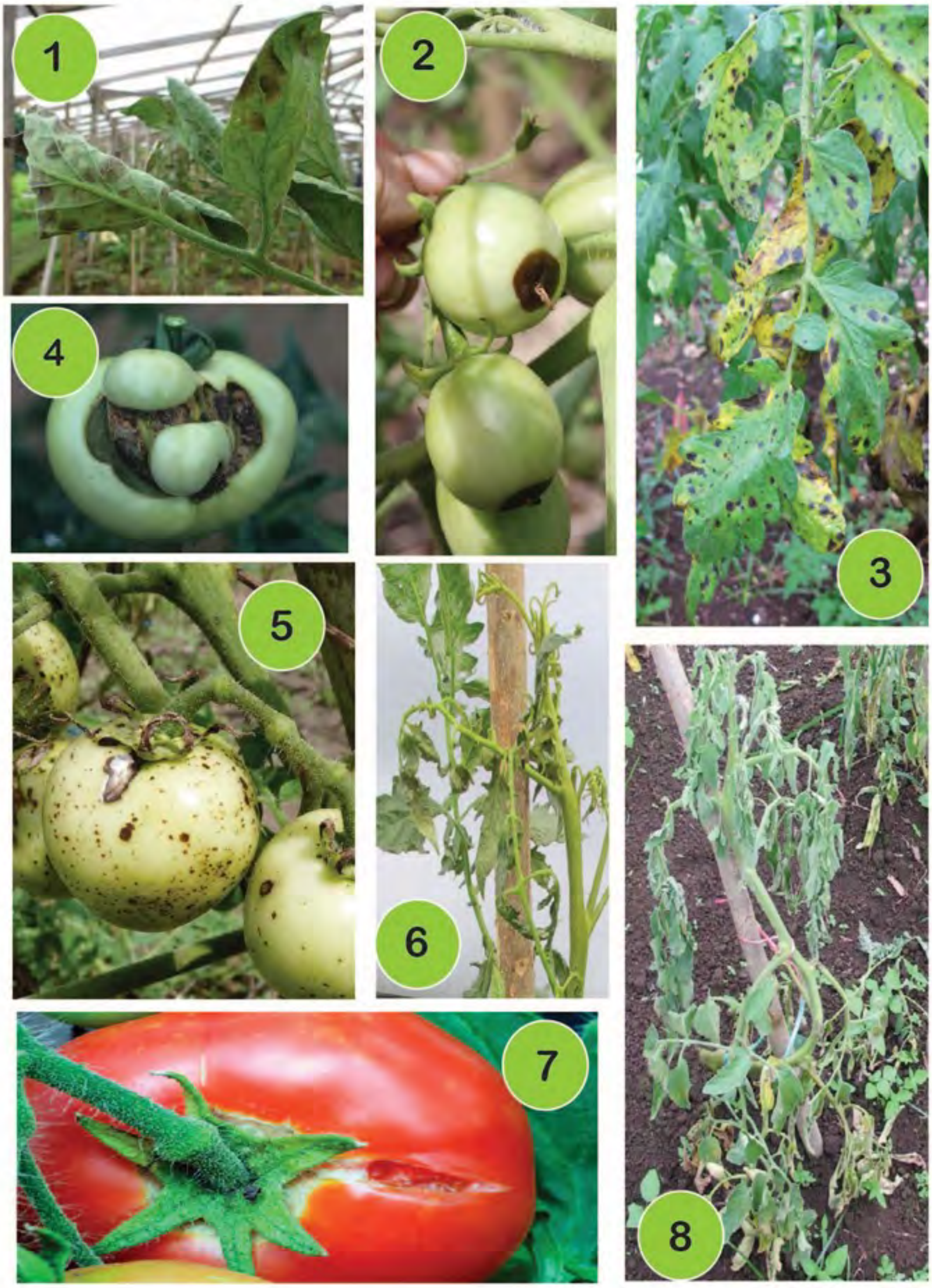
COCONUT

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?



TOMATO

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?



MIXED

Are these symptoms caused by something abiotic (A), biotic (B), or confusing (C)?

EXERCISE 2: Speed dating

This exercise is fun and helps your trainees practise identifying and describing symptoms on plants carefully and accurately. Ensure that they have enough samples of pests and diseases for one per trainee, and that you have set up three tables marked A,B and C.

Trainees should form two lines facing each other so they are standing opposite a partner. Give each person a sample of a plant pest or disease. One trainee carefully describes the symptoms to their partner ('date') opposite, and then both try to decide whether the cause is abiotic (A), biotic (B), or confused (C).

Trainees have two minutes. When you say "Stop", the other partner has to repeat the process with another sample. Next, everyone in one line moves to the left to a new partner, and repeats the process of describing the symptoms.

Trainees now place their samples on a table marked A, B or C, depending on what they think the cause is.

Now go through the next sections (2.3–2.8) of the manual with your trainees. You could create a PowerPoint slide show if you have the facilities for this. Alternatively, if they have access to the information, ask your trainees to read the sections for homework.

When you have completed this, your trainees will have a chance to change their minds about A, B or C (Exercise 5).

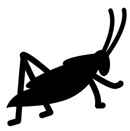
2.3 What is a pest?

In this manual we treat pests as organisms that you can see with the eye or with a hand lens. This includes insects, mites, slugs and snails, as well as larger animals, such as birds, mice, rats and even humans! Weeds are also regarded as pests. Most pests that farmers are concerned with are **insects** and **mites**. They usually cause problems by **chewing, sucking or, more rarely, piercing when laying eggs**. When they are on leaves, stems or flowers, they are quite easy to identify. It is more difficult to identify them on roots, unless there is obvious chewing, or the roots are decayed. For this reason, farmers often bring only the leaves to the clinic because that is where they see the symptoms.

Note: Insects[6] have **six** legs, except for some uncommon butterflies that have four. Mites belong to the arachnid class, along with spiders, scorpions and ticks, and have **eight** legs. Here are some important facts about insects/mites/spiders that will help identify them as plant pests.

There are 30 orders of insects, but only eight orders contain pests. The insects in these eight orders are listed below.

1. Grasshopper, crickets and katydids (Order: Orthoptera)
2. Moths and butterflies (Order: Lepidoptera)
3. Beetles and weevils (Order: Coleoptera)
4. Flies (Order: Diptera)
5. Termites (Order: Blattodea)
6. Ants, bees, wasps and sawflies – many of these are beneficial insects as well as pests (Order: Hymenoptera)
7. Thrips (Order: Thysanoptera)
8. Aphids, ‘bugs[1]’ (true bugs), leafhoppers, planthoppers, psyllids, mealybugs, scales and whiteflies (Order: Hemiptera)



[6] The word ‘bug’ is meant to describe an insect in the order Hemiptera, not just any insect. The Australian Museum notes that not all insects are bugs. There are many different forms, including aphids, hoppers, scale insects, cicadas and, confusingly, the 'true' bugs – stink bug, assassin bug, coreid bug, and many more. The ‘true bugs’ are a sub-order known as the Heteroptera.
https://australianmuseum.net.au/learn/animals/insects/bugs-order-hemiptera/ ;
https://australianmuseum.net.au/learn/species-identification/ask-an-expert/what-do-true-bugs-look-like/

The taxonomy of mites is still being researched. Of the six or so orders, the plant parasitic mites belong to the order Trombidiformes; this contains the spider mites (tetranychid) and those smaller mites (eriophyid) living in galls and buds.

There are both 'good' and 'bad' insects

Insects that are considered 'good' for humans are those that pollinate flowers, e.g. flies, bees, butterflies, moths and beetles. These are necessary for seed and fruit crops. There are also insects that prey on other insects. These predators can be generalists, e.g. some wasps and beetles, or specialists, e.g. parasitoids – wasps and flies that lay their eggs on or in a pest, and whose larvae eventually kill it.

'Bad' insects are those that are bad for humans. These include: ☺ ☹

- Crop feeders – many
- Carriers of human diseases, e.g. mosquitoes that carry the malaria parasite or the dengue fever virus
- Carriers of plant diseases, e.g. aphids, mealybugs, whiteflies and planthoppers transmit viruses
- Nuisances, e.g. fire ants that 'sting' people with secretions of formic acid, or mosquitoes that bite

Some insects and mites are both good and bad

Some insects and mites can be both good and bad. For example, some ants keep generalist plant-feeding insects away – they prevent butterflies and moths from laying eggs, and their larvae (caterpillars) from developing. At the same time, they leave sap-sucking insects like aphids and scales alone, as the ants feed on their sugary secretions (honeydew). In this way, ants defend the aphids and scales from predators. There are also species of predatory mites, which are available for farmers to purchase in some countries. They are usually used in greenhouses against spider mites.

Spiders are almost entirely beneficial, mites less so

There are some 45,000 species of spiders and, unlike insects, none of them eats plants. Spiders hunt their prey or spin webs to trap them. Their effect on small caterpillars (e.g. on cabbages), on leaf and planthoppers (e.g. on rice), and on insect pests feeding on many other crops, is often overlooked. The only bad thing about spiders is that they also prey on honeybees, butterflies and other beneficial insects.

Mites are related to spiders, but some are bad. The so-called spider mites are plant pests that cause silvering on many plants. They live commonly on the underside of leaves along the main veins. Webs are often present. The other bad mites are the plant parasitic eriophyid mites; some cause galls and others feed in buds, causing distortions to developing leaves and flowers. Rarely, eriophyid mites spread viruses, but none are known to do so in the Pacific region.

However, as with insects, not all mites are bad. There are species of predatory mites, which are available for farmers to purchase in some countries. They are usually used in greenhouses against spider mites, and they also eat small insects.

Although many people don't like them, spiders are not insects and they are good for our crops, so should be left alone

2.4 Insect life cycles

Insects have two different life cycles – either complete or complex metamorphosis ('holometabolous', where the immature stages are different from adults) or incomplete or simple metamorphosis ('hemimetabolous', where the immature stages are similar to adults).

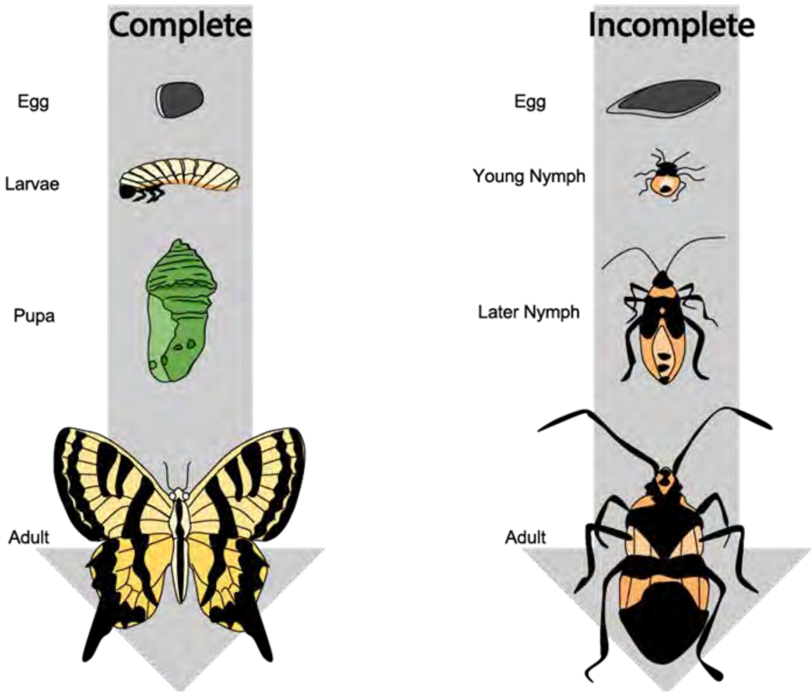


Fig. 2.3 Examples of complete and incomplete metamorphosis[7].

[7] Fig. 2.3 is adapted from an image courtesy of Wikimedia Commons, the free media repository and is available at https://commons.wikimedia.org/w/index.php?curid=49034418.

Life cycles of insects with complete metamorphosis

Insect groups that undergo complete metamorphosis are: Coleoptera (beetles); Lepidoptera (moths and butterflies); Hymenoptera (wasps, ants and bees); and Diptera (flies). All these groups have a life cycle where the egg hatches into a larva (e.g. a grub, caterpillar or maggot) that develops into an inactive pupa stage (or puparium in the case of flies) before emerging as an adult (e.g., a butterfly, beetle, wasp).

Life cycles of insects with incomplete metamorphosis

Typical insects that undergo incomplete metamorphosis are: Hemiptera (aphids, true bugs, cicadas, hoppers, mealybugs, scales and whiteflies); Orthoptera (grasshoppers and crickets); Blattodea (termites); and Thysanoptera (thrips). Immature stages of these insects are called nymphs, which gradually increase in size and change form. As the insects grow, they shed their skin (called moulting). After each moult, the nymphs look a little different or a little larger but, unlike a caterpillar of a butterfly or moth, the nymphs are not that different from the adults. After a final moult, the full adult form emerges (Fig. 2.3).

Life cycles of mites

Spider mites have four stages - egg, larva, nymph and adult. There is one larval stage with six legs and two nymphal stages that are small versions of the adult, with eight legs. The minute, carrot-shaped Eriophyid mites have three stages - egg, and first and second nymph. They have two pairs of legs.

Why is it important to know the life cycle of an insect pest?

Once you know which group your pest belongs to, the next most important step is to determine its life cycle. This allows you to suggest ways to control the pest at its most vulnerable stage, or possibly suggest how to avoid it all together. This is one of the basic concepts behind integrated pest and disease management (IPDM).

As we have seen already, insects have different types of life cycle, incomplete (simple) and complete (complex). Those insects with incomplete life cycles have nymphs that are similar to adults, which gradually change. They usually occur in the same habitat and eat the same food. For these, control strategies are the same for both stages. However, those insects with complete life cycles have larvae, pupae and adults that appear very different from each other and, importantly, often live in different habitats, eat different foods or, in the case of the pupa, do not eat at all. This means that controlling these insects may require a different response from insects with incomplete, simple life cycles.

Life cycles of the eight insect and single mite orders that damage crops are as follows (Figs. 2.4-2.18).

Grasshoppers, Crickets and Katydids

KATYDID
(unknown species)

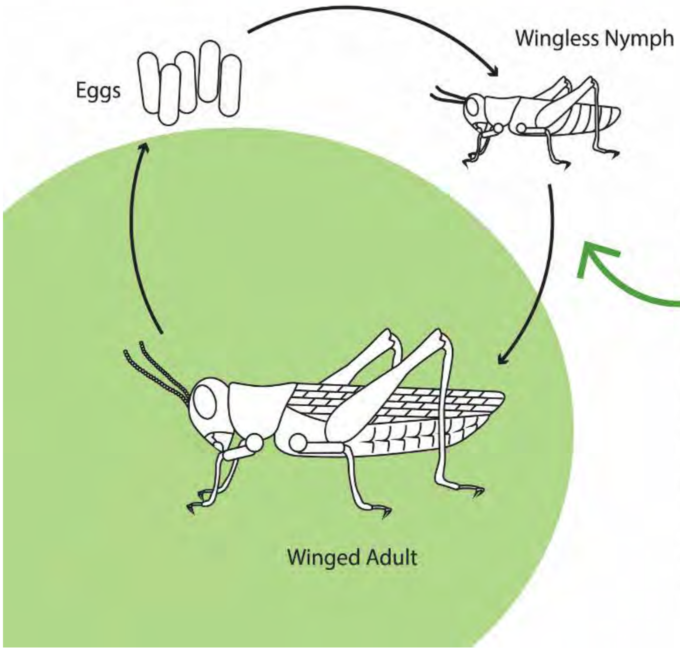
They have long antennae, longer than the body, and are often thin and thread-like. They also have very large hind legs. Most feed on plants.

GRASSHOPPER
(*Aiolopus* sp.)

Usually they have short antennae, shorter than the body length. They feed during the day. Most feed on plants.

CRICKET
(*Teleogryllus* sp.)

These have long antennae, but differ from katydids. They have long ovipositors, eat both plants and insects, and live in burrows in the ground during the day.

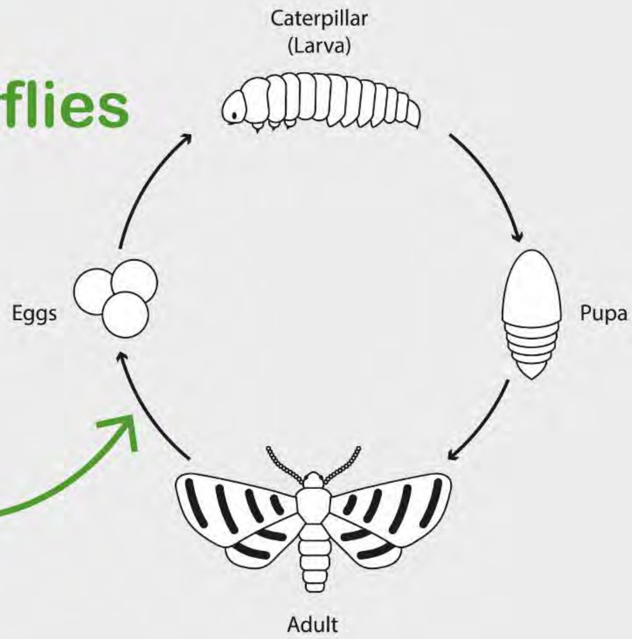


These have simple life cycles. Eggs laid in the soil, hatch into small versions of the adult, gradually getting larger by successive skin shedding (moults). Small wing-buds can often be seen, and these get larger after each moult. There is no resting stage. The adult has fully developed sex organs, and wings may be fully developed, but in many species wings are short or absent.

Fig. 2.4 Life cycle of grasshoppers, crickets and katydids (order Orthoptera).

Moths and Butterflies

These have complex life cycles. Eggs are laid singly or in groups, usually on plants. A larva hatches and gradually gets larger as it passes through several skin changes or moults. Finally, it forms the non-feeding pupa (resting stage). The pupa may be on a plant or in the soil. The pupa stage ends with the emergence of the adult.



Adult moths and butterflies usually feed on plant nectar, but there are rare exceptions, e.g., the fruit piercing moth, which sucks juice from fruits. Adults (not caterpillars) are used by taxonomists to categorise them. This is a *Diaphania* sp. adult.

Moths and butterflies differ:
i) while at rest, adult butterflies fold their wings, while moths spread theirs flat;

ii) the antennae of adult butterflies end in club-like tips, while moth antennae are feathery;

ili) moth pupae are wrapped in a silk-like covering, whereas butterflies' pupae are hard, smooth and without silk.

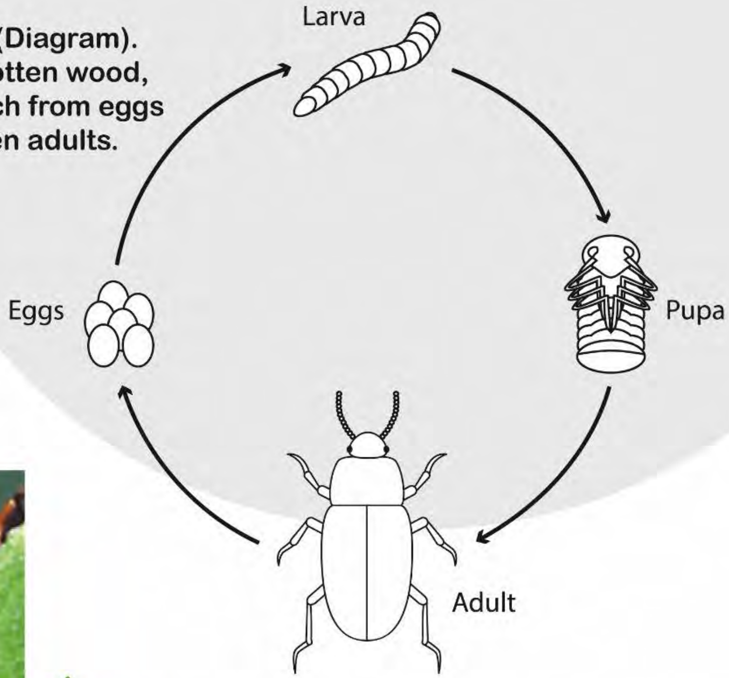
Caterpillars (*Agrius* sp.) (right) have three true legs from the thoracic (front) segments just behind the head and usually five pairs of fleshy prolegs on the third to the sixth abdominal segments, used to hang onto leaves, stems, bark, etc.

Looper caterpillars are different: they have three true legs, an anal or last pair, but fewer other pairs depending on the family. This reduction means that the caterpillars travel in 'loops' as seen in the image of (*Chrysodeixis* sp.) (left).

Fig. 2.5 Life cycle of moths and butterflies (order Lepidoptera).

Beetles and Weevils

These have complex life cycles (Diagram). Eggs are laid on or in the soil, rotten wood, even animal faeces. Larvae hatch from eggs and develop into pupae, and then adults.



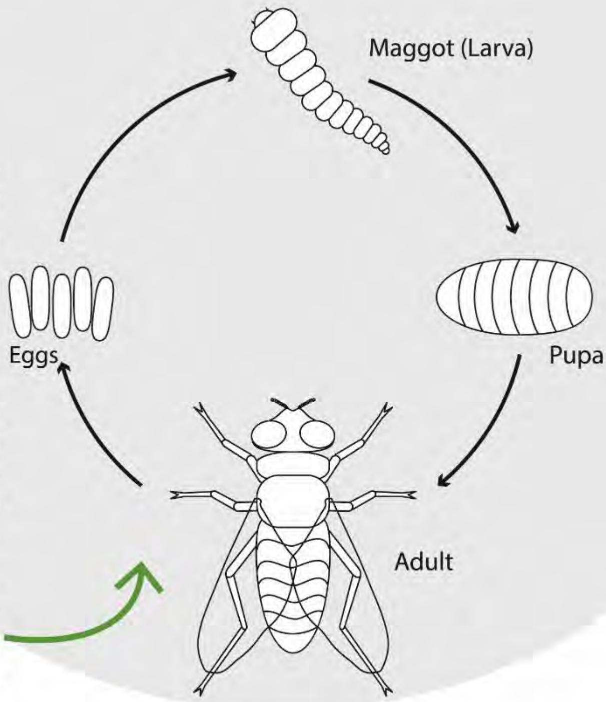
Beetles have two pairs of wings the first or front pair are hardened (the elytra) to protect the second pair which are used for flight, although not all beetles fly. Note, the wings meet in the middle of the back (unlike the 'true bugs').

Weevils are a group within beetles. They have characteristic snouts, although some are not long as in the image above.

Fig. 2.6 Life cycle of beetles and weevils (order Coleoptera).

Flies

Flies have complex life cycles (see diagram). The eggs (many species do not have eggs, but give birth to living young) hatch into legless larvae (maggots), which increase in size after successive moults. They pupate within the dried skin of the larva to form a small, walled 'puparium'. Some produce free-living pupae in water (e.g., mosquitoes) that hatch into adult flies. Adults may be useful pollinators of flowers, or fruit fly pests. Leafminers and fruit flies are common pests in the Pacific islands. Note, whiteflies are not members of this order; they are members of the aphid, leaf and planthopper, psyllid, mealybug, scale insect order (Hemiptera).



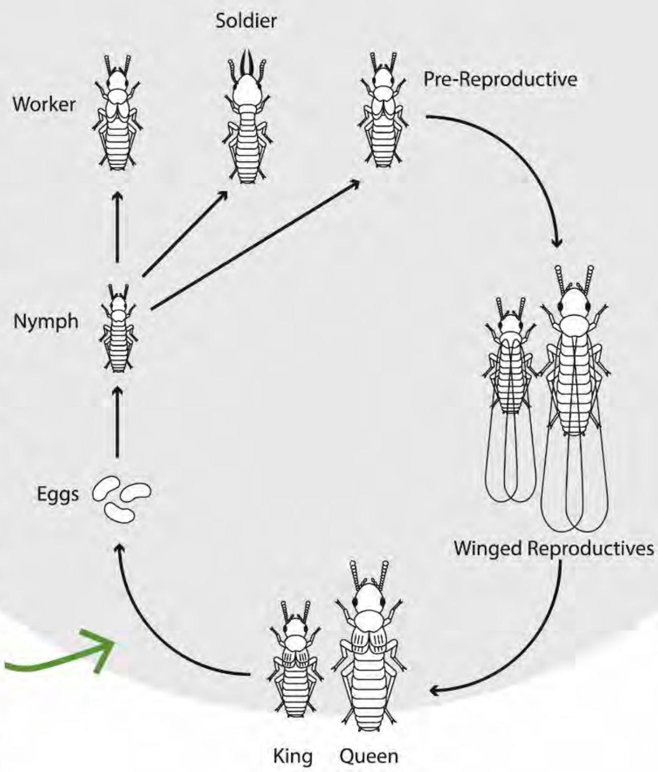
Leafminer (*Liriomyza* sp.). The adult fly is tiny and not easily seen. It is the larva (the maggot) that causes the damage as it mines the leaves. The pupa usually falls from the leaf and matures in the soil.

Fruit fly (*Bactrocera* sp.). Adult flies have a single pair of wings. In most cases, they lay 1-20 eggs into maturing fruits together with bacteria that provide food for maggots, either directly, or indirectly by causing fruits to rot. The fruit fall to the ground and the larvae enter the soil to pupate.

Fig. 2.7 Life cycle of flies (order Diptera).

Termites

Termites have simple life cycles. Unlike ants, termites have only egg, nymph and adult stages. They are social insects that are now placed in the cockroach order (Blattodea). Like ants, and some bees and wasps, termite colonies have sterile male and female 'workers' and 'soldiers' (see diagram). They also have fertile 'reproductives' (with two pairs of wings) – producing males called 'kings' and one or more fertile females called 'queens'. Termites mostly feed on dead plant material - wood, leaf litter, soil, or animal dung. In subtropical and tropical regions, their recycling of wood and plant matter is ecologically important. Termite colonies range from a few hundred to several million individuals.

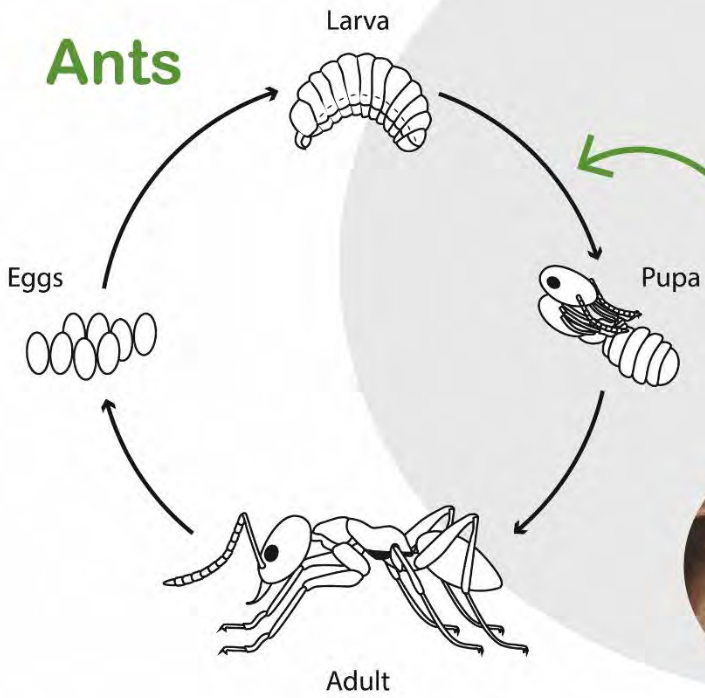


Termite (*Neotermes* sp.). The life cycle begins with the winged (they have two pairs) reproductives leaving the colony to swarm. Females and males pair, they shed their wings, look for a place to start a new colony, and mate. The female lays eggs and both sexes (king and queen) take care of the offspring until there are enough workers to take over.

Mating continues for life (unlike ants which mate only once). It may take up to 10 years before the king and queen have built a colony that produces reproductives once more.

Fig. 2.8 Life cycle of termites (order Blattodea).

Ants



Ants have complex life cycles (see diagram). The eggs hatch into legless larvae, which increase in size as they moult before becoming pupae then adults.

Oecophylla weaver ant.

Within an ant colony there are one or multiple queens, a few sexually active males (from unfertilised eggs) and large numbers of wingless female workers (from fertilised eggs) that cannot reproduce. Female workers have different tasks: caring for the eggs and larvae; gathering food; or defending the colony. Adults feed on liquid foods (hence their attraction to honeydew) and parts of seeds rich in fat and protein. They are also predators or scavengers of insects and spiders that are fed to larvae. A new colony starts when a queen lays eggs and the resulting larvae develop into new winged queens and males, and they leave the nest and mate in the air. The males die and the queen finds a new place to start a colony by laying eggs which become workers.

Weaver ants tending mealybugs on cocoa.

Fig. 2.9 Life cycle of ants (order Hymenoptera).

Bees (leafcutting)

Bees and wasps have complex life cycles much like ants (see the lifecycle diagram for ants). The eggs hatch into legless larvae, which increase in size as they moult before becoming pupae then adults.

Leafcutting bees (like this *Megachile* sp.) are mostly solitary, occurring in countries throughout the world. They cut discs from leaves to build nests, often in rotting wood. The nest has a line of cells each with a single egg and a ball of pollen for the larva when it hatches. Adults feed on nectar and pollen, and are important pollinators of some crops, ornamentals and wildflowers. They are regarded as pests where they spoil the aesthetic look of plants and take pieces from leaves.

Wasps

Wasps are mostly solitary, although some, such as the yellowjackets and hornets, live in colonies with queens and non-reproductive workers. Social wasps have life cycles similar to ants and bees, except the workers hunt other insects and spiders to feed their carnivorous larvae. However, there is considerable difference between social and solitary wasps. Some solitary wasps lay eggs in other insects, and are important in biological pest control. They are similar to parasites but, importantly, they kill their hosts, and are known as 'parasitoids'. All life stages - eggs, larvae, pupae or adults - of other insects (and some other arthropods) are targeted as hosts, depending on the parasitoid species. Adult parasitoid wasps mainly feed on nectar, but only a very few species are involved in pollination.

Diadegma sp., a wasp parasitoid, laying its egg in a larva of Diamondback moth

Fig. 2.10 Life cycle of bees and wasps (order Hymenoptera).

Sawflies

Many species of sawflies have males, but many do not, and females produce eggs without fertilisation. Sawfly larvae often feed on leaves (sometimes defoliating trees). They look very much like the caterpillars of moths or butterflies – they have thoracic legs and prolegs.

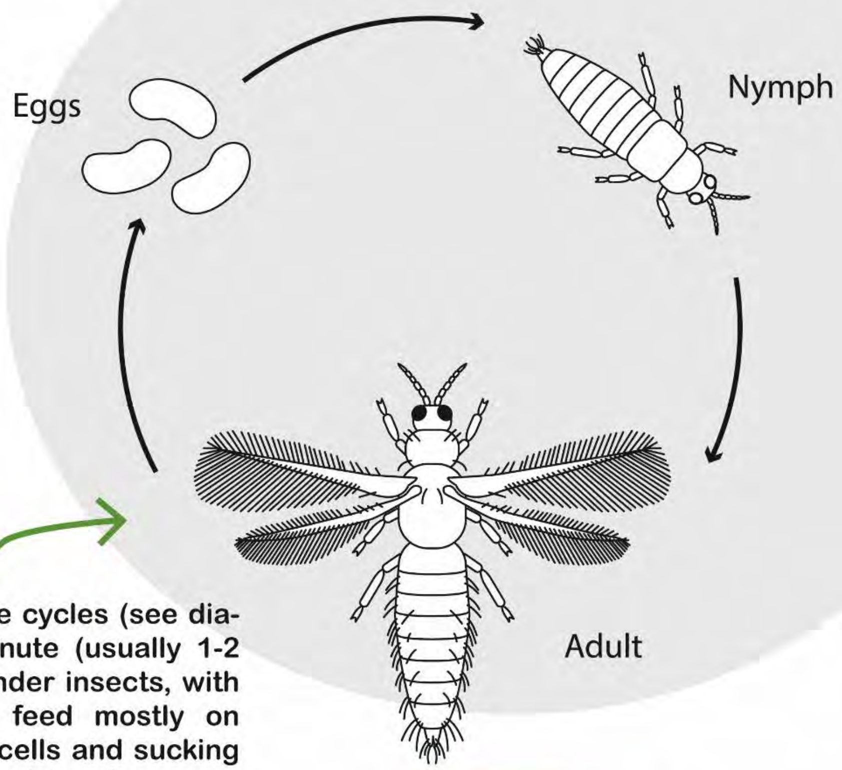
Sawfly caterpillars (*Neodipiron* sp.). Note there are eight pairs of prolegs, greater than the number of pairs commonly seen on caterpillars of moths and butterflies

Adult sawfly (*Neodipiron* sp.)

Adults do not have a 'waist', typical of bees and wasps, and they feed on pollen, nectar and sap. Females have long ovipositors that have a saw-like appearance used for cutting into plants to lay their eggs (hence their common name). The ovipositor looks like a 'stinger'.

Fig. 2.11 Life cycle of sawflies (order Hymenoptera).

Thrips

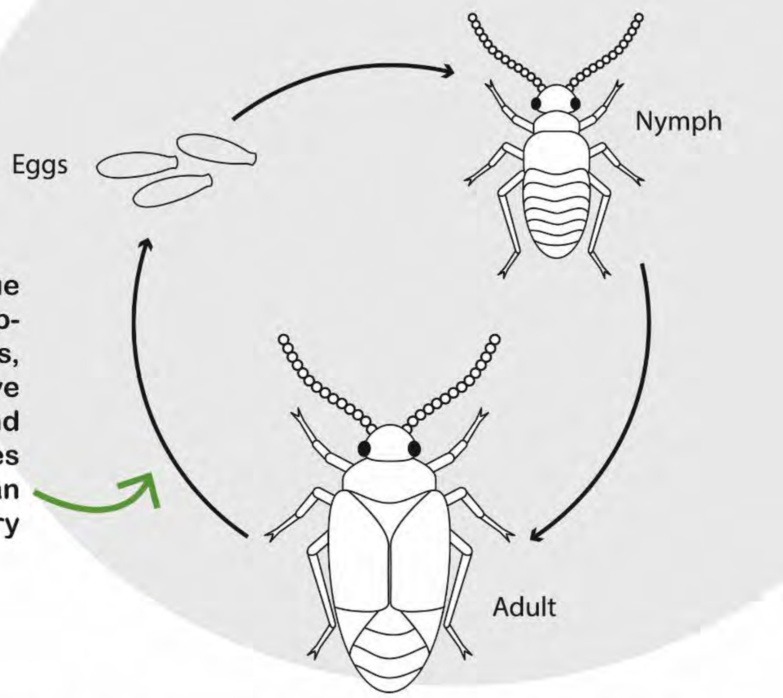


Thrips have simple life cycles (see diagram). Thrips are minute (usually 1-2 mm long or less), slender insects, with fringed wings. They feed mostly on plants by puncturing cells and sucking up the contents, although in a few cases they are predators of other thrips, other insects or mites. They are weak fliers, but are often spread on the wind. Many thrips are pests, and some, such as the tomato spotted wilt virus, cause important plant diseases. Others are beneficial pollinators.

Eggs, nymphs and adults.

Fig. 2.12 Life cycle of thrips (order Thysanoptera).

Aphids



Various aphids, bugs ('true bugs'), leafhoppers, planthoppers, psyllids, mealybugs, scales and whiteflies have both complete (complex) and incomplete (simple) life cycles (see diagram). Hemiptera is an order of insects with very diverse life cycles.

Aphids have a simple life cycle. Some species lay eggs, i.e., where they have to survive the winter in temperate or sub-tropical regions. In the tropics, females give birth to living young, without having to mate, producing more females. The young are wingless versions of adults. Colony development is rapid. Later, when colonies become crowded or the host plants begin to die, winged forms develop for dispersal.

Citrus aphids (*Taxoptera* sp.): nymphs, winged and wingless adults.

Fig. 2.13 Life cycle of aphids (order Hemiptera).

True bugs

'True bugs' are members of the sub-order Heteroptera (order: Hemiptera). They have simple life cycles: they lay eggs or give birth to living young that get larger gradually by moulting. There is no resting (pupa) stage. Adults have fully developed wings, although some species are without wings or have short wings. If present, the wings form an X-shaped pattern when folded at rest. The word heteropteran means 'different wings' as most have forewings that are part membranous and part hardened. Nymphs are generally softer and 'squishier' than adults.

An adult bean pod sucking bug (*Riptortus* sp.). Note, the X made by the folded wings when at rest. The bodies of nymphs mimic that of ants (inset)

Leafhoppers & planthoppers

Leaf and planthoppers have a simple life cycle, and are members of the sub-order Auchenorrhyncha. There are males and females. Eggs, produce nymphs, then short-winged adults; later, when crowded or food supplies are short, long-winged forms develop for dispersal. Some members of both groups spread important plant diseases.

Nymphs of a leafhopper (*Amrasca* sp.).

Planthoppers, *Tarophagus* sp., showing winged adults and nymphs at different stages of development.

Fig. 2.14 Life cycle of true bugs, leafhoppers and planthoppers (order Hemiptera).

Psyllids

Psyllids have a simple life cycle, and are members of the sub-order Sternorrhyncha. They look like miniature cicadas. Commonly called a plant louse (or plant lice for plural), or even jumping plant lice. Eggs are laid on new shoots, and nymphs go through several moults. Adults are about the size of winged aphids, but, in contrast, they have wings folded over their bodies. Nymphs and adults suck sap. Many species produce strings of wax, or waxy covers over their bodies, e.g., the citrus psyllid that spreads Huanglongbing (citrus greening) disease.

An Asian citrus psyllid (*Diaphorina citri*). The angle of the body relative to the suface the insect is resting on is characteristic of this species.

Mealybugs

Mealybugs (and scales) are closely related (sub-order Sternorrhyncha), but in different families. The soft bodies of mealybugs are covered in mealy or cottony wax with waxy threads around them. They are often found in groups and generally able to move short distances. Eggs are laid singly or in clusters (often embedded in waxy threads), and hatch to produce 'crawlers' which have legs and are quite mobile; these wander around or are spread on the wind before settling down to feed by sucking sap. They moult through several stages. In males, the last stage, called a 'pupa', produces a winged adult that looks like a tiny mosquito with one pair of wings, but without a mouth, whose function is only to mate. Note, not all species lay eggs: some give birth to living crawlers, and some other species do not have males – females are produced without fertilisation.

Adult mealybugs (*Phenacoccus* sp.): showing mealy/waxy covering and immature nymphs.

Fig. 2.15 Life cycle of psyllids and mealybugs (order Hemiptera).

Scales

Adult breadfruit scale, *Icerya seychellarum.* Presently, a huge infestation occurs in Fiji after the introduction of a white-footed ant which tends the ant protecting it from natural enemies.

Scale insects are divided into many different groups with considerable variations in their life cycles. In general, however, there are similarities with mealybugs: some lay eggs (and hatch as crawlers), some give birth to living crawlers, some reproduce without mating, and some have mosquito-like males. They are hermaphrodites, and able to self-fertilise, which is unusual in insects. As adults, the females are without legs, heads or wings. The scale of hard scales is not attached to the body, whereas it is with soft scales. In both cases, these waxy covers protect them from predators, parasitoids and pesticides. Note, hard scales do NOT produce honeydew, so they are not associated with fungal sooty moulds. Three families are illustrated below that are common scale insects of Pacific island countries: the breadfruit and cotton cushion scales (*Icerya* species) in the family Monophlebidae; armoured scale (family Diaspididae), and soft scale (family Coccidae).

Adult fluted scales (*Icerya purchasi*). They are hermaphrodites, able to self-fertilise, which is unusual in insects. The fluted part is an egg sac with many red eggs. Adults are covered in white wax.

White peach scale (*Pseudaulacaspis* sp.). Cocoons of the winged males are on the left branches; the minute, winged, males mate with females shown on the right branch. It is an armoured scale.

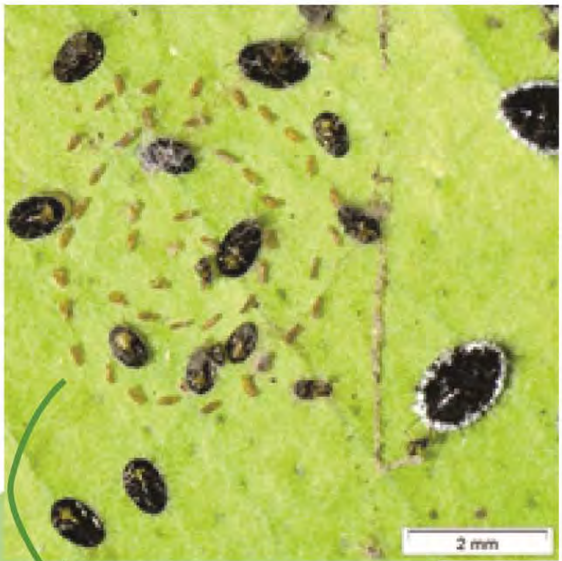
Adult Brown coffee (soft) scale (*Saissetia* sp.) Females reproduce without mating, i.e., parthenogenically, males unknown. Eggs laid under the female.

Fig. 2.16 Life cycle of scale (order Hemiptera).

Whiteflies

The life-cycle of whiteflies is similar to that of mealybugs and scales. However, there are males and females, with females being slightly larger. Eggs are laid in circular or spiral patterns on the underside of leaves. Crawlers emerge and pass through another three nymph stages. Both sexes have an intermediate pupal stage. (Note, the word 'pupa' is disputed by some authorities). Some species reproduce without mating and, in others, females mate with their offspring. The pupal stage is used for identification. Whiteflies produce honeydew which leads to sooty moulds on foliage.

Sweet potato whitefly (*Bemisia* sp.) adults and pupae with slits from which they have emerged.



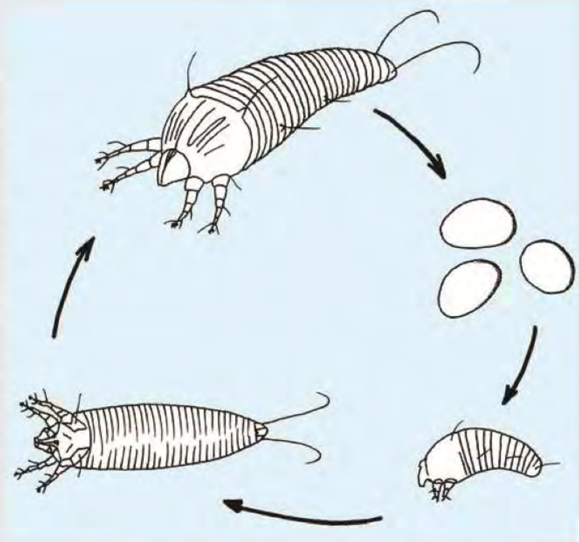
Not all whiteflies are white! Orange spiny whitefly (*Aleurocanthus* sp.) on citrus lays eggs in a spiral, produces black nymphs, and white-fringed pupae.

Pupa and adult orange spiny whitelfy

Fig. 2.17 Life cycle of whiteflies (order Hemiptera).

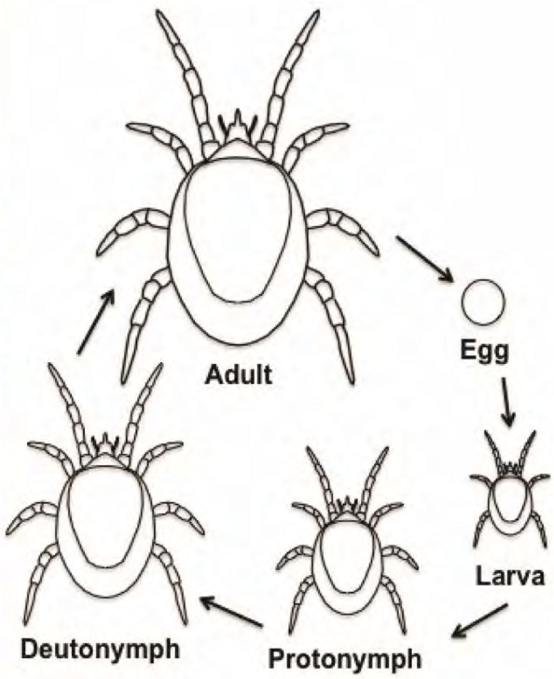
Plant mites

Tetranychid spider mites are less than 1 mm long, they lay relatively large, round, transparent eggs, and spin webs to protect themselves. Eggs hatch, producing a larvae; these moult into 1st-stage (proto) and 2nd-stage (deuto) nymphs, which then mature into adults. In hot, dry conditions populations enlarge rapidly. Eriophyid mites are smaller, and usually found living in the buds of plants, or in galls. The life cycle is relatively simple: egg, first and second nymphs, and adult.



Life cycle of an eriophyid mite.

Appearance of eriophyid (top) and tetranychid (bottom) mites.



Life cycle of a tetranychid mite.

Fig. 2.18 Life cycle of plant mites (order Trombidiformes).

2.5 Symptoms of insects and mites – what can they tell us?

Pests can be divided into those with mouthparts that chew, those that suck, and those that pierce when laying eggs (Fig. 2.19). Thrips are often said to rasp, but it is now agreed that they pierce and suck, with different mandibles (mouthparts) adapted for the tasks. See the damage they cause in Figs. 2.20-2.68.

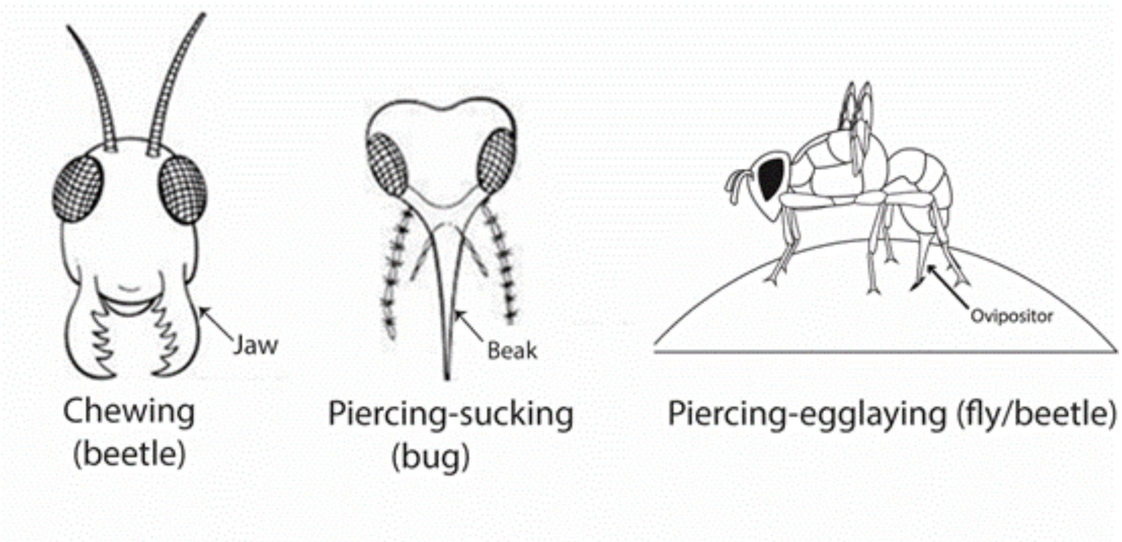


Fig. 2.19 Three ways insects cause damage on plants - chewing, sucking and piercing.

Table 2.2 describes a variety of ways that pests can damage crops, with examples and an explanation of which stages of the lifecycle are most likely to produce particular types of damage.

Table 2.2 The ways that insects damage plants, the signs of damage and the principle stage in their life cycle when the damage is done.

Mouthparts	Pests	Sign of damage	Stage of life cycle causing damage	Comments
Chewing	Grasshoppers, crickets & katydids (Orthoptera)	• Chewed leaves, flowers & stems	Adults & nymphs	
	Moths & butterflies (Lepidoptera]	• Chewed leaves, flowers & stems • Boring or tunnelling into stems and trunks	Moth & butterfly larvae (caterpillars), rarely adults (e.g., fruit-piercing moths)	
	Beetles & weevils (Coleoptera)	• Mining of leaves • Chewed leaf surface or holes through the leaf • Boring or tunnelling in bark, trunks & roots, leaving frass • Mining of leaves	Adults & grubs (larvae)	Frass is insect excrement Leaf-mining less common than Lepidoptera and Diptera
	Flies (Diptera)	• Rots in fruit • Mining of leaves	Maggots (larvae)	
	Termites (Blattodea)	• Chewed trunks & roots	Adults & nymphs	The only example in the region is the coconut termite
	Ants, bees, wasps & sawflies (Hymenoptera)	• Some bees cut out pieces of leaves • Some wasps cause galls • Ants protect aphids, scales, mealybugs from parasitoids & predators	Larvae of sawflies, adults of leaf-cutting bees & larvae of gall wasps	Ants do not damage plants directly; they protect other insects from natural enemies so they can take their honeydew. Excessive

				honeydew leads to leaves blackened by sooty mould
Sucking	Thrips (Thysanoptera)	• Scars on fruits, especially from the stalk end • Curled leaves • 'Silvering' of leaves and flowers	Adults & nymphs	'Silvering' is caused by air entering the leaf when the insect (or mite) pierces the leaf to suck the sap
	Moths & butterflies (Lepidoptera)	• Fruit-rots (round at first)	Adults (rare)	The fruit-piercing moth is an example of the adult in this group
	Aphids, bugs, leafhoppers, planthoppers, psyllids, mealybugs, scales & whiteflies (Hemiptera)	• Small spots on leaves, flowers fruits (leading to rots) & also on seeds • Sooty moulds (fungi) • Wilts, stunted foliage & dieback • Galls	Adults & nymphs	Sooty mould fungi grow on the honeydew excreted from aphids, mealybugs, planthoppers, scale & whiteflies
	Mites (Trombidiformes)	• Speckling and/or 'silvering of top surface of leaf, with mites & webbing beneath • Severe leaf distortions and/or galls	Adults & nymphs	Two types of mites: those living on leaves (tetranychids) & those in buds or galls (eriophyid)
Piercing	Flies, beetles & weevils	• Small spots or holes on fruits with bruising around • Dark liquid oozing from fruit	Adults	The damage is called a 'strike' when done by fruit fly

2.5.1 Chewing pests

Grasshoppers, crickets and katydids (Figs. 2.20-2.22)

Adults and nymphs eat large areas of leaves and soft stems, e.g., grasshopper attack on sugarcane and katydid damage to banana and oil palm. Note, leaf damage is similar to that caused by caterpillars, but there is no frass (i.e. faeces). Often, damage from grasshoppers and katydids starts from the margin of the leaf, but not always. Crickets are different in their eating habits from the other two; they are 'omnivorous', meaning they eat many different kinds of food - plants, other insects including eggs, larvae and pupae, and also the remains of dead animals.

Fig. 2.20 Damage on long bean by small (identity unknown) grasshopper that eats only patches of the leaf surface; the patches may turn into holes later as the damaged parts fall away. There is no sign of frass. Other groups of insects only eat the surface areas of leaves (Fig 2.23).

Fig. 2.21 Grasshopper (unknown) damage on sugarcane shows a solitary insect, and clearly the damage started at the edges of the leaf, where the grasshopper continues to feed. Note, lack of frass, which might otherwise suggest caterpillar damage.

Fig. 2.22 Katydid (*Sexava* sp.) on oil palm and banana can be devastating, where the entire leaf is stripped, leaving only the midrib.

Moths and butterflies (caterpillars) (Figs. 2.23-2.31)

Caterpillars chew all plant parts, but most commonly leaves. They also bore into succulent stems and fruits. In many cases, the damage they cause is diagnostic for a particular type of insect on a particular crop, e.g., cluster caterpillars on taro, but symptoms can also be similar to those of other groups. For example, moths, flies, sawflies and beetles all have larvae that produce leafmines and blotches - although in terms of numbers, moths have the greatest number of species that feed in this way. Similarly, holes in leaves are caused by caterpillars, but also by grasshoppers (nymphs and adults) and beetles (adults and larvae). Larvae of both moths and beetles also bore into stems, producing wilts and leaving frass. The following examples show the variety of damage done and, importantly, show that by comparison with other groups, the damage is not exclusive. The symptoms illustrated are: chewing surface layers of leaves, eating entire leaves, mining leaves, making holes in leaves, folding leaves, rolling leaves, and boring stems and fruits.

Fig. 2.23 Surface layers eaten by young, gregarious taro armyworm (*Spodoptera* sp.), called a taro cluster caterpillar at this stage (left). Later, solitary caterpillars eat the entire leaf, leaving only the petioles (right).

Fig. 2.24 Surface layers eaten by the coconut flat moth (*Agonoxena* sp.) from the underside of the leaf.

Fig. 2.25 Mines (blotches) made under the leaf surface by the cowpea leaf miner (*Phodoryctis* sp.). Compare this symptom with the mines made by leafminers of flies (Fig. 2.42) and beetles (Figs. 2.34-2.36).

Fig. 2.26 Holes in leaves. At first, caterpillars of diamondback moth (*Plutella* sp.) make 'windows' in the leaves of cabbages by eating the surface layers; later, the larger caterpillars eat through the leaf making holes.

Fig. 2.27 Folds and holes in leaves (*Psara sp*.). The caterpillars fold the leaves, presumably for protection, and eat holes in the leaves as they mature. The red sweet potato beetle *(Candezea)* sp.) makes similar holes in leaves, although it does not fold them.

Fig. 2.28 Rolls of leaves. The banana skipper (*Erionota* sp.) caterpillar has rolled the leaves to live and eat inside.

Fig. 2.29 In a similar way to the banana skipper, the cotton leaf roller (*Haritalodes* sp.) on *bele* has rolled the leaves, although less spectacularly.

Fig. 2.30 Wilt caused by a caterpillar (*Erias* sp.) boring into a stem, *bele* (left). Internal boring of *bele* stems, rot, caterpillar and frass (right).

Fig. 2.31 Bored fruit. A common symptom of capsicum caused by the caterpillar of the corn earworm (*Helicoverpa* sp.). It also attacks fruit of tomato and eggplant.

Beetles and weevils (Figs 2.32-2.42)

Symptoms caused by beetles and weevils vary, and some are similar to those made by caterpillars of moths and butterflies. Adults in or on leaves may make straight lines, wavy lines, circles from stripping surface tissues on one side of leaves, holes through leaves, and holes into stems and trunks. Some larvae (called 'grubs') mine leaves. Weevils – a large sub-group of beetles, some with long snouts – attack fruits, leaves, trunks, roots and stored products, as well as causing many other symptoms similar to those of beetles. Many weevils are also biocontrol agents of weeds and therefore beneficial to human beings.

Fig. 2.32 Feeding grooves cut parallel to the veins of ginger caused by unknown beetle (left). Feeding grooves cut into sweet potato leaves by flea beetles (*Chaetocnema* sp.) stripping the surface and making wavy lines (right).

Fig. 2.33 Outer layers of the cucumber leaf stripped away by a phytophagous ('plant-eating') 28-spot ladybird beetle (*Epilachna* sp.). The adults and larvae have 'skeletonised' the leaf in patches.

Fig. 2.34 Mines (blotches) made by the larvae of the coconut leafminer (*Promecotheca* sp.), a beetle.

Fig. 2.35 Small holes in *bele* caused by a flea beetle (*Nisotra* species).

Fig. 2.36 Holes in cucumber cut by the pumpkin beetle *(Aulacophora* sp.). It is thought that the beetle cuts out leaf circles in order to reduce toxic substances from entering them.

Fig. 2.37 Boring in oil palm fronds by the coconut rhinoceros beetle (*Oryctes* sp.). Similar holes are bored through the base of coconut fronds.

Fig. 2.38 Boring by larva (grub) of the cocoa weevil borer (*Pantorhytes* sp.). Gum is often produced by the tree in response to the presence of the larva, and there may be frass at the opening of the hole.

Fig. 2.39 Wilt of *Amaranthus* caused by a stem weevil (*Hypolixus* sp.). A symptom similar to that of *bele* (Fig. 2.30 left). Several larvae bore into the stem eating the interior and filling it with frass. Cankers form on stems and branches as fungi take advantage of the damaged plants.

Fig. 2.40 Boring into the corm of taro by adult taro beetle (*Papuana* sp.)

Fig. 2.41 Boring into storage roots by larvae of sweet potato weevil (*Cylas* species).

Fig. 2.42 Bored grain in storage damaged by the lesser grain weevil (*Sitophilus* sp.). Both adults and larvae do the damage, by feeding inside the grains.

Flies (Fig. 2.43)

Leaf-mining fly maggots burrow just beneath the outer leaf layers similar to leaf-mining caterpillars. Note that larvae of leaf mining moths deposit frass down the middle of the mine, whereas leaf-mining fly maggots tend to leave the frass alternating between the sides of the mine. The reason for these alternating deposits of flies is the larva feeds on its side, and from time to time rolls over. Larvae of moths (and beetles and sawflies) feed either belly-up or belly-down, and frass is deposited down the middle of the mine[8].

Fig. 2.43 Mines made by the larva (maggot) of a fly leafminer (*Liriomyza* sp.) on tomato. The mines are very similar to those made by larvae (caterpillars) of moths.

Termites (Figs. 2.44-2.45)

Crop damage by termites is unusual in Pacific islands, although damage to buildings is common. Serious damage on coconuts does occur, but this appears to be confined to atoll countries. If symptoms are seen similar to those of Fig. 2.44, they should be reported immediately to agricultural authorities. The presence of the coconut termite in Rotuma (Fiji) is thought unlikely, but another species is damaging both coconut and citrus.

Fig. 2.44 It is not common for termites in the region to attack living plants or trees, but there are exceptions. The coconut termite (*Neotermes* sp.) attacks living palms in some atoll countries. It makes grooves into the bark for reasons unknown, but their appearance is considered diagnostic for the species.

Fig. 2.45 Surface termite tunnels and a nest in the trunk of a living coconut (Rotuma, Fiji). An unknown termite species is attacking coconuts and citrus on the island.

[8] Eiseman, C. (2020). Leafminers of North America. 2nd Edition. (http://charleyeiseman.com/leafminers/).

Ants, bees, wasps and sawflies (Figs. 2.46-2.48)

Within this group there are relatively few examples of damage caused directly by chewing adults or larvae. There are leaf-cutting bees that spoil ornamental flowers, gall wasps, e.g., *Quadrastichus* larvae on *Erythrina* trees, and sawflies that occasionally strip leaves.

Fig. 2.46 Leaf cutting bee (*Megachile sp.).* The adult causes the symptoms. The bees live in burrows; they make cells from the leaf pieces, place eggs and pollen inside for the young and then seal the cell.

Fig. 2.47 Sawfly larvae (*Nematus sp*.) are similar to moth caterpillars except for a greater number of prolegs. The damage by sawflies and caterpillars can be similar.

However, for the most part, bees and wasps are considered beneficial and important, wasps especially so, as they are parasitoids, natural enemies of plant pests. Where problems exist they are of different kinds. Introduced Asian bees compete with honey bees, and wasps (and hornets) may be a nuisance as they sting humans and animals.

Invasive ants especially are a major problem in Pacific islands, some out-compete native species, seriously disrupting ecosystems. Further, they feed on honeydew from scale insects, mealybugs, aphids, psyllids and planthoppers, protecting them from their natural enemies. Plants are weakened as honeydew supports mould fungi which blacken leaves, restricting photosynthesis. See also Section 2.5.2 on aphids and related insects under sucking insects.

Fig. 2.48 Galls produced by the larvae of the *Erythrina* gall wasp (*Quadrastichus* sp.). The larvae feed on the leaves and the tree responds by producing swollen deformed leaf galls. Note, insects of many orders as well as mites, produce galls.

2.5.2 Sucking pests

Thrips (Figs. 2.49-2.51)

Silvering on fruits and leaves is a common symptom on plants in Pacific island countries; this is seen commonly on capsicum, onion, mango and eggplant. On capsicum and eggplant, thrips enter the fruit buds when they are very young. Symptoms also occur on the flowers of some plants.

Most thrips feed by puncturing plant cells and sucking up the contents. The damage is done early, but becomes noticeable only later when the leaves and fruits expand: they become discoloured, silvery, and distorted. Some thrips are beneficial predators.

Symptoms of thrips are similar to those caused by spider mites. However, often the thrips have disappeared by the time that the leaves and fruits emerge. In some species, populations of thrips can be found within the folded, rolled leaves (e.g., *Ficus*) or on the underside of leaves (e.g., taro). Note, some species of thrips spread viruses.

Fig. 2.49 Thrips on shallot (*Thrips tabaci*) Thrips have unusual mouth parts: one side cuts or hammers the leaf surface to rupture the cells, while the other part has a tube to suck up the contents.

Figure 2.50 Thrips sp. silvering of leaves is a typical symptom of thrips.

Fig. 2.51 *Thrips* sp. scarring on fruit of capsicum (left) and eggplant (right). On both, the thrips have entered the bud at an early stage, fed on the fruit as it developed, creating the 'dragged-out' symptom as the fruit expanded (especially noticeable on eggplant). By this stage, the thrips have moved to younger fruit.

Moths and butterflies (Fig. 2.52)

Sucking damage by moths and butterflies is rare. The one important example in Pacific island countries is the fruit-piercing moth, a pest of citrus and many vegetables, especially tomato. The caterpillars develop on *Erythrina* trees.

Fig. 2.52 Fruit piercing moth (*Eudocima* sp.) on orange. The moth has sucked juice from the fruit and secondary invasion by rotting-causing organisms has caused the fruit to drop.

Aphids, true bugs, leafhoppers, planthoppers, psyllids, mealybugs, scale insects and whiteflies (Figs. 2.53-2.63)

All these groups suck sap to feed, and symptoms vary. Aphids, leaf and planthoppers, and psyllids cause distortions and wilting; true bugs cause spotting and stem cankers; and mealybugs and scales can cause leaf distortion and dieback. Many produce honeydew (aphids, leaf and planthoppers, mealybugs, soft scales, whiteflies), which promotes sooty moulds which reduce photosynthesis, stunt growth and cause early leaf fall. Ants tend these insects for their honeydew and protect them from natural enemies. Aphids, psyllids, leaf and planthoppers, mealybugs and whiteflies spread pathogenic bacteria and viruses.

Fig. 2.53 Distorted young leaves of basil caused by aphids (*Aphis* sp.) feeding on the underside. Mealybugs can produce similar symptoms on other plants (Fig. 2.54).

Fig. 2.54 Distorted young leaves of tomato caused by mealybugs (species unknown) on plants grown under protected cropping. The white fluffy waxy growth often covers eggs and young stages and is typical of mealybug infestations.

Fig. 2.55 Spotting on fruits by the feeding of the fruit spotting bug (*Amblypelta* sp). A related species causes premature nut fall of coconuts, and dieback of cassava (Figs. 2.56 & 2.57).

Fig. 2.56 Cankers on stem of cassava from 'true' bug (*Amblypelta* sp.) feeding. The scars on the stem have been invaded by a (secondary) fungus - notice the fruiting bodies - which assist in the development of the cankers.

Fig 2.57 Feeding by *Amplypelta* results in leaf wilt, dieback, and cankers on the stem.

Fig. 2.58 Wilt of rice due to planthopper attack (*Nilaparvata* sp.). Large numbers cause 'hopper-burn' as the plants become dehydrated, wilt and collapse. This is a common symptom in rice when pesticides are used and natural enemies are destroyed, and the planthoppers increase in number as a result.

Fig. 2.59 Psyllid galls on Malay apple, common in Pacific island countries, caused by the Malay apple gall psyllid (*Trioza* sp.). Eggs are laid on the underside of the leaf and the nymphs enter the leaf, stimulating the leaf to develop galls on the upper surface.

Fig. 2.60 Sooty mould, an indirect result from soft scale infestations *(Ceroplastes* sp.). The scale produces 'honeydew', a waste liquid from feeding on plant sap which falls onto the foliage and is colonised by fungi, resulting in characteristic black growth.

Fig. 2.61 Ants (*Technomyrmex* sp.) tend scale insects for their honeydew, and in the process protect them from their natural enemies, allowing large infestations to occur. This has happened in Fiji with the introduction of the white-footed ant.

Fig. 2.62 Lesser snow scale (*Pinnaspis* sp.), an armoured scale on oil palm fruit. The female scale can be seen as pale brown round objects on the fruits in the centre; the white areas are the cocoons of the male scale.

Fig. 2.63 Spirals and adults of the spiralling whitefly (*Aleurodicus* sp.). Eggs are laid in the waxy spirals.

Mites (Figs. 2.64-2.66)

There are two types of mites that are common pests in Pacific island countries. One is represented by the two-spotted mite, that causes white/greyish speckling on the top of leaves and webbing on the underside. The other is represented by the much smaller broad mite that lives inside buds and causes yellow patches and distortions on leaves and fruits. It is common on capsicum and tomato. A hand lens or microscope is useful to see mites.

Fig. 2.64 Speckling symptom on taro caused by the feeding of two-spotted mites (*Tetranychus* sp.), most often on the under surface of leaves. The silvering is said to be caused by air entering cells punctured by the mites as they feed.

Fig. 2.65 Distortions on capsicum, commonly caused by broad mite (*Polyphagotarsonemus* sp). Symptoms can be mistaken for distortions caused by virus infection.

Fig. 2.66 Galls formed by the sweet potato gall mite. This is caused by an eriothyid mite (*Eriophyes* species).

2.5.3 Piercing pests

Flies (Figs. 2.67 & 2.68)

Some insects pierce fruits when laying eggs. In Pacific island countries, fruit flies are a common example of this. At the same time as they insert eggs, they inject bacteria that cause rots and provide food for the maggots. Weevils also lay eggs in fruit.

Fig. 2.67 Eggs laid by the mango seed weevil *(Sternochetus* sp.*)* cause sap to be released which dribbles down the fruit before hardening.

Fig. 2.68 'Strikes' on tomatoes where fruit has been pierced by fruit flies (*Bactrocera* sp.) in the process of laying eggs.

2.5.4 Similar symptoms, different groups

It is not surprising that different groups of pests may cause similar symptoms, as they have only two methods of feeding on plants (chewing and sucking) and one method of laying eggs (piercing). For instance, among the chewing insects it can be hard to tell whether the damage was done by an adult chewing beetle, an adult (or nymph) katydid or a leaf-cutting bee (Table 2.3). All have mandibles, which are hardened and tooth-like for cutting and crushing.

When it comes to sucking insects and mites, again buds, leaves and stems are damaged, but the symptoms differ from those caused by chewing insects. Again, this should not surprise us as the method of feeding is quite different - sucking insects tap into vascular systems for liquid food. This kind of feeding causes distortions, galls, stippling/silvering, wilting, and dieback.

In only two cases do we see different groups causing similar damage. Galls are produced by some aphids, psyllids, thrips and broad mites, and speckling/silvering can be caused by thrips, true bugs, and both kinds of mites (Table 2.3). Of interest though, is that within the large grouping, order Hemiptera, similar symptoms are produced by insects that appear quite different, but this is understandable, considering their common underlying biology.

From a plant health doctor standpoint, all this information can be quite confusing, but it is provided here as a warning to doctors not to assume that a particular symptom can always be interpreted as the result of the feeding of a particular kind of insect or mite. A smart plant health doctor, when given a sample with symptoms but without any likely cause, will always have questions to ask! Table 2.3 summarises the similar symptoms caused by different orders of pest.

Table 2.3 Similar symptoms but different orders: examples from the Pacific Pests, Pathogens & Weed app.

Plant part attacked/ Symptoms	Order (common name)	Stage causing damage	Insect or mite (examples)	Crop (example)	Fact sheet #
TYPE OF DAMAGE: CHEWING					
Leaf, make holes, or stripping					
	Coleoptera (beetle)	Adult	*Candezea*	Sweet potato	53
	Lepidoptera (moth)	Larva	*Plutella*	Cabbage	20
	Orthoptera (katydid)	Adult, nymph	*Sexava*	Oil palm	246
	Hymenoptera (bee)	Adult	*Megachile*	Ornamentals	N/A
Leaf, mining (serpentine or blotch)					
	Coleoptera (beetle)	Larva	*Promecotheca*	Coconut	60
	Diptera (fly)	Larva	*Liriomyza*	Tomato	110
	Lepidoptera (moth)	Larva	*Phodoryctis*	Cowpea	378
	Hymenoptera (sawfly)	Larva	*Phylacteophaga*	Eucalyptus	N/A
Leaf, scraping top layer					
	Coleoptera (beetle)	Adult, larva	*Epilachna*	Eggplant	58
	Lepidoptera (moth)	Larva	*Spodoptera*	Taro	31
	Orthoptera (grasshopper)	Adult, nymph	*Aiolopus*	N/A	N/A
Stem/trunk, boring					
	Coleoptera (weevil)	Larva	*Pantorhytes*	Cocoa	61
	Coleoptera (beetle)	Adult	*Oryctes*	Coconut	108
	Diptera (fly)	Lava	*Ophiomyia*	Cowpea	291
	Isoptera (termite)	Adult	*Neotermes*	Coconut	116
	Lepidoptera (moth)	Larva	*Earias*	*Bele*	23
Fruit, boring					
	Coleoptera (weevil)	Larva	*Cryptorhynchus*	Mango	437
	Lepidoptera (moth)	Larva	*Deanolis*	Mango	281
Seed, boring					
	Coleoptera (weevil)	Adult, larva	*Sitophilus*	Rice	338
	Lepidoptera (moth)	Larva	*Sitotroga*	Rice	337
Tuber/corm/storage root, boring					
	Coleoptera (weevil)	Larva	*Cylas*	Sweet potato	29
	Coleoptera (beetle)	Adult	*Papuana*	Taro	30
	Lepidoptera (moth)	Larva	*Phthorimaea*	Potato	298
TYPE OF DAMAGE: SUCKING					
Leaf, sooty mould					
	Hemiptera (aphid)	Adult, nymph	*Rhopalosiphum*	Maize	330
	Hemiptera (leafhopper)	Adult, nymph	*Idioscopus*	Mango	263
	Hemiptera (scale)	Adult, nymph	*Ceroplastes*	Gardenia	271
	Hemiptera (psyllid)	Adult, nymph	*Diaphorina*	Citrus	185
	Hemiptera (whitefly)	Adult, nymph	*Aleurocanthus*	Citrus	244
Leaf, distortions					
	Hemiptera (aphid)	Adult, nymph	*Aphis*	Basil	38
	Hemiptera (scale)	Adult, nymph	*Aspidiotus*	Coconut	104
	Hemiptera (mealybug)	Adult, nymph	*Phenacoccus*	Tomato	373
Leaf, galls					
	Hemiptera (aphid)	Adults, nymph	*Eriosoma*	Apple	N/A
	Hemiptera (psyllid)	Nymph	*Trioza*	Malay apple	366

	Trombidiformes (broad mite)	Adult, nymph	*Eriophyes*	Sweet potato	138
	Thysanoptera (thrips)	Adult, nymph	*Gynaikothrips*	Acacia	N/A
Leaf/fruit, speckling					
	Thysanoptera (thrips)	Adult, nymph	*Thrips*	Capsicum	49
	Hemiptera (true bug)	Adult, nymph	*Corythucha*	Eggplant	253
	Trombidiformes (Eriophyid)	Adult, nymph	*Phyllocoptrata*	Citrus	344
	Trombidiformes (2-spotted)	Adult, nymph	*Tetranychus*	Taro	24
Leaf, wilt, dieback					
	Hemiptera (true bug)	Adult, nymph	*Amblypelta*	Cassava	19
	Hemiptera (scale)	Adult, nymph	*Icerya*	Citrus	343
	Hemiptera (planthopper)	Adult, nymph	*Tarophagus*	Taro	41
	Hemiptera (mealybug)	Adults, nymph	*Phenacoccus*	Cassava	329
TYPE OF DAMAGE: PIERCING					
Fruit, egg laying (strike)					
	Coleoptera (weevil)	Larva	*Cryptorhynchus*	Mango	437
	Diptera (fly)	Larva	*Bactrocera*	Tomato	425

N/A - there are no examples in the Pacific Pests, Pathogens & Weeds app.

EXERCISE 3: Similar symptoms, different groups

Table 2.3 shows that pest symptoms can be confusing as similar symptoms can be caused by very different types of pests. Exercises 3 and 4 will help your trainees to think about symptoms of pest damage and the range of possible causes. This is a challenging exercise, but the purpose is for your trainees to recognise that similar symptoms can have may causes. It is not necessary for them to learn the names of every pest.

By thinking about and discussing the possible answers in their groups and then with the whole class, your trainees will have a deeper understanding of the complexity of pest diagnosis, so they do not immediately jump to one answer when they see symptoms.

In pairs or threes, ask your trainees to draw and complete the table below by filling in the blank cells. They will need access to the Pacific Pests, Pathogens & Weeds app facts sheets. Then ask them to compare their answers with another group and make changes if they need to. Also, they should check their answers with Table 2.3.

Discuss their answers with the whole class, especially paying attention to symptoms that are confusing.

An example is given in the first row.

Symptom	Damage type	Possible causes (pest orders – common names)	Life stage of pest	Confirmed by fact sheet #
Stem/bark boring	*Chewing*	*1. Fly* *2. Moth/butterfly*	*Larva (maggot)* *Larva (caterpillar)*	*291 & 23*
Leaf speckling				
Leaf mining				
Sooty mould				
Leaf galls				
Seed boring				
Wilt				
Leaf sooty mould				
Leaf distortions				
Leaf scraping				
Fruit strike				

*chewing, sucking or piercing

EXERCISE 4: Understanding chewing, sucking and piercing damage

For this exercise, try to find samples of leaves, fruit or roots that show symptoms of chewing, sucking or piercing, but with no visible pests. Give each pair or group of trainees a different sample of pest damage (or a photograph if you cannot find field samples). Your trainees should examine their sample carefully with a hand lens and answer the following questions. Then they should share their answers with the whole class and discuss the diagnosis process.

Plant part (leaf, fruit, root):

1. Describe the symptoms.

2. Are the symptoms typical of i) chewing, ii) sucking or iii) piecing? Explain your answer.

3. List all possible causes of these symptoms, including the life cycle stage of the pest.

4. What further information would you need to find out the actual cause?

2.6 What is a disease?

Plant diseases are caused by fungi, bacteria, nematodes, viruses, viroids and phytoplasmas. Together they are known as **pathogens.** The causes of many diseases are difficult to identify, as the pathogens are mostly hidden inside the leaves, stems, seeds, roots or soil.

Sometimes, damage caused by pests and diseases looks similar, e.g. virus and mite damage, but this is rare.

More commonly, viruses are spread by insects, sucking ones in particular, so if you suspect a virus, look for an insect too!

Fungi

Fungi (singular, fungus), vary in size from single cells to masses of thin, branched, cottony growth (called hyphae). A single strand is called a hypha (plural, hyphae), and a mass of hyphae a mycelium. Fungi feed on dead organic material or on living organisms by releasing enzymes which break down the food they are growing on into chemicals that they can absorb. Unlike plants, they are without chlorophyll so do not carry out photosynthesis, and their cell walls are of chitin (the exoskeleton of arthropods – insects, spiders and crustaceans) not cellulose, which is used by plants. They reproduce by spores, either asexually (without mating) or sexually. Spread occurs in wind and rain, on and in seeds and in other propagation materials, often associated with the domestic and international trade in plants.

Oomycetes

Oomycetes (singular, oomycete**)** were once thought to be fungi; now they are classified with algae. They are known as 'water moulds' as they like high humidity and wet soils. Differences from fungi include the fact that their cell walls are made of cellulose not chitin; the branching cottony growth (filaments) do not have cross walls; and they produce asexual spores (sporangia), each of which releases tiny spores (zoospores) with two whip-like hairs (flagella). Like fungi, sexual spores are produced, and methods of spread and survival are also similar. Many are important pathogens, including the following groups: i) *Phytophthora* species; ii) *Pythium* species; iii) downy mildews; and iv) white blister rusts. There are examples of these in the Pacific Pests, Pathogens & Weeds app.

Bacteria

Bacteria (singular, bacterium), are microscopic, single-celled organisms, found in all environments on Earth. They range in shape from spheres to rods to spirals, have a rigid cell wall, a single, circular chromosome of DNA, and some have flagella, whose whip-like actions provide movement. Nutrition is by photosynthesis or by breaking down chemical compounds using enzymes. Reproduction is by binary fission: the cell DNA duplicates, the cell content increases and the cell splits in two. Bacterial root infections can sometimes be identified by putting a cut root into water. Milky streams of bacteria may be seen streaming from the root.

Viruses

Viruses (singular, virus) are single-celled microscopic parasites of many different shapes and sizes, with a core of DNA or RNA surrounded by a protein coat or shell (called a "capsid"). They are mostly much smaller than bacteria. They need cells of other organisms for reproduction, and that is why many scientists say they are not living. They have been on the earth for billions of years, and are found in all other organisms, including bacteria and fungi. Viruses are important in transferring genes between species, so-called 'horizontal genetic transfer', which is important in the evolution of species.

Viroids

Viroids (singular, viroid) are the smallest pathogens known, and are simpler than viruses. They consist of a piece of circular RNA without a protein coat or shell. They can only reproduce within a host cell and are only found in plants, where they may cause diseases. Like viruses, viroids are thought to be non-living by many scientists.

Phytoplasmas

Phytoplasmas (singular, phytoplasma). The previous name was mycoplasma-like organism. They are similar to bacteria but do not have a cell wall, and because of that their shapes vary. They occur in the phloem of plants and are spread by sap-sucking insects, mostly leafhoppers. A little-leaf or witches' broom symptom is common, with small yellow leaves on bushy shoots. Flowers may become leaf-like. They are usually detected by electron microscopy or by molecular methods.

Nematodes

Nematodes (singular, nematode) are tiny worms that live in the soil. Males mate with females which produce eggs and the young, called 'juveniles', moult several times before becoming adult. Most are free-living, feeding on bacteria, fungi and protozoans (single-cell organisms).

Some are plant parasites and have a spear in their mouth used to enter and move through plants. Commonly, they damage root tips, causing excessive root branching or galls.

Here are five important facts about pathogens, that will help you to understand them.

1. Most pathogens are small

Of all the pathogens, only fungi can be seen with the naked eye, and then only those that produce masses of cottony growth, or the large fruiting bodies we call mushrooms, toadstools or brackets. However, when the length of all the cottony growth of some soil fungi is measured, they may not be so small - some are thought to be the largest organisms in the world as their growth extends over many hectares.

The spores of fungi are also small, and a microscope is needed to see them.

A microscope is also needed to see nematodes, and especially the plant pathogens. Fig. 2.69 shows the relative size of various pathogens compared with humans.

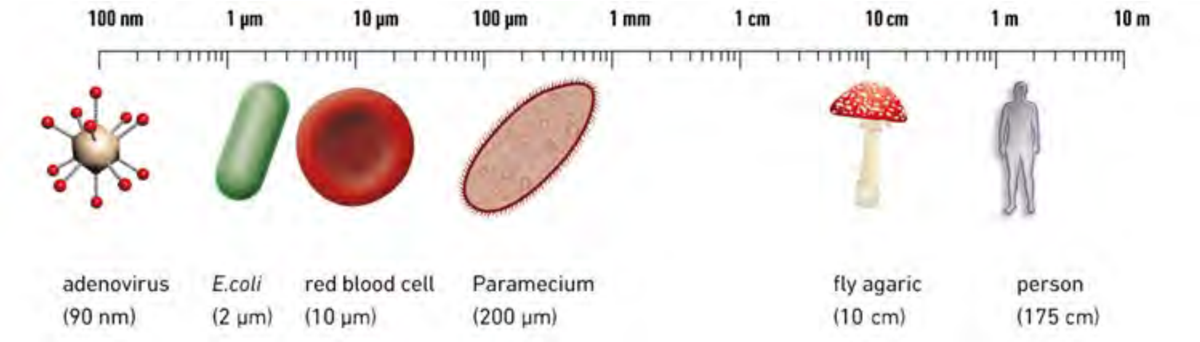


Fig. 2.69 The relative size of various pathogens compared with humans (1 µm is a millionth of a metre).

2. Pathogens reproduce very quickly

Fungi make spores of many shapes and sizes in open or closed structures (Figs. 2.70-2.71). Bacteria make copies of their DNA and then split into two. If conditions were right, it is estimated that starting with one bacterium that divides after 30 minutes, and the progeny maintain this rate of division over every generation, it would take only 48 hours to cover the world! Viruses enter plant cells and direct the cell to make their components, which are assembled into new viruses and released (Figs. 2.72-2.73).

Fig. 2.70 Fungal spores are produced in sacs through which they emerge during times of rain.

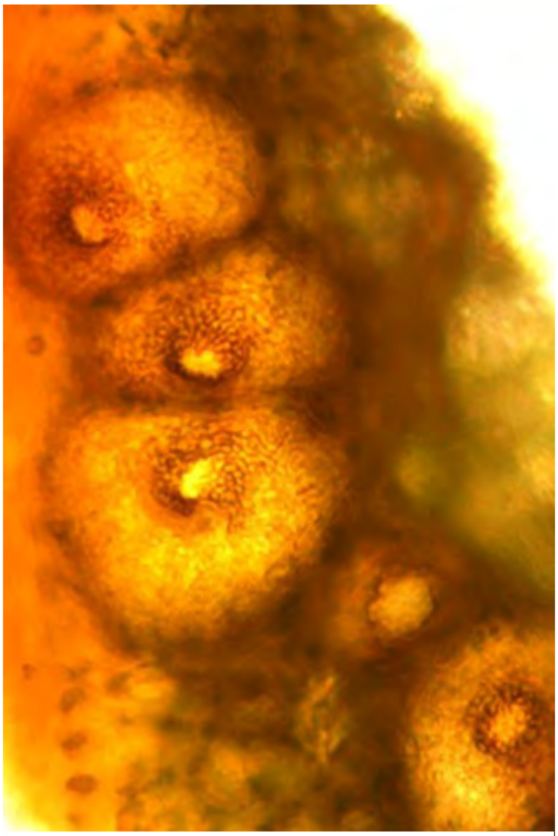


Fig. 2.71 A close-up of the sacs is shown from a similar fungus to that in Fig. 2.70.

Fig. 2.72 Fungal spores are produced on the underside of the tomato leaflets.

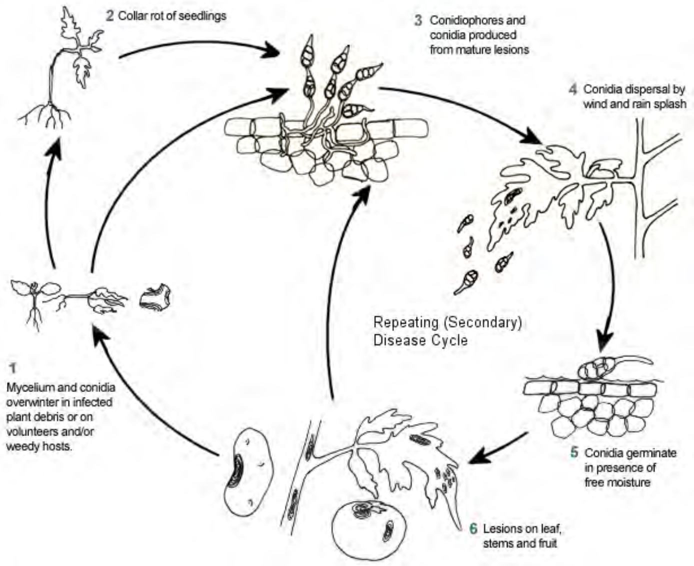


Fig. 2.73 This diagram shows how fungus emerges through the plant leaf to produce spores. In contrast to Figs. 2.70 and 2.71, the spores are not enclosed in sacs.

Plant parasitic nematodes have a spear in the mouth to damage cells of roots (Fig. 2.74) and to feed on them. In some cases, they produce chemicals that stimulate plants to make galls.

Nematodes reproduce rapidly, too. Most lay eggs that pass through immature stages (the juveniles) before becoming adult. Life cycles can be as rapid as 3-7 days, depending on the soil conditions. They have a hollow needle-like spear (called a stylet) in the mouth and this is used to puncture cells to extract food (Fig. 2.74). Some nematodes produce chemicals that stimulate plants to make galls (e.g., root knot nematodes).

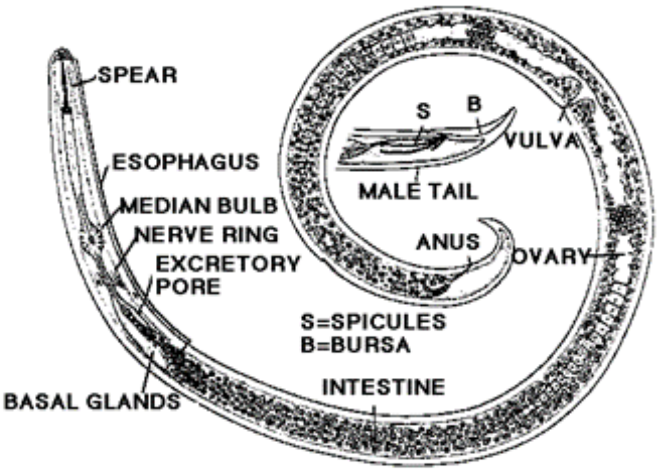


Fig. 2.74 Diagram to show the spear in the mouth of a nematode. Note that these minute organisms, mostly smaller than the naked eye can see, have a complex structure, with intestine, male and female reproductive and nervous systems.

3. Fungi and bacteria need water for infection

Fungal spores need water for germination and infection, either above or below ground. Germination produces a germ tube that penetrates either directly or through natural openings (mostly stomata), taking a few hours to do so (Figs 2.72 and 2.73). Powdery mildews are an exception: they do not need free water, but they do need high humidity. Most powdery mildews grow over the surfaces of plants, putting down short tubes to draw out nutrients. Bacteria enter through natural openings, assisted by wind-driven rain. In the soil, wounds made by nematodes or fungi assist them. Occasionally, bacteria are injected into plants by insects as they feed, in the same way that plants are infected by viruses.

4. Pathogens have many ways of spreading

A majority of fungi, oomycetes and bacteria are spread above ground in rain-driven wind (Fig. 2.75). For the most part their spores or cells are delicate and cannot withstand dehydration. There are instances where wind is the main agent of spread. There is also involvement of insects in the spread of these groups above ground, but this is less common.

Below ground, too, water plays a role, with movement of fungal and oomycete spores and bacterial cells in ground water, which also spreads nematodes. In some oomycetes, there are mobile spores (Fig. 2.76).

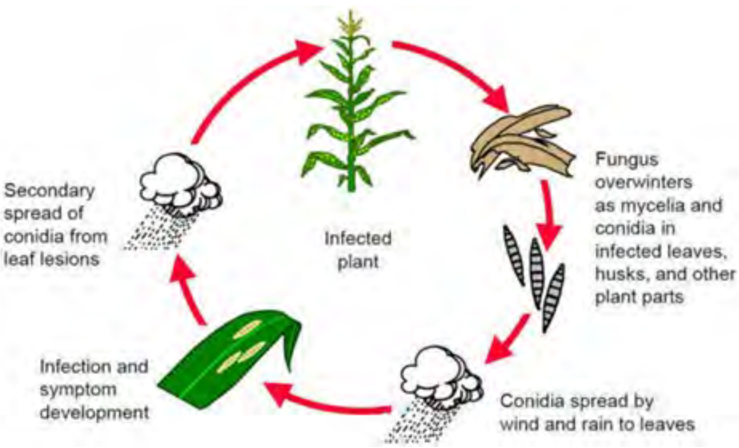


Fig. 2.75 In this fungal disease of maize, spores called 'conidia' are spread by wind and rain. In the soil, the situation is different: some pathogens, for instance, fungi, oomycetes, bacteria and nematodes, move (or are moved in water).

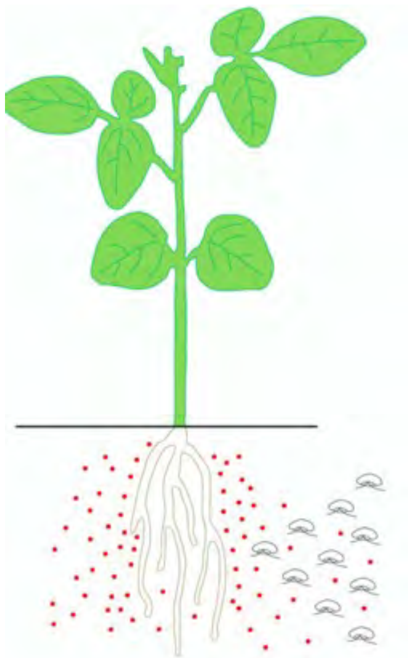


Fig. 2.76 Pathogens that have the ability to self-propel in the soil water are attracted by chemicals from the roots of plants.

Although insects play a minor role overall in the spread of fungi, bacteria and nematodes, this is not the case for viruses. Here, they are the main agent of spread. To be successful, a virus needs assistance to break through the cellulose wall of plant cells, and do it in such a way that the cells remain alive, in order to manufacture more virus. In the act of feeding by piercing and sucking, or less often by chewing, on succulent leaves and stems, insects place viruses where they need to be (Fig. 2.77).

Insects are not the only organisms that transfer viruses in this way: fungi also do it and so do nematodes, but the number of examples is very small.

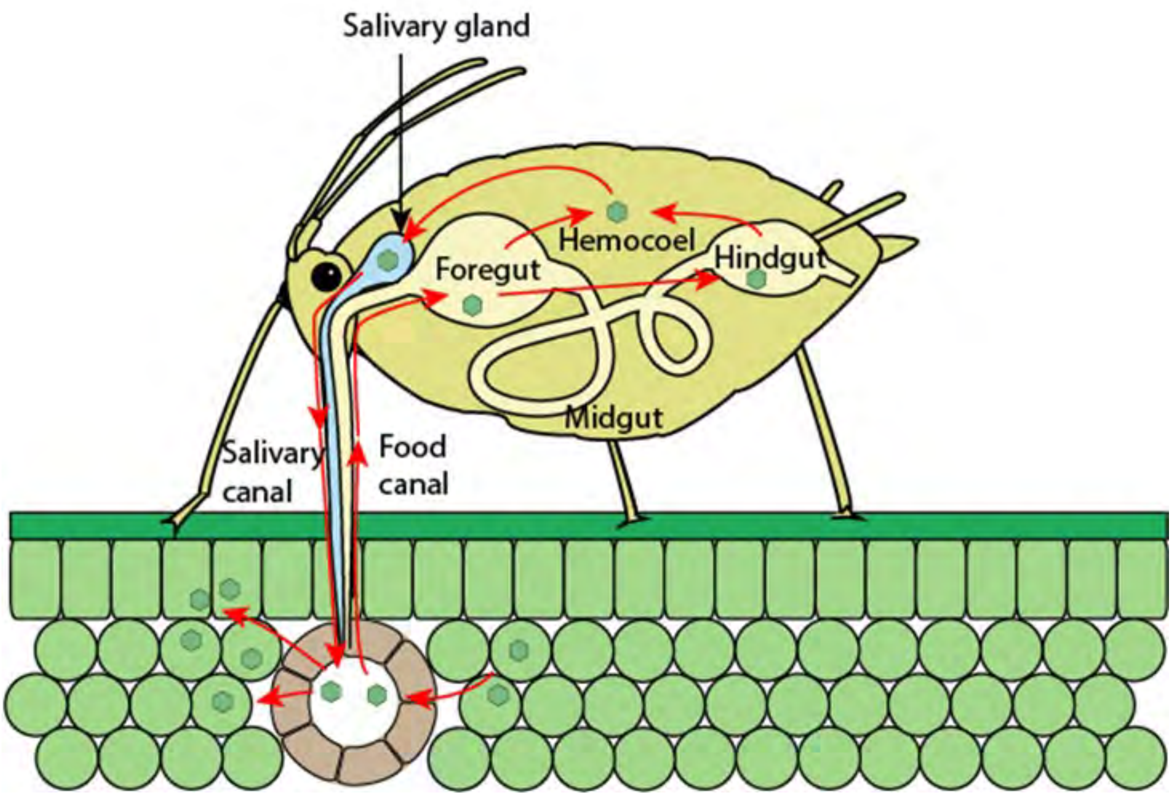


Fig. 2.77 Aphids and many other sap-sucking insects infect plants with viruses as they feed. The viruses may be i) attached to the stylets and quickly transferred or ii) passed out through the stylets after a lengthy period of multiplication within the insect and during a feed on a new host.

It is unfortunate to note that in addition to the many natural methods of pathogen spread, human beings are also involved, and this association is now occurring at rates not seen previously. Much of it is associated with the international trade of plants and plant parts, whether as ornamentals or for propagation as seeds or cuttings. Local spread occurs too. Farmers often unwittingly spread pathogens in or on planting materials - the cuttings of *bele* or cassava, the corms of taro and banana, vines of sweet potato, or sets of yam. Careless use of agricultural machinery harbouring pathogen-contaminated soil is yet another way that human beings assist pathogens to spread.

5. Pathogens have many ways of surviving

To survive and pass their genes to the next generation is clearly an aim of all pathogens. Many methods are used by the groups described in this manual to ensure that it occurs. Your trainees should become acquainted with the methods associated with some of the main diseases in the region where PHCs are held. It is important to discuss survival of plant diseases with farmers because IPDM relies heavily on disrupting pest life cycles to achieve success. For instance, healthy planting material is a must, as is the destruction of harvest remains if they are likely to harbour pathogens for future crops.

Some methods of survival are listed below:

- In or on seeds (fungi, bacteria and viruses)
- In plant trash on or in soil (fungi and bacteria)
- On weeds – all
- On 'volunteer' (self-sown or those remaining from the previous harvest) plants – all
- On over-lapping crops – all
- As dormant spores or eggs in soil **–** fungi and nematodes
- Inside insects – viruses, some bacteria

2.7 Symptoms of pathogens – what can they tell us?

Fungi, oomycetes (fungus-like, *Phytophthora*, *Pythium* and relatives), bacteria, phytoplasmas, viruses, viroids and nematodes which collectively we call pathogens, commonly cause **symptoms** when they infect plants**.** These symptoms are important in helping us to diagnose plant diseases, so here we look at the type of symptoms that they produce.

Spots and shot-holes

Leaf spots are common and mostly caused by fungi. The spots grow to a particular size and then stop (Fig. 2.78). Spores develop on the underside of the leaves as furry patches, or inside black sacs embedded in the top surface. In both types, the spores are spread by wind and rain.

When the centre of the spots fall out,which is typical of some diseases, we call it a shot-hole (Fig. 2.78 top right). It is hard to tell fungal spots from those caused by bacteria (Fig. 2.78 bottom left) without studying them in the laboratory. Viruses occasionally develop ringspots (Fig. 2.78 bottom right) but, as with bacterial spots, they are rare.

Fig. 2.78 Examples of spots and shot-holes. (Top left) spots (fungus) on coconut. (Top right) spots (fungus) on taro. (Bottom left) Tomato with a bacterial infection. (Bottom right) spots (virus) on sweet potato.

Blights

Some spots do not stop growing and the symptoms develop into a blight. Blights are typically wet-weather diseases, such as taro leaf blight (Fig. 2.79 left), watermelon gummy stem blight (Fig. 2.79 right) and yam dieback. Spots develop, expand and form masses of spores, which spread rapidly, infecting and defoliating leaves and killing stems.

Fig. 2.79 Examples of blights. Taro leaf blight (left) and gummy stem blight on watermelon (right). These blights can totally destroy their respective crops in a few days of wet weather.

Mildews

There are two kinds of mildew - powdery and downy. Powdery, as the name suggests, causes white growths over leaves, common on cucurbits and okra in Fiji (Fig. 2.80 left), and rose in Tonga, during dry weather. The fungus forms long chains of oval spores that stand erect from the leaf, giving it a powdery appearance. These mildews are unusual fungi as they grow on the outside of leaves and feed from organs that penetrate the leaf surface to feed on cells inside. Their spores do not germinate well in water, they just need high humidity.

Downy mildew is different. It is not a fungus, but an oomycete or water mould, related to algae. It needs water for the spores to germinate. Downy mildew of cucumber (Fig. 2.80 right) and squash (especially in Tonga) is the common example in the Pacific region. Typically, the mildew forms squarish or rectangular areas on the top of the leaf that are yellow at first and then turn brown. Patches of greyish/brown occur below where the spores develop. *Phytophthora* and *Pythium* (common on taro causing blight and wilt, respectively), are also oomycetes.

Fig. 2.80 (Left) powdery mildew on okra. (Right) downy mildew on the underside of cucumber leaf where spores are produced; the upper surface (inset bottom right) has the same 'squarish' infections confined by the veins, but are yellow.

Wilts

Wilts can be caused by fungi, oomycetes, bacteria and nematodes. It is difficult to tell which is the cause from symptoms alone, unless you are familiar with the disease on a certain crop. Experience will help you to know what diseases are common on different crops (Fig. 2.81).

Fig. 2.81 (left) The disease is caused by a fungus, *Phellinus*, common on cocoa, causing a wilt. In Fiji the fungus grows through the soil, infects the roots and kills them. Leaves wilt and the crust-like fungus grows up the cocoa trunk (right).

For instance, a wilting cocoa plant would suggest *Phellinus*, a soil-borne fungus (Fig. 2.81); a wilting taro, *Pythium*, an oomycete that destroys the fine roots (Fig. 2.82 left); and a wilting tomato would suggest a fungus (e.g. *Athelia*) or a bacterium (e.g. *Ralstonia*, bacterial wilt). Examination of the wilted plants would be needed to decide the cause.

Symptoms of wilt can be confusing to farmers. Usually, the roots are diseased and the leaves droop down or collapse, as they lack water. Farmers and plant health doctors might mistake the symptoms on the leaves for the cause of the problem, so suggest that if they see wilted plants they inspect the roots. Dig up the plant carefully, wash the roots and look for death and decay of the fine, side roots; these are the ones that take in water and nutrients from the soil. Without them, leaves collapse.

Remember, insects can damage roots, too. For instance, *Papuana* beetles cause a wilt when they attack the young roots and corms of taro (Fig. 2.82 right).


Fig. 2.82 Two kinds of wilt in taro with different causes but similar appearance: i) (left) *Pythium*, an oomycete, attacks the fine roots of taro, and many other crops, and also causes the leaves to wilt; and ii) (right) *Papuana* beetle attacks the corm of the planting piece and burrows into the growing point causing leaves to wilt. Both plants look similar above ground.

Damping-off

Damping-off is a special case of wilt that affects seeds and seedlings. There are two kinds of damping-off: **pre-emergence**, when seeds or seedlings are killed before they reach the soil surface; and **post-emergence**, when they die soon afterwards (Fig. 2.83). Often, fungi and oomycetes are involved. When the disease occurs in a nursery, it is likely that the soil has not been pasteurised.

Fig. 2.83 Damping-off showing both pre- and post-emergence symptoms where the seedling are killed either before or after they have penetrated the soil surface. Fungi are usually the cause and are common in nurseries if the soil has not been pasteurised.

Canker

A canker is an area on a branch or trunk that is dead in the centre and alive at the edges, where it expands slowly. There may be gum at the edges. Fungi, oomycetes or bacteria are the likely cause. Cankers on cocoa are often seen as a result of the oomycete *(Phytophthora)* that causes black pod disease growing back into the branch or trunk (Fig. 2.84).

Fig. 2.84 Canker on cocoa*. Phytophthora* has grown from the pod into the branch.

Smuts

Smuts infect cereal crops and grasses. They are not common in the Pacific region. In Pacific islands countries, boil smut might be seen (Fig 2.85) but only in Solomon Islands and Papua New Guinea. Spores of the fungus are in the soil; they germinate, infect and grow inside the plant, reaching the cob, where the seeds are transformed into a mass of black spores. Small galls occur on the leaves.

Fig. 2.85 Smut on maize. The seeds in the cob have been transformed into masses of black spores.

Rusts

When leaves with rust are stroked with a finger, a brownish/orange colour is left behind, hence the name, rust. The powder is a mass of spores formed by the rust fungus in numerous leaf pustules. Rusts have complex life cycles; there are several stages and, for some, the life cycle involves two unrelated hosts. Spores are able to travel high in the atmosphere and spread over large distances. Breadfruit, yams, peanuts (Fig. 2.86 left), maize (Fig. 2.86 right) and many other plants have rust diseases in Pacific island countries.

Fig. 2.86 Rusts: (left) pustules on the underside of peanut leaflets; (right) pustules on the top of a maize leaf.

Yellows and distortions

The word 'mosaic' is often applied to virus diseases that cause yellowing or distortions of the leaves. It describes the patches of yellow or light green mixed with the normal green colour on infected leaves. Mosaic symptoms occur commonly on yam, *bele* (slippery cabbage), sweet potato (Fig. 2.87 left), chilli, taro and beans (Fig. 2.87 right). On monocotyledonous plants, mosaics occur parallel to the main veins, and therefore as stripes. It is commonly seen in maize infected with maize mosaic virus where bands of green and yellow occur from the base to the tip of the leaf.

Fig. 2.87 Mosaics: (left) Faint patterns of yellow amongst the green of sweet potato leaves; (right) yellow and green patterns with distortions on leaves of long bean.

Sometimes, colour changes are just seen along the sides of major veins, as in virus diseases of taro, or in stripes parallel to the veins, as in maize and banana.

Often, viruses also cause distortions. Taro infected with *Alomae* or *Bobone* is a good example (Fig. 2.88 left). In this case, infections can be caused by several viruses, and symptoms depend on the number and type present. Less severe are the crinkles and bumps that occur on leaves or fruits, such as those seen on zucchini.

Distortions are also produced by phytoplasma infections. Phytoplasmas are spread by insects (often leafhoppers) and cannot be grown in the laboratory on artificial media. Different kinds occur on coconuts throughout the world, and In recent years, coconuts near Madang, PNG, have also been found infected with phytoplasmas. It seems that the same phytoplasma also infects banana, causing leaves to yellow. Yellowing of leaves is just one symptom caused by phytoplasmas; more common is little leaf, for example on sweet potato (Fig. 2.88 right) and legumes.

Fig. 2.88 Distortions and little leaves: (left) young leaves of taro with *Alomae*; a lethal virus disease; (right) little leaf symptom on sweet potato caused by a phytoplasma.

Post-harvest/storage diseases

Just as diseases infect plants in the field, they also occur after harvest. They are especially common in corms, storage roots, tubers and many kinds of fruit and vegetables. Few harvested crops stay uninfected for more than a few days after harvest. Wounds caused at harvest make the produce susceptible to infection by fungi, bacteria and also nematodes. Many species are involved. In some cases, rots in the field continue in storage, for example, *Pratylenchus* (nematode) on yam, and *Pythium* (oomycete) on taro (Fig. 2.89). Other rots, such as those on citrus (*Penicillium*), mango (*Colletotrichum*) start after harvest. Some insects, especially beetles and weevils, also cause post-harvest rots.

Fig. 2.89 Post-harvest rots: dry caused by nematodes (left) and taro with two rots (right): *Pythium* is the cause of the whitish rot at the base, and *Athelia* the white cottony growth on the left side.

A WARNING

Some symptoms can be misleading

Example 1: Sooty mould is not a disease but is caused by fungi growing on honeydew from aphids, mealybugs and scale insects

Example 2: Cassava roots blacken after harvest due to physiological (chemical) processes

Example 3: Taro corms shrivel after harvest through water loss

EXERCISE 5: Using symptoms to make a diagnosis

Now that your trainees have more information about pests and pathogens, they should collect their samples from Exercise 2 tables A, B and C and have another look at them using a hand lens. Trainees should carefully and clearly describe all the symptoms (signs) on the plant and try to make a diagnosis.

Trainees should copy and complete the table below and fill in the last column after discussion.

Table 2.4 Using symptoms to make a diagnosis.

Crop	Plant part affected (leaf, stem, fruit, root, other)	Symptoms/signs DESCRIBE VERY CAREFULLY AND CLEARLY	Diagnosis: possible causes with reasons	Actual cause (Fill in AFTER class discussion)
Example: Rose	*Leaf, stem, flower bud*	*Grey/white powder on the stalk and bud of the flower. It is not present on the older parts of the plant.* *Looks like dust*	*Mildew – a fungus that grows on the outside of leaves and stems (and buds)* *Dust from the road*	*Powdery mildew (Podosphaera pannosa). Spores can be seen with the hand lens*

EXERCISE 6: What have you learned about pests and diseases?

In pairs or threes, trainees should complete this table. Some cells have been filled in as an example. They should check their answers with another group, then discuss the answers as a class.

Table 2.5 What have you learned about pests and diseases?

	Fungi	Bacteria	Viruses	Nematodes	Insects
Size – can they be seen with the naked eye?		*No*			
How do they reproduce?	*Spores*				
How do they spread?					
How do they survive?			*In living cells*		
What are some typical symptoms/signs on plants?		*Wilts*			

2.8 Most common crops and diseases in your region

It is very important that before the clinic, plant health doctor trainees become familiar with crops commonly grown in the area where the plant health clinic is to be held, so that they can be prepared. Once these crops are identified, they should use the Pacific Pests, Pathogens & Weeds app for those that they are not familiar with. See also Section 3.3 in Chapter 3. Remind trainees always to be prepared for something new!

Some of pests and pathogens of common crops in Samoa are given in Table 2.6 and in Tonga in Table 2.7.

Table 2.6 Some common pests and pathogens of crops in Samoa with Fact sheet numbers

SAMOA	
Crop	**Fact Sheet (pest/pathogen or disease)**
Banana	• Black Sigatoka (002) • Bunchy top (121) • Burrowing nematode (257) • Leaf spot (309) • Scab moth (017) • Weevil (109)
Beans	• Lace bug (253)
Cabbage	• Diamondback moth (020) • Centre grub (114) • Cluster caterpillar (LCM) (078) • Club root (283) • Black rot (204)
Chinese cabbage	• Diamondback moth (see under cabbage) (20) • Centre grub (see under cabbage) (114) • Cluster caterpillar (LCM) (see under cabbage) (78) • Stalk rot (101)
Citrus	• Tristeza disease (250) • Fruit-piercing moth (113) • Scab (048)

Cocoa	• Black pod (006) • Pink disease (012)
Coconut	• Hispine beetle (059) • Rhinoceros beetle (108) • Embryo rot (070)
Mango	• Anthracnose (009) • Seed weevil (353)
Papaya	• *Phytophthora* fruit and root rot (152)
Passionfruit	• Woodiness (156) • Spots (153) • Southern blight (011)
Peanut	• Southern blight (011) • Rust (034) • Leaf spots (036)
Pineapple	• Wilt disease (380)
Solanaceae (tomato, capsicum, eggplant)	• Bacterial wilt (081) • Root-knot nematode (254) • Frog-eye spot (092) • Target spot (163) • Fruit-piercing moth (113) • Leaf mould (076) • Spider mites (024) • Broad mites (049) • Southern blight (011)
Taro	• Root rot (044) • Rhabdovirus diseases (089)

Table 2.7 Some common pests and pathogens of crops in Tonga with Fact sheet numbers.

TONGA	
Crop	**Pest/Pathogen**
Yam	• Rose beetle (107) • Anthracnose (016) • Scale (post-harvest) (093) • Dry rot (nematode) (008)
Cucurbits (cucumber, melon, watermelon, squash, zucchini, etc.)	• Cucumber moth (033) Watermelon gummy stem blight (007) • Downy mildew (143) • Powdery mildew (063) • Leaf miner (262) • *Corynespora* leaf spot (189) • Zucchini mosaic virus (202) • Papaya ringspot virus-W (392)
Cabbage	• Large cabbage moth (078) • Diamondback moth (020) • Damping-off (047) • Basal stem rot (101)
Cassava	• Spiralling whitefly (025) • White peach scale (052)
Banana	• Banana weevil (109) • Banana scab moth (017) • Black Sigatoka (002) • Banana bunchy top virus (121) • Banana burrowing nematode (257)
Coconut	• Coconut flat moth (065) • Coconut rhinoceros beetle (057) • Coconut stick insect (102)
Tobacco	• Frog-eye spot (304)
Sweet potato	• Weevils (029 & 119) • Sweet potato whitefly (284) • Little leaf (055) • Scab (013)

Solonaceae (tomato, capsicum, eggplant)	• Fruit flies (171) • Fruit-piercing moth (113) • Anthracnose (177) • *Corynespora* target spot (163) • Bacterial wilt (146) • Leaf moulds (045 & 076) • Spider mites (024)
Taro, giant taro, Xanthosoma	• Cluster caterpillar (031) • Taro hornworm (032) • Aphids (038) • *Pythium* wilt (044)
Kava	• CMV dieback (160) • Nematode (254)
Papaya	• Papaya crown rot (172) • Phytophthora fruit & root rot (152)
Bean	• Aphids (356) • Bean pod borer (037) • Green vegetable bug (098)
Maize	• Rust (042 & 225) • Maize mosaic virus (074)

EXERCISE 7: Complete this table for your own country.

In pairs or threes, your trainees should complete this table for the most common pests and diseases in their country. If the country is one of the examples listed in Tables 2.6 or 2.7, they should add some crops with their pests and diseases that may have been missed. They should share their answers to develop a good profile of their country's most common pests and diseases.

Country:	
Crop	**Three (or more) important pests/diseases**

EXERCISE 8: Completing a 'stem' table (optional exercise)

This exercise helps your trainees to summarise their learning so far about pests and diseases.

Trainees should do this on their own or in pairs. It is like completing a sentence (the 'stem' is the beginning of the sentence). Starting with the first column (Insect Pests), they fill in the answers. Then they fill in the second column (Nematodes) and so on, until the table is completed.

There will be many correct answers. A few cells have been filled in as examples.

	Insect Pests	Nematodes	Nitrogen Deficiency	Viruses	Fungi	Bacteria	Drought
Are:				*Very small*			
Are not:		*an insect*					
Can:							
Cannot:	*Produce spores*						
May cause:						*Wilting*	
Does not cause:					*Chewing of leaves*		
Can be controlled by:							
Cannot be controlled by:			*Fungicide*				*Fertiliser*

EXERCISE 9: What am I?

This exercise can be as easy or as difficult as you decide to make it. Make a list of the words that you would like your trainees to understand. The exercise can be carried out at any point during the training to strengthen your trainees' learning.

Write words associated with plant protection (see below) on cards, and stick one on the back of each trainee with masking tape. They are not allowed to look at it! Trainees then move around the room asking other trainees questions to find out what the word is. The other trainees can ONLY answer "yes", "no" or "sometimes/maybe". If, after a while, people are having difficulty, clues may be given.

Trainees should sit down after they have found the correct answer. Discuss how difficult or easy it was to find the right answer, and why.

Some examples of words you could use:

- Bacteria
- Rhinoceros beetle
- Phytoplasma
- Potassium deficiency
- Rust
- Aphid
- Spore
- Weed
- Snail
- Mite
- Sooty mould
- Fall army worm
- Leaf spot
- Wilt
- Drought
- Nematode
- Mosaic
- Abiotic
- Soil
- Variegation
- Virus

2.9 Making a diagnosis: symptoms, possibilities and probabilities

It is very important for plant health doctors to be able to work through a process of 'possibilities and probabilities' in diagnosis to be able to give good advice to the farmers. Some problems are easy to diagnose, especially pests that you can see; others are difficult. As well, some plant problems may have similar symptoms. For example, yellowing of leaves can be due to nutrient deficiency and can also be due to fungal or bacterial disease.

Do I need to know the names of everything?

No!

Specific diagnosis, like that of the name of the insect or fungus, is not always possible and it is not really necessary

Farmers do not need to know scientific names, but **they do need to know the pest or disease *type*** to give them an understanding of the information and management recommendations

E.g. Farmers do not need to know that the scientific name of the nematode in yams with dry rot is *Pratylenchus coffeae.* It is enough to know that it is a nematode and why hot water treatment is recommended (and how to apply it)

2.9.1 Using the possibilities and probabilities process to diagnose a problem

Now that your trainees have some knowledge of pests and diseases, they can look at symptoms to see if they are distinctive in any way in order to develop a diagnosis. The best approach to making a diagnosis is to think like a detective! What is likely or unlikely to be the cause; what is possible or what is probable?

Successful diagnosis can be difficult because there are so many insects, mites, pathogens and abiotic causes, and plants respond to them in different ways. However, diagnosis is essential for good management.

Use the examples and exercises below to build your trainees' confidence in their ability to make correct diagnoses. They should practise these steps as often as they can with a range of different pest and disease samples.

Work carefully through the following possible and probable causes process with your trainees, using eggplant as the example. Once you think they have understood the process, ask them to complete Exercises 10, 11 and 12.

EXAMPLE: Blotch symptoms on eggplant

Symptoms:
1. Dark blotches on the fruit.
2. The spots/blotches are roughly circular.
3. Minute black dots in the spots: possibly containing spores.
4. Spots dispersed over the fruit and merging together.

Possible causes	Possible? ✓✗	Probable? ✓✗	Why did you decide this?
BIOTIC			
Insects	✓	x	No insects found and no frass, but could be secondary infection after sucking insects.
Mites	✗	✗	No mites found and not typical of mite symptoms.
Fungi	✓	✓	Fungi cause spots/blotches on eggplant, and fungal fruiting bodies present.
Bacteria	✓	✗	Bacteria may cause spots/blotches on eggplant, so could be a new disease, but fungal fruiting bodies suggest not bacterial.
Virus	✗	✗	Not a typical symptom for virus.
Phytoplasma	✗	✗	Not a typical symptom for phytoplasma.
Nematode	✗	✗	Not a typical symptom and most nematodes are on roots.
Weeds	✗	NA	NA for these symptoms
Parasitic plants	✗	NA	NA for these symptoms
Slugs & Snails	✗	✗	Absence of chewing and slime trails.
Mammals	✗	✗	Absence of scratching or chew marks.
Birds	✗	✗	Would expect to see pecking damage.
ABIOTIC			
Nutrient deficiencies	✗	NA	NA for these symptoms
Sun scald	✗	NA	NA for these symptoms
Water (too much or too little)	✗	NA	NA for these symptoms
Lightning	✗	NA	NA for these symptoms
Herbicide	✗	NA	NA for these symptoms
It's natural	✗	NA	NA for these symptoms

NA = not applicable in this case
X = not possible for this symptom

NOTE: This is likely to be anthracnose caused by *Colletotrichum*. There is a fact sheet in the Pacific Pests, Pathogens & Weeds app (no. 50). Yes, a bacterial cause is a possibility, but the probability for a fungus is higher. *Colletotrichum* spots are common on eggplant fruits, but bacterial spots are unknown. Also, inside the large black areas there are tiny round black structures which are likely to contain fungal spores.

EXERCISE 10: Using the possible and probable approach

In pairs or threes, now work though this example, following the steps above. Then check your answer with the Pacific Pests, Pathogens & Weeds app. Discuss with the rest of the class.

EXAMPLE: large blotches on cassava leaves

Symptoms:

1.

2.

3.

4.

Possible causes	Possible? ✓✗	Probable? ✓✗	Why did you decide this?
BIOTIC			
Insects			
Mites			
Fungi			
Bacteria			
Virus			
Phytoplasma			
Nematode			
Weeds			
Parasitic plants			
Slugs & Snails			
Mammals			
Birds			
ABIOTIC			
Nutrient deficiencies			
Sun scald			
Water (too much or too little)			
Lightning			
Herbicide			
It's natural			

NOTES:

Now check your answer with the Pacific Pests, Pathogens & Weeds app.

- What is your diagnosis?

- Do you still need more information? What information do you need and why?

- What would you ask the farmer who brought this sample in?

Discuss with the class:

REMEMBER

When working with farmers, NEVER go straight to the Pacific Pests & Pathogens & Weeds app.

ALWAYS work through the ABC activity and then the possibilities and probabilities process in your mind first!

EXERCISE 11: Using the possible and probable approach

In pairs or threes, now work though this example following the steps above. Then check your answer with the Pacific Pests, Pathogens & Weeds app. Discuss with the rest of the class.

EXAMPLE: yellowing on sweet potato

Symptoms:

1.

2.

3.

4.

Possible causes	Possible? ✓✗	Probable? ✓✗	Why did you decide this?
BIOTIC			
Insects			
Mites			
Fungi			
Bacteria			
Virus			
Phytoplasma			
Nematode			
Weeds			
Parasitic plants			
Slugs & Snails			
Mammals			
Birds			
ABIOTIC			
Nutrient deficiencies			
Sun scald			
Water (too much or too little)			
Lightning			
Herbicide			
It's natural			

NOTES:

Now check your answer with the Pacific Pests, Pathogens & Weeds app.

- What is your diagnosis?

- Do you still need more information? What information do you need and why?

- What would you ask the farmer who brought this sample in?

Discuss with the class:

Exercise 12: Using the possible and probable approach to diagnosis

In pairs or threes, now work though this example, following the steps above. Then check your answer with the Pacific Pests, Pathogens & Weeds app. Discuss with the rest of the class.

E hosoma leaves

Symptoms:
1.
2.
3.
4.

Possible causes	Possible? ✓✗	Probable? ✓✗	Why did you decide this?
BIOTIC			
Insects			
Mites			
Fungi			
Bacteria			
Virus			
Phytoplasma			
Nematode			
Weeds			
Parasitic plants			
Slugs & Snails			
Mammals			
Birds			
ABIOTIC			
Nutrient deficiencies			
Sun scald			
Water (too much or too little)			
Lightning			
Herbicide			
It's natural			

NOTES:

Now check your answer with the Pacific Pests, Pathogens & Weeds app.

- What is your diagnosis?

- Do you still need more information? What information do you need and why?

- What would you ask the farmer who brought this sample in?

Discuss with the class:

END OF CHAPTER 2 QUIZ: Test your knowledge.

Multiple choice. Pick one answer only.

1. In ORDER, abiotic and biotic factors that cause damage on plants are:

A. a fungus and a mite
B. a bird and drought
C. potassium deficiency and bacteria
D. phytoplasma and poor soil

2. **Symptoms on tomatoes and cabbages caused by bacteria are:**
A. leaf spots and evenly spread leaf yellowing
B. wilt and V-shaped yellowing at the edges of leaves
C. rust spots and mosaics
D. dieback and with leaves going purple

3. A common disease of tomatoes in the Pacific is:
A. witches' broom
B. tobacco mosaic
C. early blight
D. ring spot

4. The smallest of these pathogens is:
A. virus
B. phytoplasma
C. bacterium
D. fungal spore

5. A plant doctor finds a plant with symptoms of wilt. The most <u>unlikely</u> cause would be:
A. bacteria in the soil
B. powdery mildew
C. nematodes
D. stalk borer

6. Pests with eight legs are:

A. mites
B. insects
C. nematodes
D. millipedes

7. Which of these diseases is caused by a fungus?

A. bunchy top on banana
B. blossom end rot on tomato
C. citrus canker
D. damping-off on cabbage seedlings

8. A plant doctor finds a cabbage with a lot of holes in the leaves. Which are not possible causes?

A. diamondback moth
B. large cabbage moth
C. leaf chewing nematodes
D. snails

9. A virus cannot usually be spread between plants by:

A. nematodes
B. tools
C. rhinoceros beetles
D. aphids

10. Two insects with complete life cycles are:

A. aphids and beetles
B. butterflies and bugs
C. grasshoppers and ants
D. bees and moths

11. Where do you find the eggs of this spiralling whitefly?

A. inserted into the leaf
B. whiteflies do not lay eggs, they give birth to living young
C. in the waxy spirals
D. underneath the female whiteflies

12. What is the most likely cause for this hibiscus wilt?

A. mites or thrips have attacked the young leaves, and they have wilted
B. it was planted on a slope, and there has been a long drought
C. old age
D. a fungus or an insect is destroying the roots

CHAPTER 3

Diagnosing Unknowns Using Digital Platforms

This chapter covers a range of digital platforms available for plant health doctors to use for identification and diagnosis of plants pests and diseases.

What equipment do I need?

- ✓ **Smart phone**
- ✓ **WhatsApp membership of Plant Health Doctor group**
- ✓ **Access to PestNet via**
  - o **the website**
  - o **a mobile device**
- ✓ **Pacific Pests, Pathogens & Weeds app**
- ✓ **Hand lens**

In Chapter 2, your trainees worked through the 'possible and probable' process for the diagnosis of pests and diseases. However, trainees and even experts, will come across symptoms that they cannot diagnose. These are the 'confused and unknowns' (the 'C' in A, B and C). Confused and unknowns come about for a number of reasons:

- lack of experience with pests and diseases of the different crops
- too many symptoms are present and there may be more than one pest or pathogen present (i.e. the sample is confused)
- a problem has occurred that has not been seen in the area for some time (the sample is unknown)
- a problem has never been seen before, as it is newly arrived in the area or the country (the sample is unknown)

Chapter 3 introduces your trainees to digital resources to help them diagnose symptoms of pests and diseases that are confused or unknown. These resources are:

- WhatsApp groups
- PestNet
- The Pacific Pests, Pathogens & Weeds app

3.1 WhatsApp country plant doctor networks

WhatsApp groups have been set up for Fiji, Samoa, Solomon Islands and Tonga. These groups include extension, research and biosecurity staff as well as national and overseas experts, to assist in diagnosing unknown or confused pests and diseases. Images are posted via a smartphone or tablet for identification of problems encountered at a plant health clinic or in the field, and the plant doctor can also ask the network questions about all aspects of plant protection. This means that information on diagnosis and management of problems can be easily and cheaply shared. As well, many of the problems in the Pacific islands are now known and captured in the Pacific Pests, Pathogens & Weeds app with sufficient information for digital diagnosis. Hence, focus can be directed to confused or unknown cases to save cost, time and effort.

WhatsApp and similar networks are ideal for Extension staff and others to deal with unknowns for the following reasons:

- Exchanges between members are rapid
- They can be used in the field or at PHCs to contact experts when extension staff need help in making diagnoses or management decisions
- They provide a list of the pests and diseases of a particular crop in a locality, and alert plant health doctors to be prepared for problems farmers are likely to bring to a plant health clinic
- The information collected can be databased and used to build a knowledge bank of crop pests and diseases, location, frequency and relative importance, for research and training purposes. This database will become an essential tool for plant health doctors and the plant health system in general

Other benefits of these networks include:

- Promotion of the use of digital tools to complement plant protection research in filtering or prioritisation of field sampling and laboratory diagnoses
- Improving communication and networking of members
- Serving as a platform for continuous refreshing and updating of knowledge/information related to pest ID and management
- Providing aid to early warning and pest alert systems to support Biosecurity authorities
- Supporting further development of the Pacific Pests, Pathogens & Weeds app by supplying quality pictures and/or potential subjects for factsheets, and to update information on existing factsheets, wherever applicable

3.1.2 How to join a WhatsApp group

You and your trainees should work through these steps to ask the Administrator to join a WhatsApp group (e.g. Fiji Plant Doctor Network).

1 You MUST have the phone number (or email address) of an Administrator of the group.

2 Download WhatsApp from the Google Play Store or Apple App Store.

3 Open WhatsApp and follow this YouTube video to create your WhatsApp account: https://www.youtube.com/watch?v=ugGyYJSAlgA

Then either:

4a Send a TEXT to the Administrator asking "Please add me to the Group"

Or:

4b Send an EMAIL to the Administrator with your phone no.

5 Now watch for a WhatsApp message from the Administrator to say that you are now a member.

How the Administrator invites you to join

WhatsApp has made it easy for others to join a group by introducing an invite link, which is visible only to the administrator.

1	Tap on the group name (e.g. Fiji Plant Doctor Network) at the top of the screen.
2	Scroll down to Invite to Group via Link.
3	To activate the link, the Administrator taps on Invite to Group via Link, and this will bring up a list of 3 ways to share the link: 1) Share Link, 2) Copy Link, 3) QR Code.
4	The Administrator will store your number in their contacts and then complete the task by adding you to the group.
5	The Administrator can then share these links to one or more people by email, text, twitter, WhatsApp or other platforms.
6	Tap on the link. The following information will be displayed: '*This group is created by [Name] and has [x number] participants*'.
7	Tap on 'Join Group' to accept the invitation and activate membership of the group.

Don't forget, you can have more than one Administrator

3.1.3 How to send a photograph and information for diagnosis

Good quality pictures are essential for accurate diagnoses. Doctors need to practice their camera skills and always choose the best, clear and in-focus picture(s) from the gallery to post to WhatsApp

Plant doctors should take a picture using the WhatsApp app and send it directly to the group. Either a picture, record audio, or a video of the problem can be taken, but pictures are probably the best especially where internet costs are high.

In general, the images on WhatsApp need to be of sufficient quality to show fine detail, even when taken through a x10 pocket lens.

A number of pictures may be necessary for accurate diagnosis, so doctors should take a picture of the whole plant as well as the parts affected wherever possible. Also where possible, pictures of the plants in the field are helpful in making a diagnosis in the field.

The sender of the request should also add details about the picture that include:

- Date picture was taken
- Location
- Weather conditions – hot/cold; wet/dry
- Information on the host plant – parts infected, the extent of the infection
- Estimate of how many or what percentage of plants are infected
- Whether it is a new problem
- A possible diagnosis
- Any other information that might assist diagnosis.

You DO need a Wi-fi connection to upload a photo to WhatsApp. If you do not have one, you can still take a photo and then upload and send it later when you have internet access

The pictures in Fig 3.1 and Fig 3.2 show pictures sent to a country WhatsApp group for diagnosis.

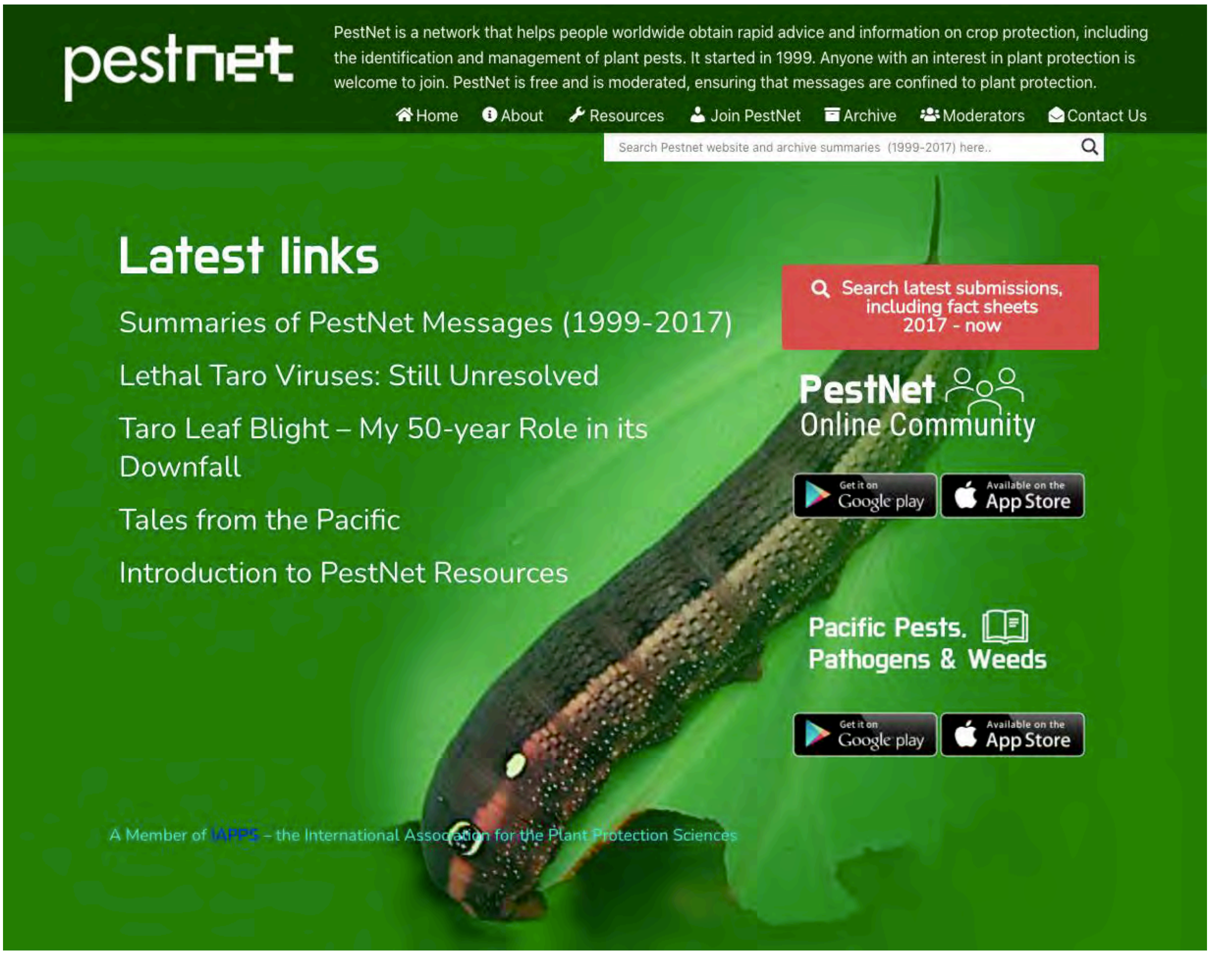
Fig. 3.1 Appearance of posts on WhatsApp Fiji Plant Health Doctors.

Fig. 3.2 Images from WhatsApp showing a cushion scale and nymphs from eggplant (top), and busy plant health doctors making a diagnosis (below).

3.2 PestNet

PestNet is an online service providing crop protection information of all kinds, in particular pest and disease identification and management. It was started in December 1999 and has about 1300 members. It is open to research and extension staff, farmers, and students, and uses emails to link members. Daily, it gives out information on plant protection from the Internet. To access PestNet go to www.pestnet.org.

PestNet is now amalgamated with the Pacific Pests, Pathogens & Weeds (fact sheet) app. So from the PestNet website (www.pestnet.org) you can access PestNet's Online Community and more than 500 fact sheets, and from each of the fact sheets you can access PestNet.

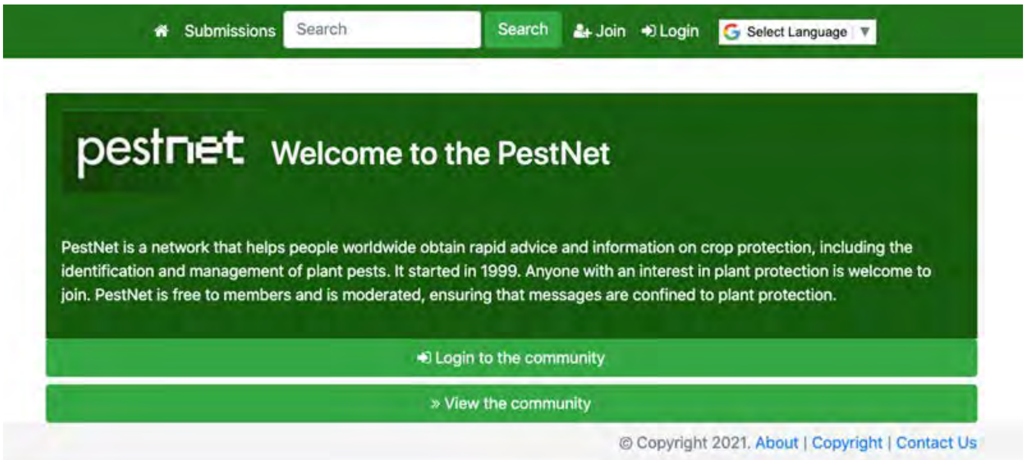


The next section shows you how to join PestNet, send a submission (e.g., request for an identification or for other information), and how to respond to someone else's submission.

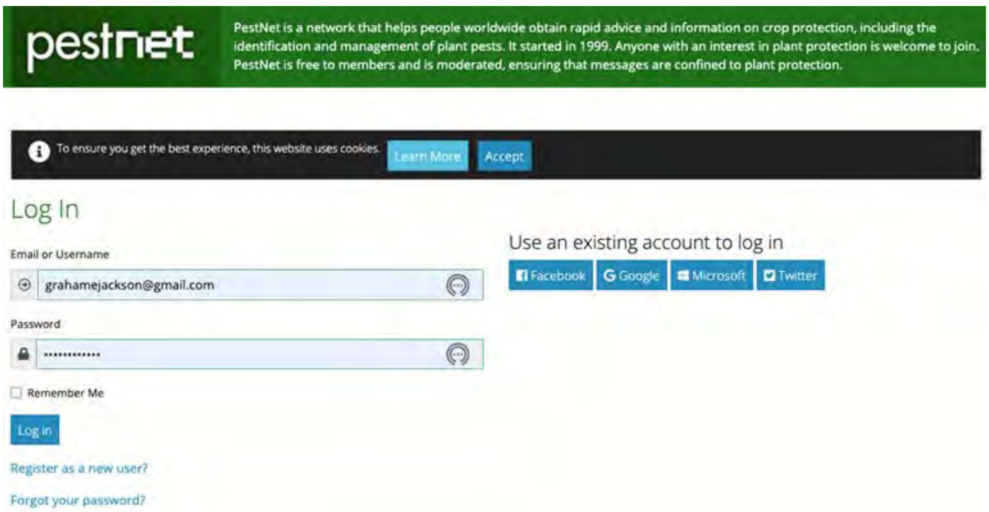
3.2.1 Accessing PestNet from a computer

Trainees should work through the following process to become familiar with accessing and using PestNet on a computer. From the PestNet website (above) they should go directly to the ‘Welcome to PestNet’ page to join, login or view submissions via the ‘PestNet Online Community’ link.

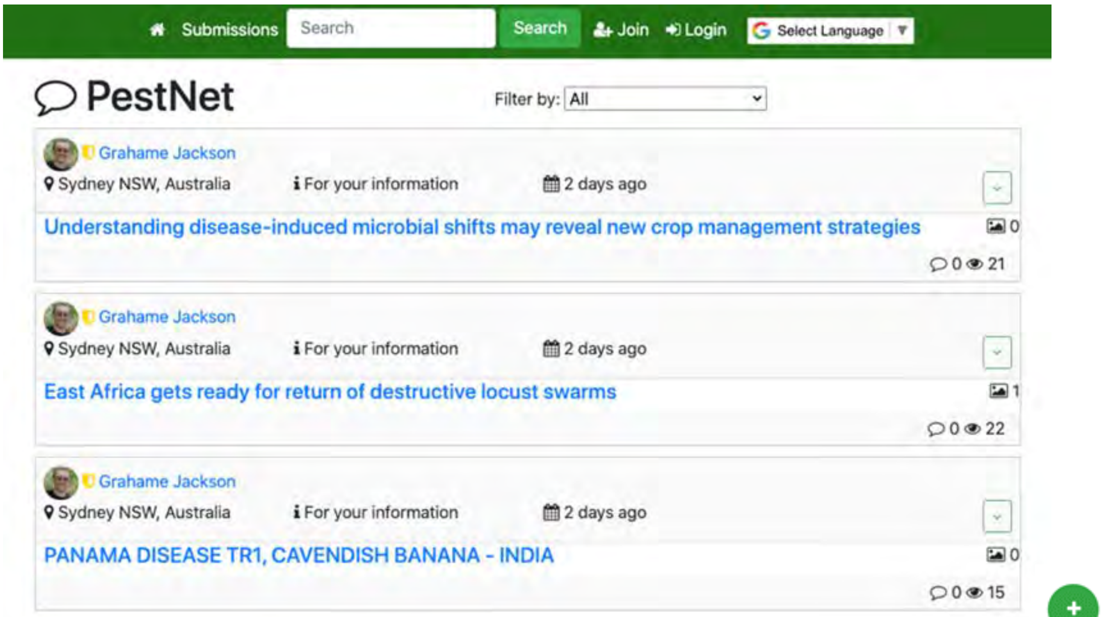
1 Welcome Page: [www.pestnet.org.](http://www.pestnet.org)



2 Choose 'Join PestNet' and either regsister with an email and password or use a social media account.

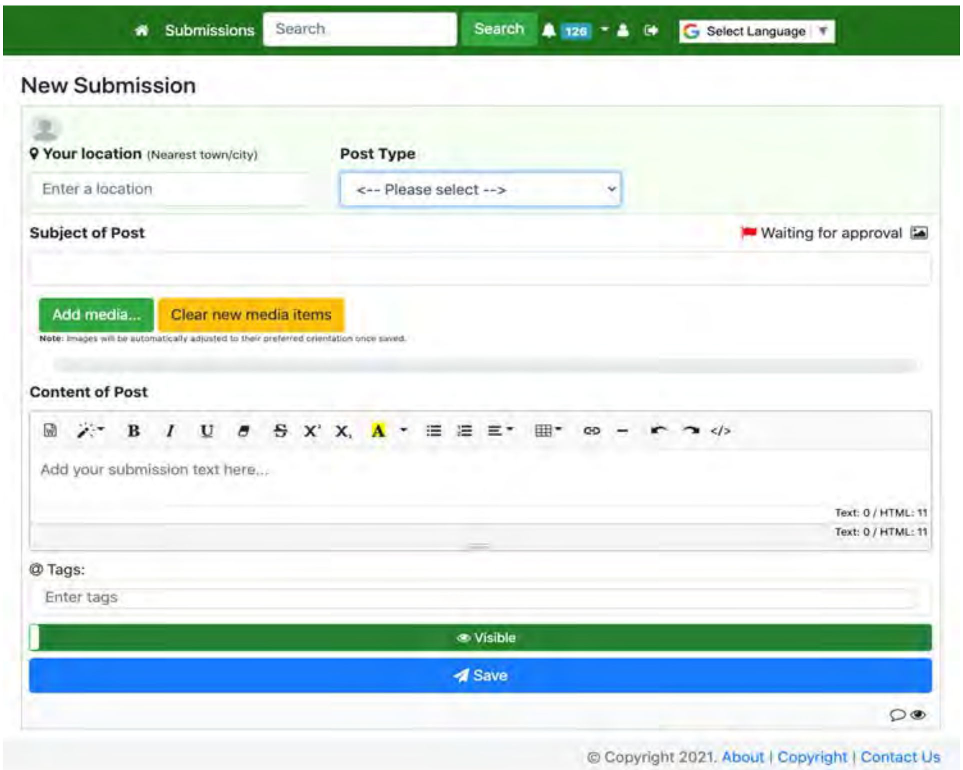


Or choose 'View the Community' just to look at submissions without signing in. In this view you will not be able to make a submission or respond to one. If you are already a member, go to Login.



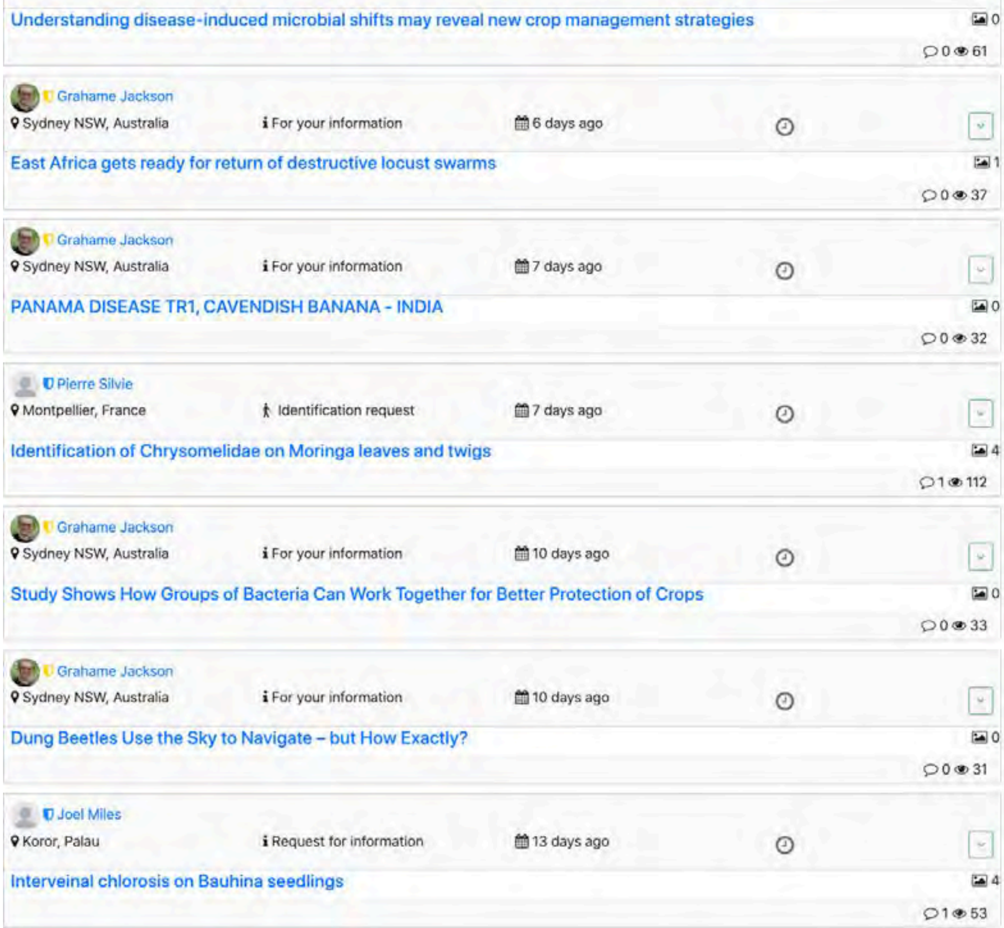
3

Once you have been accepted as a member, tap + in the green circle, fill in the form and save. Submission goes to moderators (Note, tags are optional).

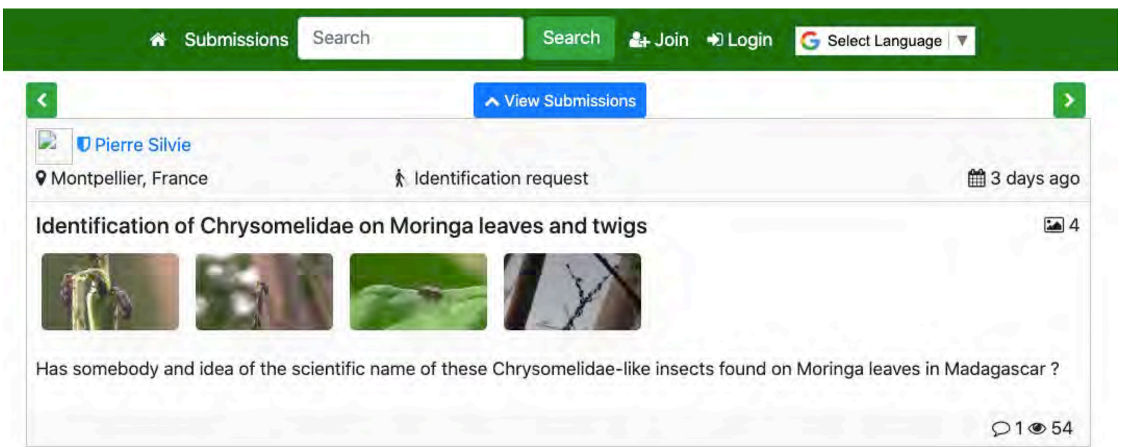


4

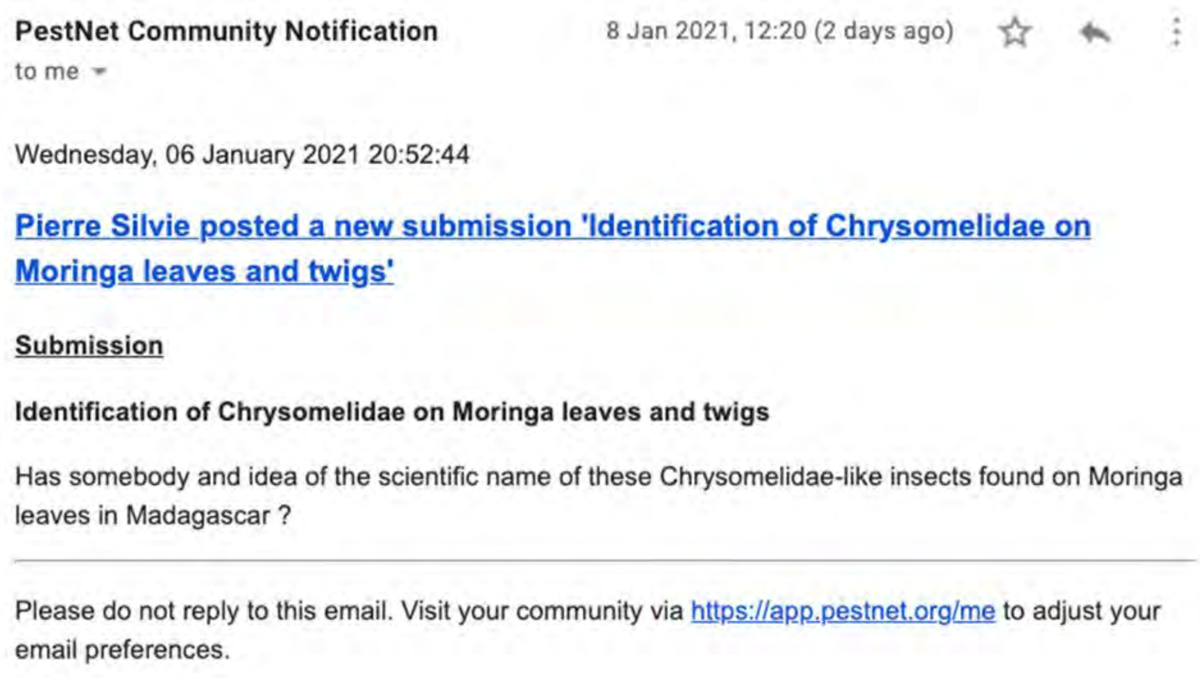
To add submissions to PestNet - Click on headings to expand.



An expanded submission. Note that images can also be expanded.



5 Members will receive an email link to view submissions.



PestNet Community Notification 8 Jan 2021, 12:20 (2 days ago)

to me

Wednesday, 06 January 2021 20:52:44

Pierre Silvie posted a new submission 'Identification of Chrysomelidae on Moringa leaves and twigs'

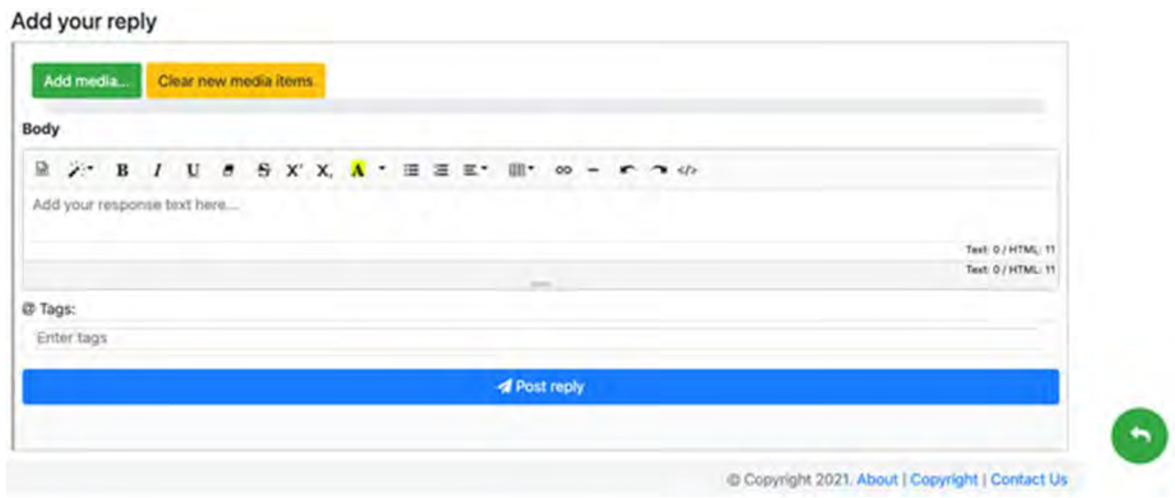
Submission

Identification of Chrysomelidae on Moringa leaves and twigs

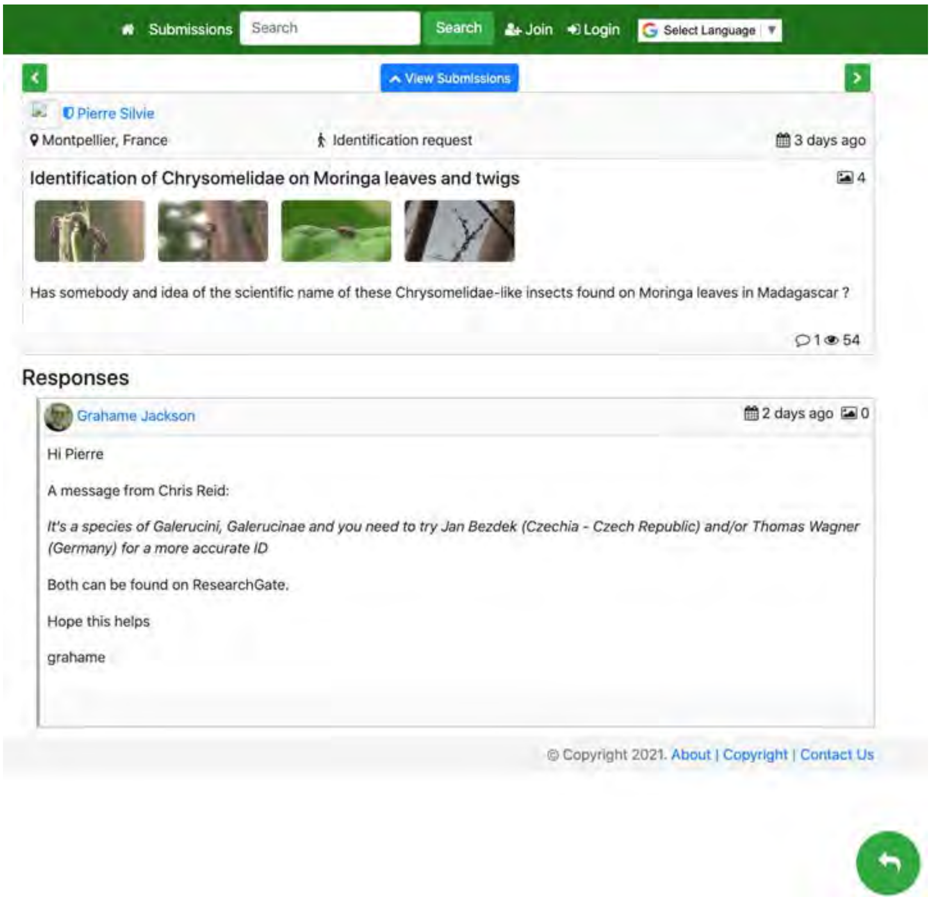
Has somebody and idea of the scientific name of these Chrysomelidae-like insects found on Moringa leaves in Madagascar ?

Please do not reply to this email. Visit your community via https://app.pestnet.org/me to adjust your email preferences.

6 Members respond by clicking on the white curved arrow in the green circle, filling in the form and sending.



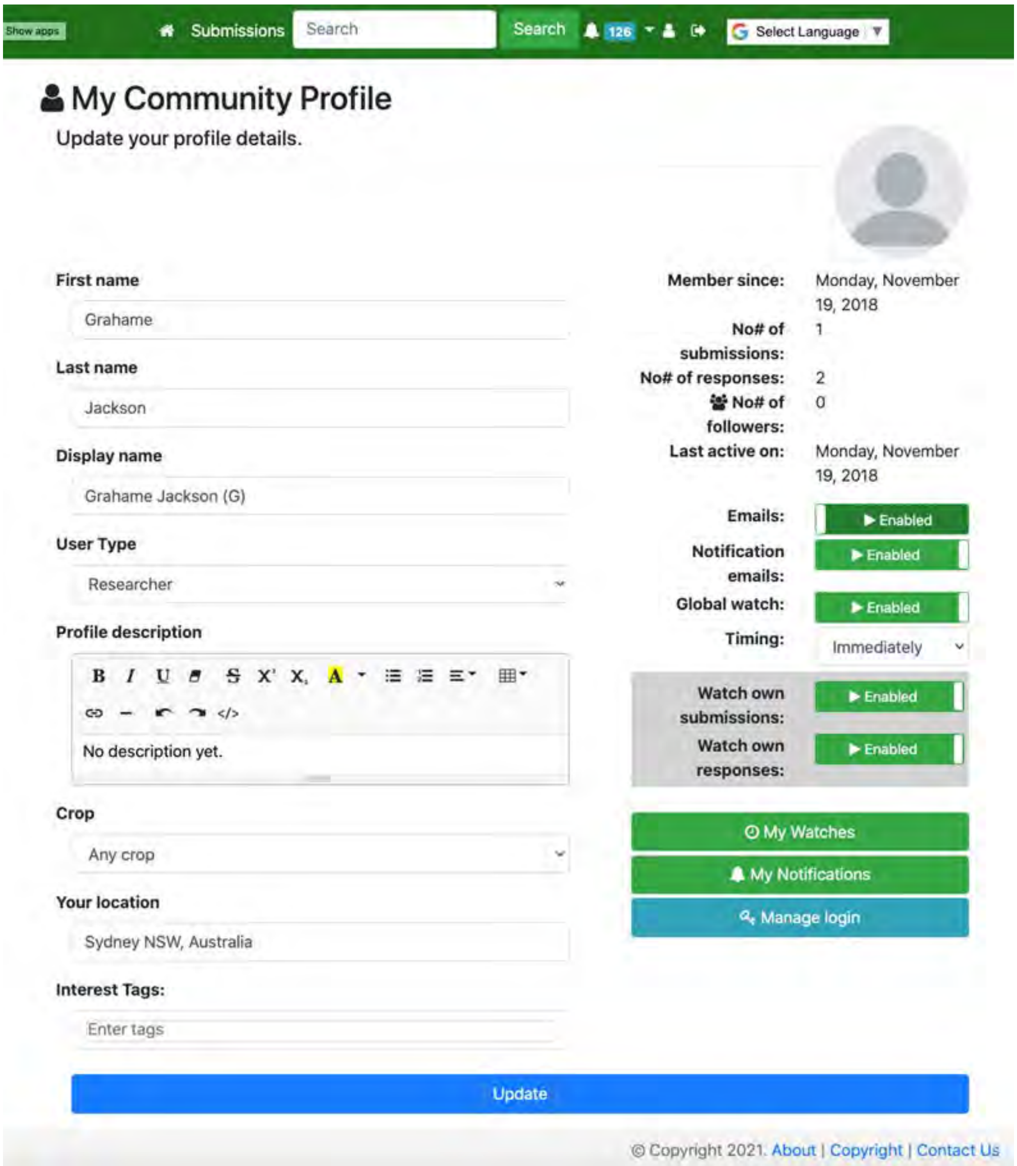
Members receive a link to the response and can reply.



7 Managing your PestNet profile (*optional*) - click on 'small man' symbol next to 'Join'.

Below are the definitions of the default position:

- **Emails**: When 'Enabled', you will receive ALL emails from PestNet
- **Notification emails**: When 'Enabled', you receive notifications (see bell and number in the top banner) for all posts and responses other than your own, generated daily and sent in an email (a digest)
- **Global watch**: When 'Enabled', you watch all the posts (by default)
- **Watch own submissions**: When 'Enabled', you will be notified if there are responses to any submission you have made
- **Watch own responses**: When 'Enabled', you will be notified if there are responses to any responses or comments you have made
- **Timing**: You will receive notifications depending on the time set: immediately, daily, weekly, etc.



If you do not want all emails, go to My Community Profile and select:

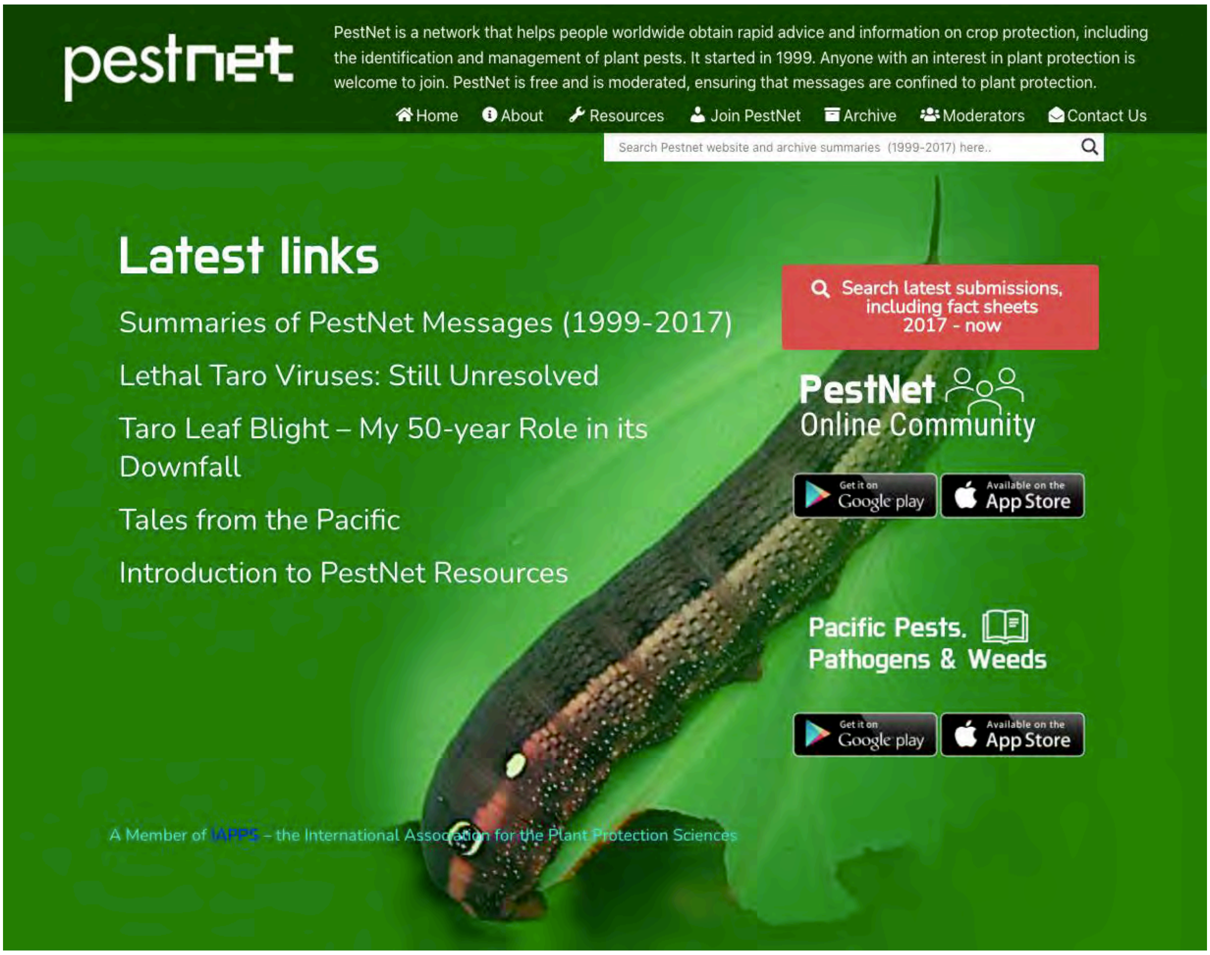
- **Emails:** Stop – you will not get any emails from PestNet.
- **Global watch:** Stop – then choose 'My Watches' to make selections
    - My Watches: You can select any of the filter items: Submissions, Responses, Tags, Users or Location
    - To watch a tag, click on the tag and then the 'clock' (or for submissions just the 'clock')
    - Timing: You can determine when you want to receive your watches
- **Notification emails:** Select Enable or Stop, depending on whether you want to receive emails with a submission or tag that matches your watches

3.2.2 Accessing fact sheets via PestNet using a computer

Here we take you through the process of accessing the fact sheets via Pestnet's website using a computer. From the fact sheets you can access the PestNet Community. Having a direct link to PestNet from every fact sheet has advantages. It means that should you wish for more information on any pest you can quickly access PestNet to make a submission. If the two apps were separate then you would have to leave the one to access the other.

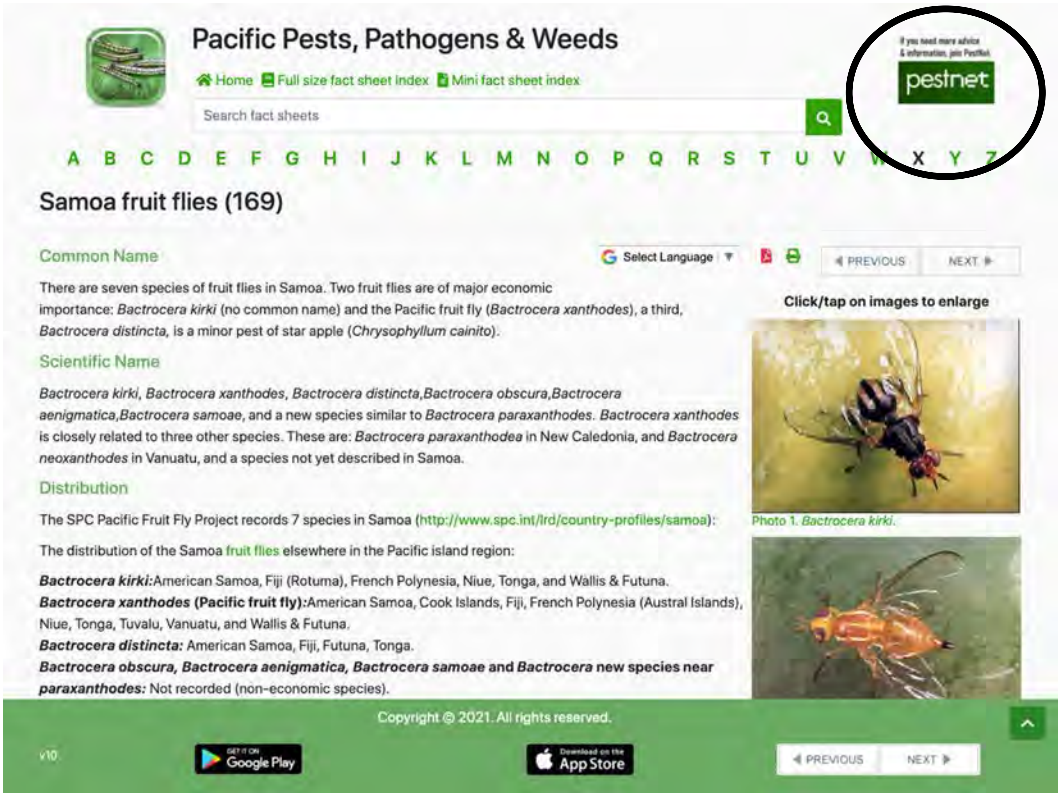
Note, the two apps (PestNet and Pacific Pests, Pathogens & Weeds) have been amalgamated.

1 From the PestNet website, choose Pacific Pests, Pathogens & Weeds.



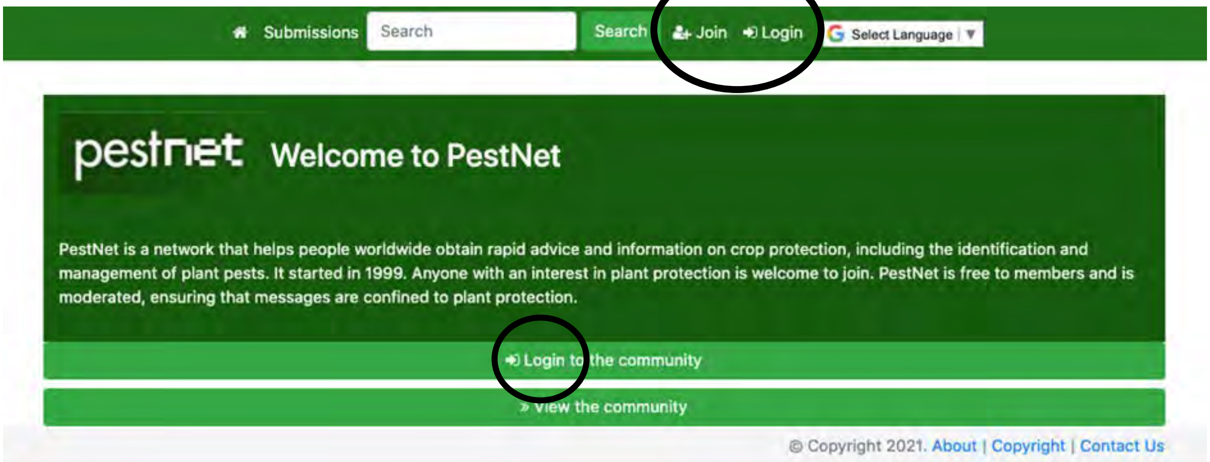
2 From the home page, choose either full or mini fact sheets.

3 Select any fact sheet and click on the PestNet logo (top right).



4

By bringing up the 'Welcome to PestNet' page you can Join or Login to send a submission, as explained under 3.2.1.



3.2.3 Accessing PestNet on mobile devices (tablets and phones)

1

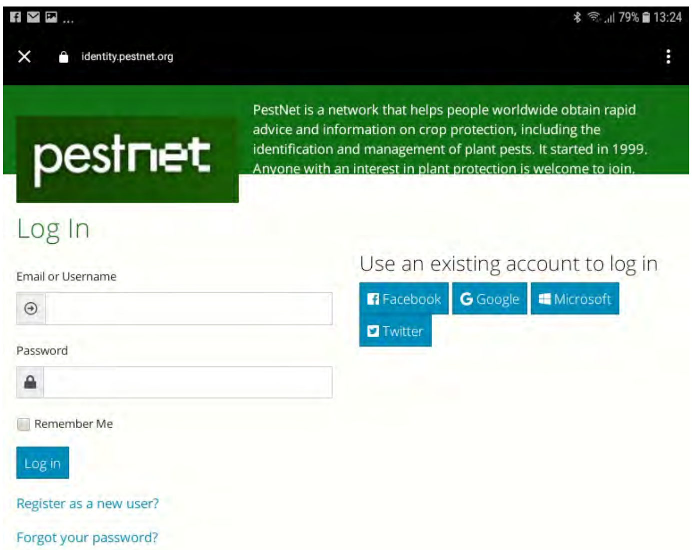
Download the app from either the Google or Apple app store. Note that PestNet and Pacific Pests, Pathogens & Weeds are now together in the one app.

2

Read and accept the Disclaimer by tapping on 'Continue'. Tap on 'PestNet Community' to go to the Welcome page.

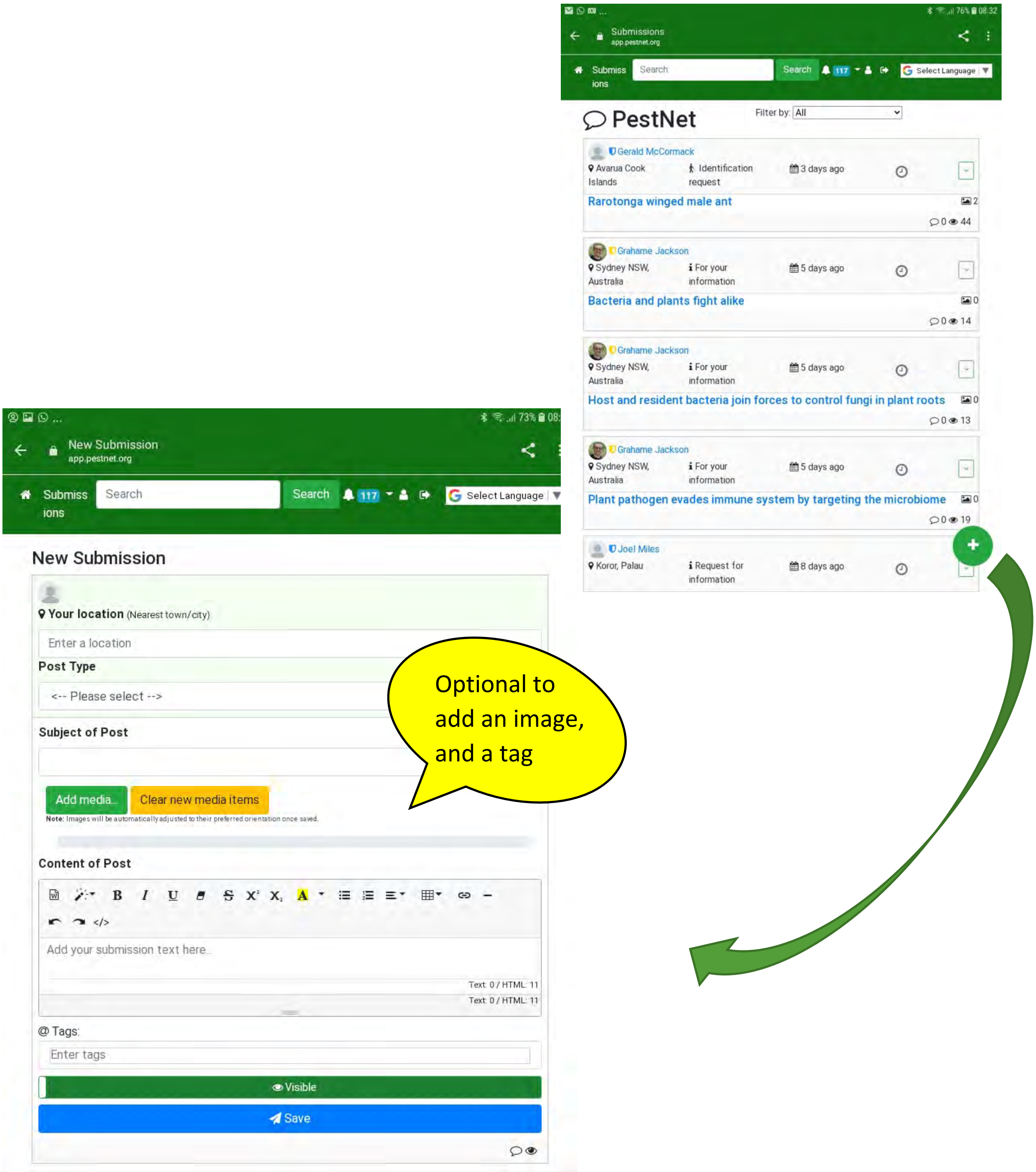
3

Either View the messages without joining or Join (or login). You need to join if you want to post a submission or reply to one.



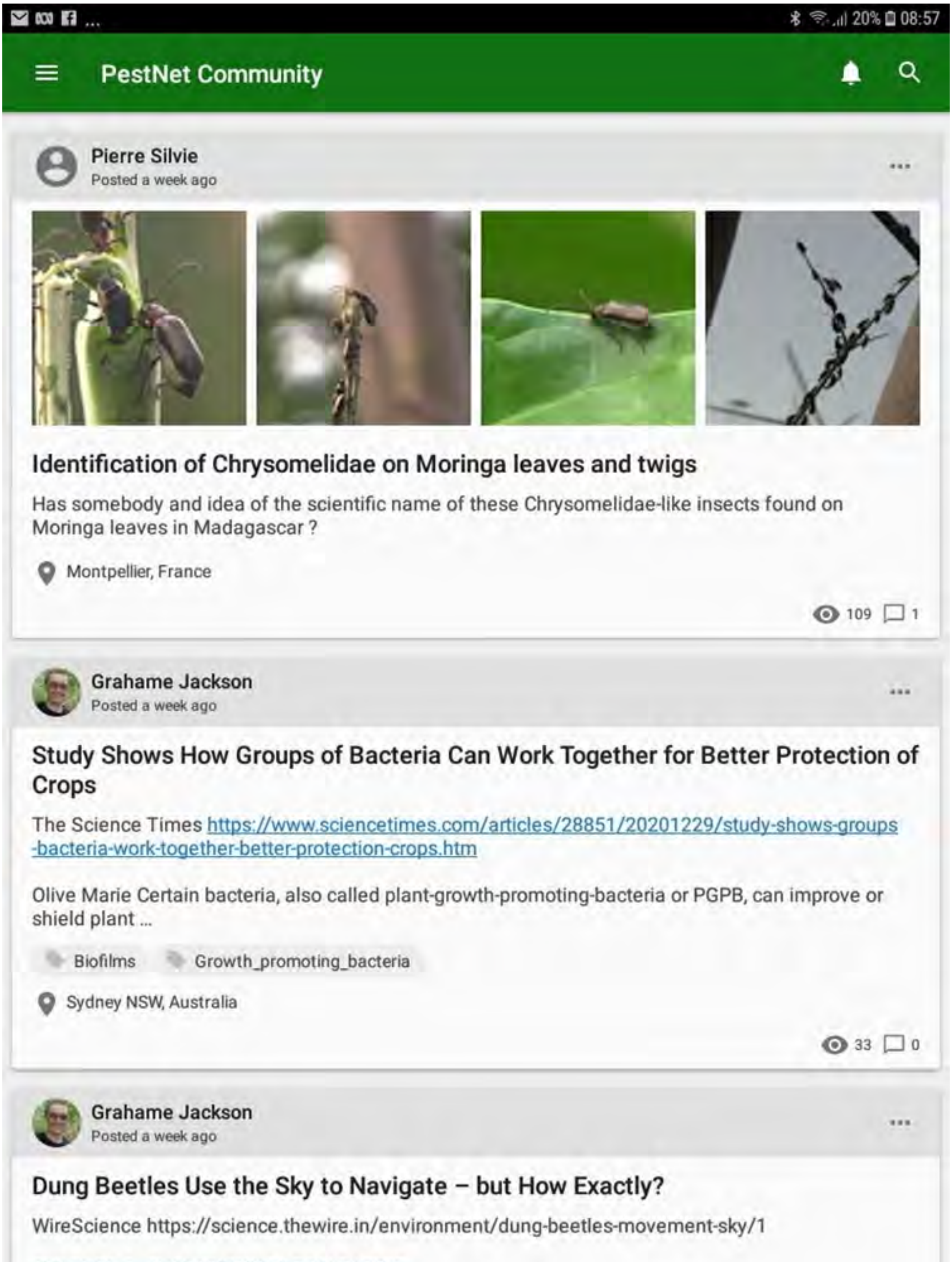
4

Post a submission - Tap on the white + in the green background, and fill out the form. Tap on the arrow (bottom right) to send.

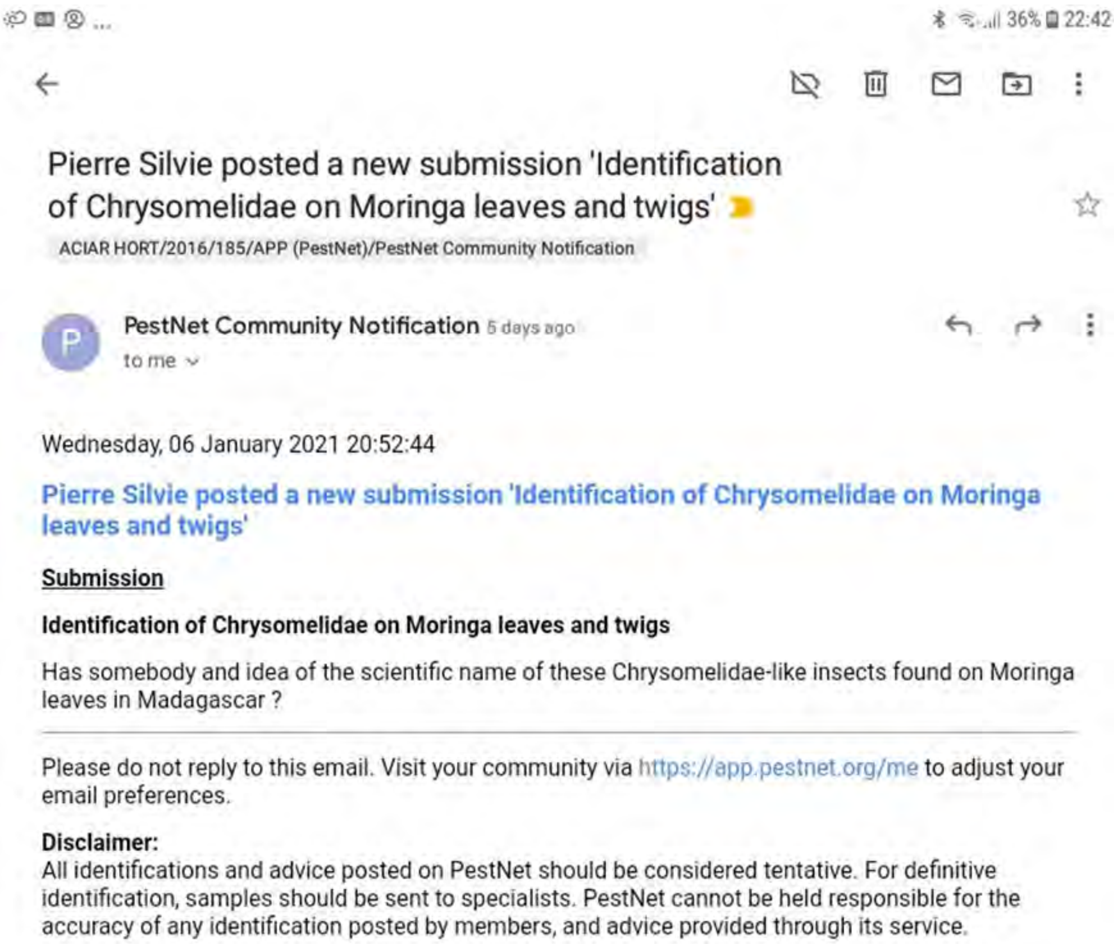


5

Submissions are cleared by moderators, added to PestNet and sent to members. Tapping within each submission opens it.



6 Members get an email with a link to the submission.


Pierre Silvie posted a new submission 'Identification of Chrysomelidae on Moringa leaves and twigs'

ACIAR HORT/2016/185/APP (PestNet)/PestNet Community Notification

PestNet Community Notification 5 days ago

to me

Wednesday, 06 January 2021 20:52:44

Pierre Silvie posted a new submission 'Identification of Chrysomelidae on Moringa leaves and twigs'

Submission

Identification of Chrysomelidae on Moringa leaves and twigs

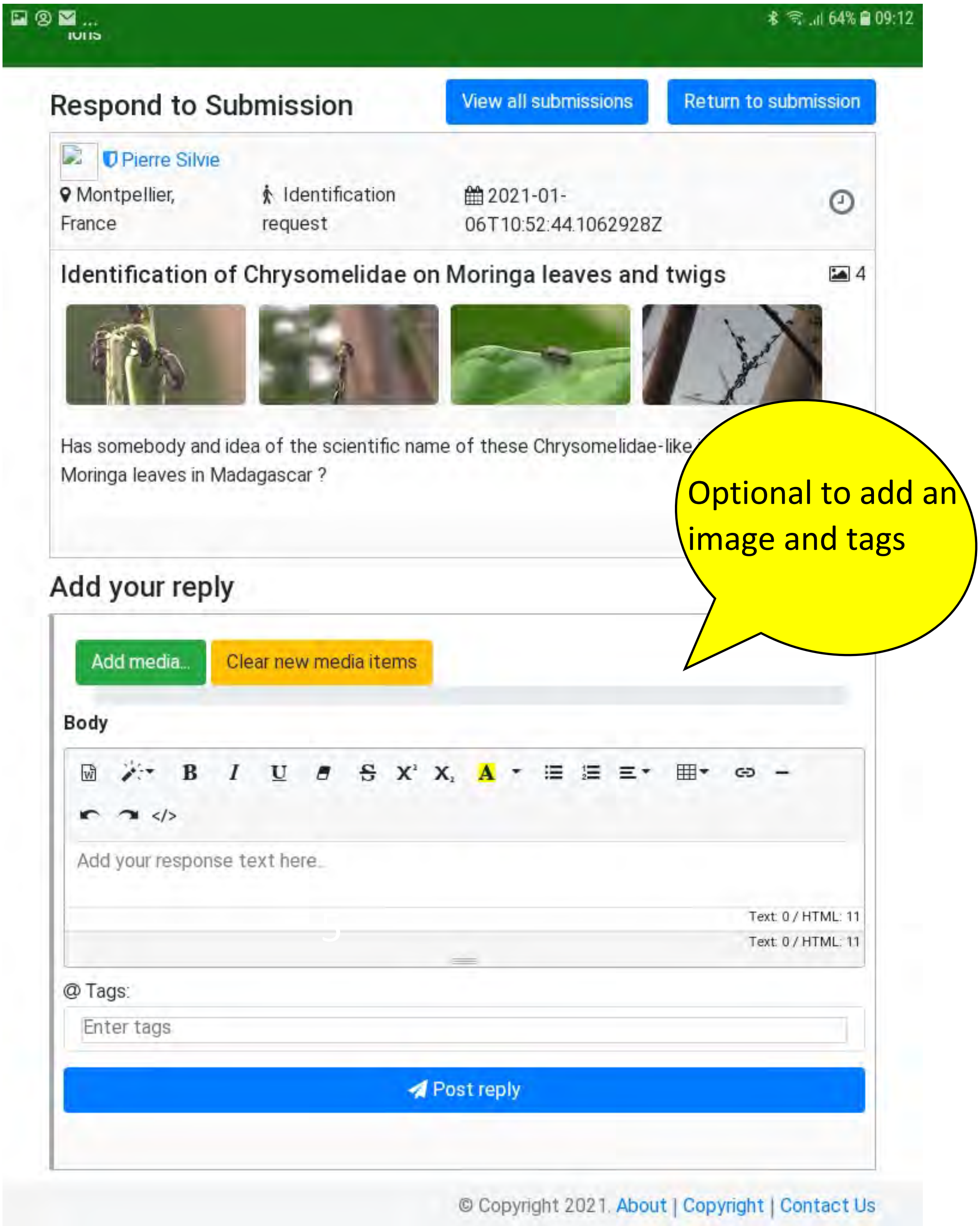
Has somebody and idea of the scientific name of these Chrysomelidae-like insects found on Moringa leaves in Madagascar ?

Please do not reply to this email. Visit your community via https://app.pestnet.org/me to adjust your email preferences.

Disclaimer:
All identifications and advice posted on PestNet should be considered tentative. For definitive identification, samples should be sent to specialists. PestNet cannot be held responsible for the accuracy of any identification posted by members, and advice provided through its service.

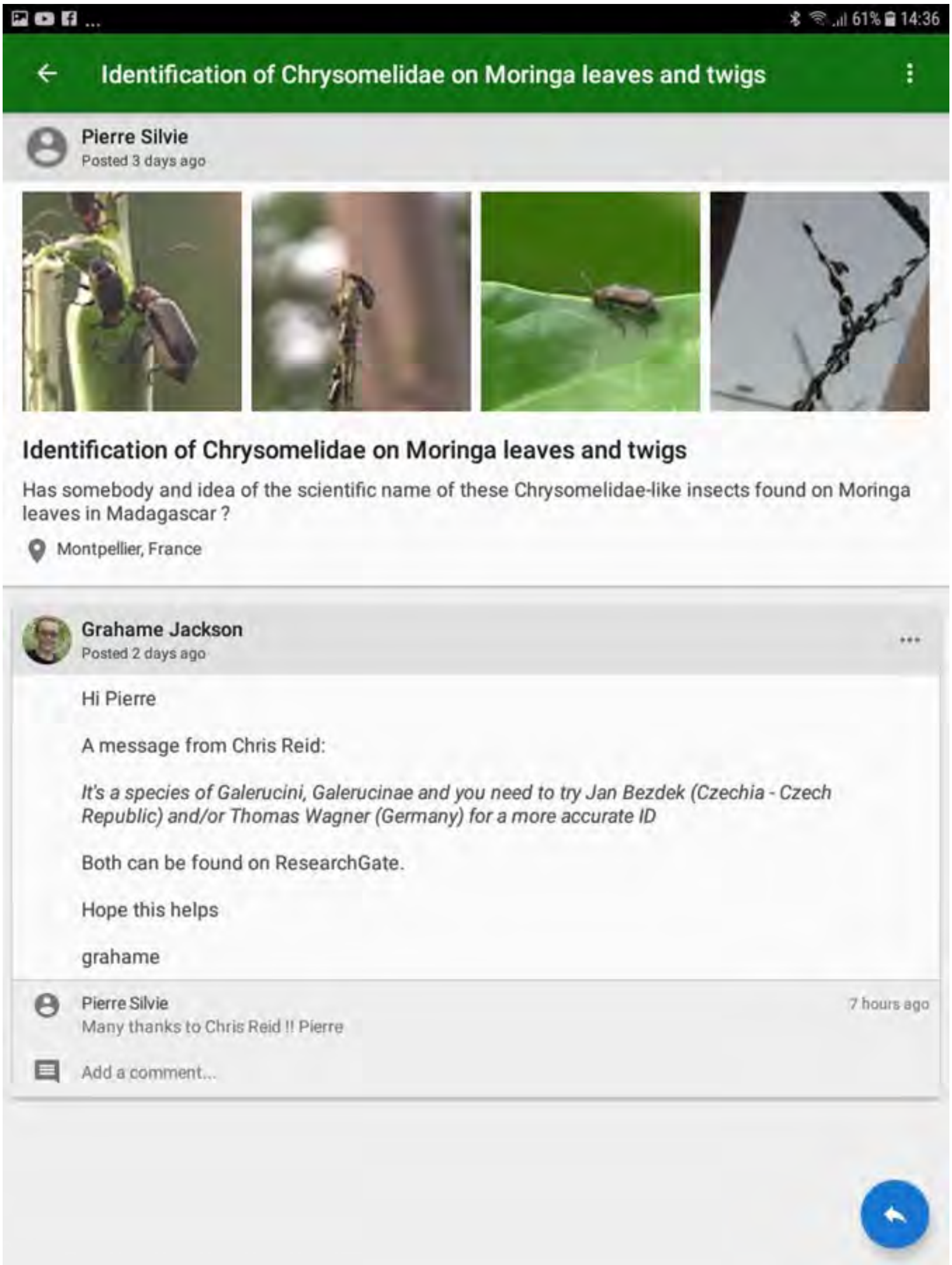
7

Post a response – Tap on the submission of interest, then tap on the white curved arrow (bottom right on 8), fill out the form (below) and send.



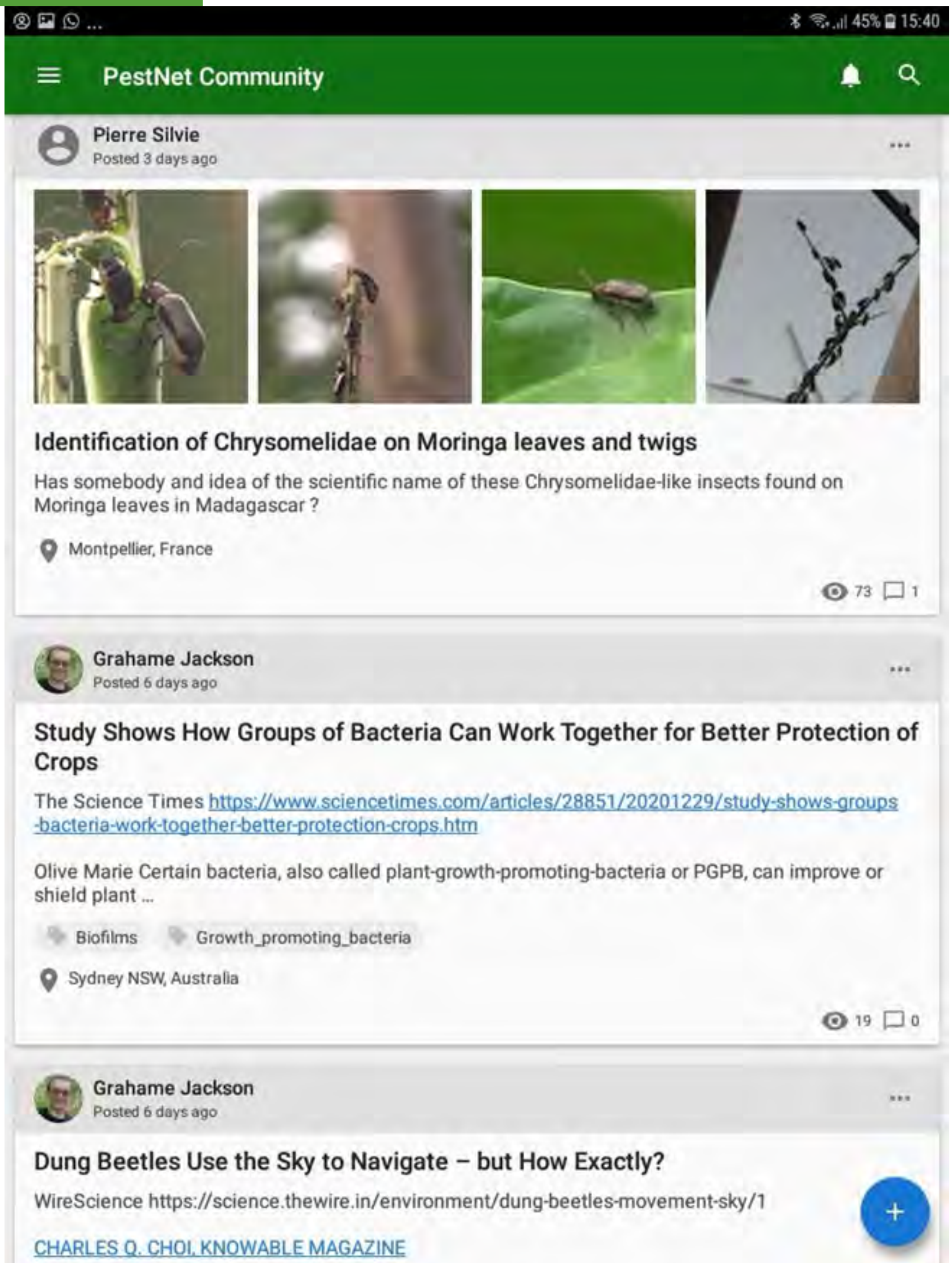
8

PestNet shows responses as a ‘thread’ - one after the other.



9

Checking responses - From the PestNet list of submissions you can click on the squarish box (below right) to see number of responses (in this case 1).



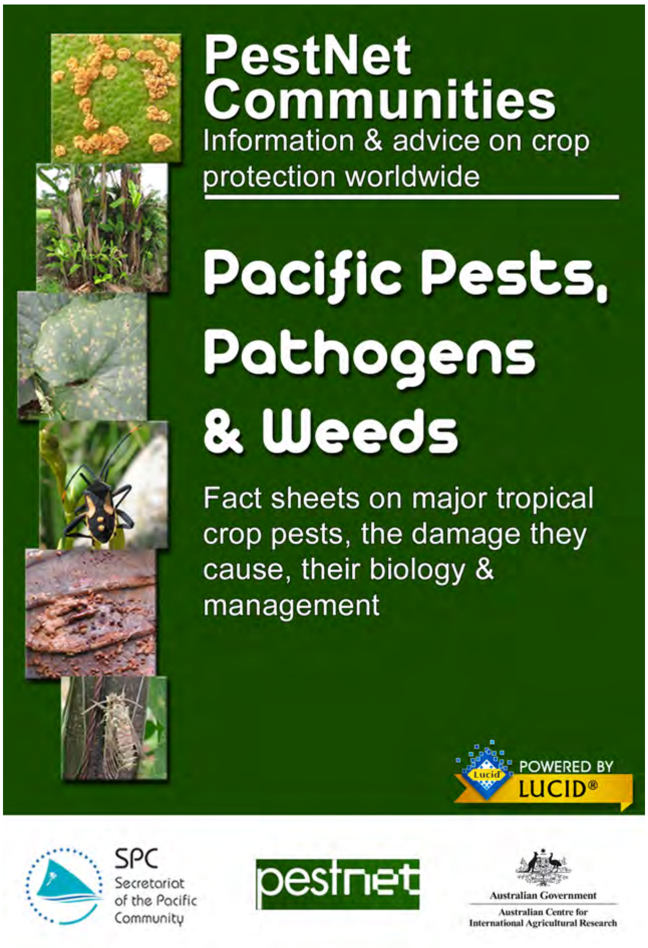
3.3 Accessing fact sheets via mobile devices

The Pacific Pests, Pathogens & Weeds app gives trainees accessible and valuable information on a wide range of plant pests, diseases and weeds found in Pacific islands. Trainees will need access to a smartphone or tablet, and internet access to download the app. Once downloaded from the Google or Apple stores, internet access is no longer needed.

Note, you can access PestNet from within any fact sheet, full or mini, in case you want more information and wish to send a message to the PestNet Community.

You can download the app from both the Google and Apple stores.

1 This app contains Full and Mini fact sheets designed to assist plant health doctors to diagnose pests and diseases to give sound management options to farmers



2

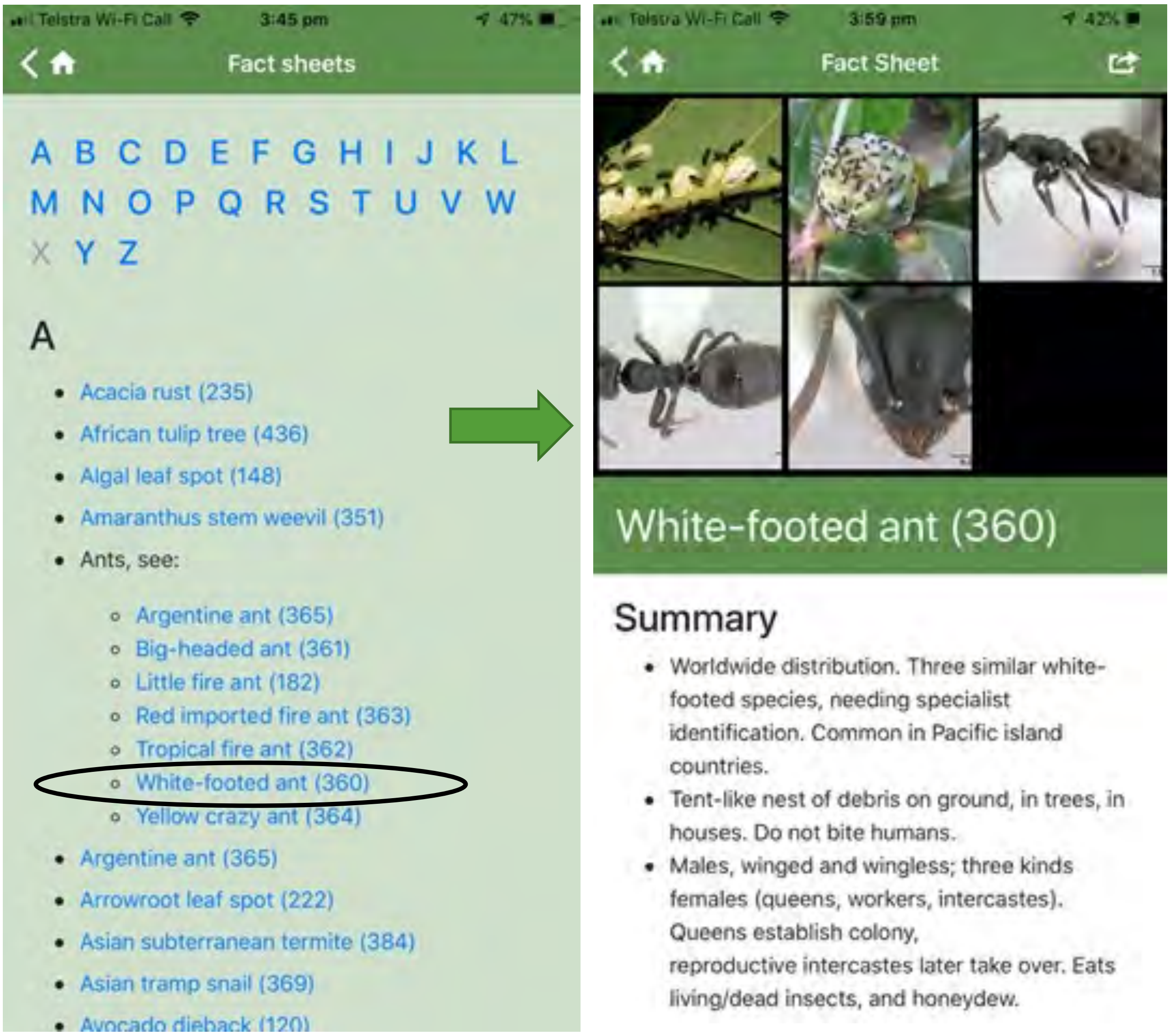
This app opens to a screen giving a choice of Full or Mini fact sheets, image downloads, and how to use the app.

3

Tapping on Full fact sheets takes you to a lists of pests, pathogens and weeds in alphabetical order. Select a fact sheet (Full).

4

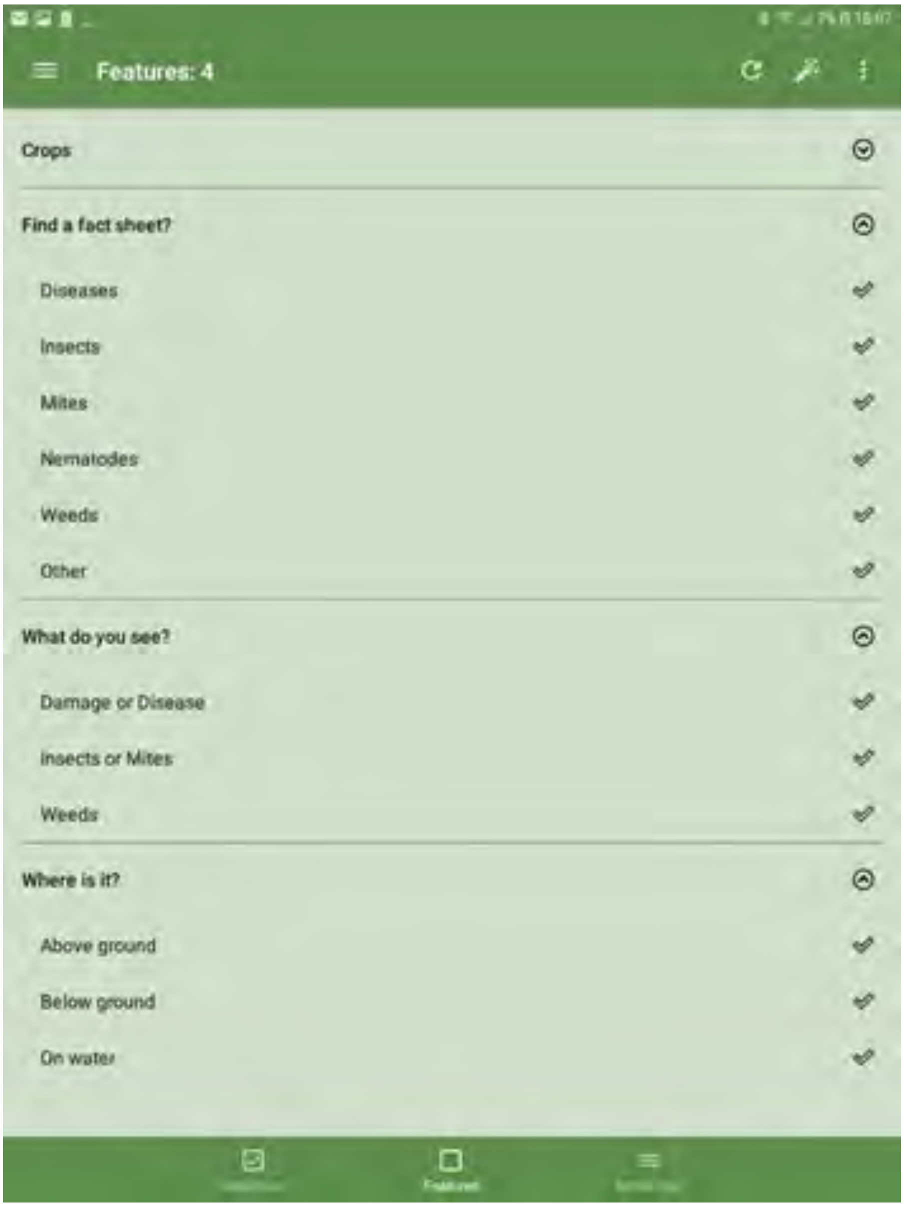
Tapping on Mini fact sheets takes you to a list of pests, pathogens and weeds in alphabetical order. Select a fact sheet (Mini).



Note, all fact sheets (either full or mini) can be shared by email. The link is at the top right corner. Once received, they can be downloaded as an attachment and printed.

5

To use the interactive key tap on 'Identity Pests, Diseases & Weeds' under step two above. Select 'Crops' and then answer the questions.



IMPORTANT: Many pests and diseases occur on more than one crop. The pest that the plant health doctor is looking for MAY be described under another crop. For example, if the problem is scale on cassava, it would commonly be white peach scale. But there is no fact sheet for cassava. The scale is described under *bele*, where it is also a common pest. So, how would the plant health doctors go about finding it?

The way to do it is through 'Identify Pests & Diseases'.

- **i.** Tap on Identify Pests & Diseases.
- **ii.** Open Crops
  - Scroll to *Bele*
  - Scroll up and close 'Crops'

- **iii.** Open Find a fact sheet?
  - Tap on insects
  - Close 'Find a fact sheet?'

- **iv.** Tap on 'What do you see?'
  - Tap on Insects or Mite
  - Close 'Insects or Mites'

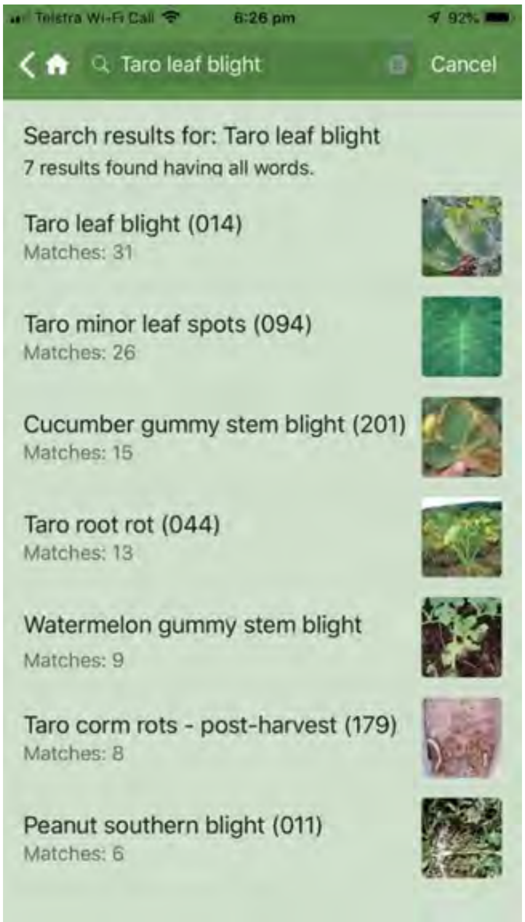
- **v.** Open 'Where is it?'
  - Tap on 'Above ground'
  - Close 'Where is it?'
  - Scroll to the left
  - There are eight possibilities
  - The only scale is Cassava White peach scale
  - Open it and look at the photos: two show the scale on bele

Trainees can practise by trying to identify the problem on a tomato plant that has wilted and there are small seed-like balls in a white cottony growth at soil level. This is possibly a disease. What is it?

6 Using the search engine.

It is important that the trainees become familiar with the search facility. It allows them to:

- Quickly see thumbnail photos of all the pests and diseases for each crop
- Search on several words together, or the words independently – compare ‘taro leaf blight’ matched to ‘any word’ compared to ‘all words’.
- Sort a list alphabetically



Searching for Taro leaf blight when ‘all words’ is selected results in 7 results, but when ‘any word’ is selected there are 316! To sort any list alphabetically select ‘item name’.

Your trainees should practice using this app with a range of pests and diseases. In a clinic it is very useful AFTER they have gone through the process of identification and diagnosis using the A,B,C and Possible/Probable processes first

CHAPTER 4

Integrated Pest and Disease Management Options 1: Cultural and Biological Control

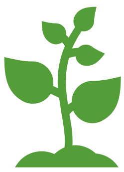
In Chapters 2 and 3, your trainees learned to identify and diagnose plant pest and disease symptoms. Chapters 4 and 5 introduce them to a range of ways farmers can manage agricultural pests and diseases. This chapter covers cultural and biological methods using the ideas and processes of Integrated Pest and Disease Management (IPDM). Chapter 5 focuses on pesticides.

What equipment do I need?

- ✓ **Samples for class exercises from the field**
- ✓ **Phone or tablet with Pacific Pests, Pathogens & Weeds app**
- ✓ **Butchers' or brown paper and marker pens**
- ✓ **Sticky notes or blu-tak**
- ✓ **Hand lens**
- ✓ **Binocular microscope (if available)**

4.1 Introduction to using integrated pest and disease management (IPDM)

Pests and diseases are always present, no matter how hard we try to eliminate them! They compete for light, water and nutrients with the crops we grow, and that causes losses of yield and quality. So what can we do? At present, much of the management of pests is done using pesticides. Every year, some 3.5 billion kilograms of chemicals are applied to crops worldwide, worth USD 45 billion. Although chemical use may have peaked, the amount used is still large, and the cost continues to rise. Herbicides form the largest group of chemicals used, followed by insecticides and fungicides.



While there is now increased awareness of the dangers of pesticides, they are likely to remain a major method of pest and disease control for a long time. This is because the world's population is increasing, and so more food is required. As a consequence, more fertiliser is used, which means potentially more plants for pests to eat or diseases to infect. As agriculture becomes more intensive, soils become less healthy and plants become less resilient to attack by pests and pathogens.

Most insecticides are broad-spectrum. They may kill all insects, good and bad; they kill bees and other pollinating insects; and they kill birds. They leak through the soil into waterways and kill fish; they add to the expense of crop production and harm humans when applying them. If residues remain on or in the produce, they may cause poisoning, cancers, birth defects or development problems. Some are also endocrine disruptors, which means they can affect hormones in insects and other animals, including human beings.

To make matters worse, resistance to pesticides often occurs, so more has to be applied for the same effect and, as climates warm, pests spread to new areas where, it is speculated, they consume more because of higher temperatures.

In recent years, integrated pest management (IPM) has been suggested as a better option than using pesticides alone. It is a method of pest control that has become very popular and is considered healthier and more environmentally sustainable. To most people, it is about managing insects, because insects are synonymous with 'pests'. However, the method is just as important for diseases, and lately the term IPM has been broadened to IPDM – integrated pest and disease management.

4.2 What is IPDM?

There are many definitions of what IPDM is. Here are a few:

IPDM uses different control measures or options to reduce pest and disease levels in an economical and environmentally sustainable way

IPDM is based on knowledge of pests and life cycles, checking the crop, making plans for action, and evaluating the results

IPDM is a way of encouraging natural enemies: using natural enemies can't be done if you are using broad-spectrum insecticides. IPDM does not preclude the use of insecticides but uses it only as a last resort

The first definition focuses on costs and the environment, the second on knowledge of life cycles, crop monitoring and making a plan, and the third on promoting biological control methods by protecting natural enemies. No one definition covers them all, IPDM includes all of these, and requires careful observation and knowledge of crops as part of a greater ecosystem.

The most important idea is that it brings together different techniques to control pests and diseases that are least harmful to human beings and the environment. Importantly, for insect pests, it promotes biological control methods. Fig. 4.1 shows that the IPDM process is a cycle:

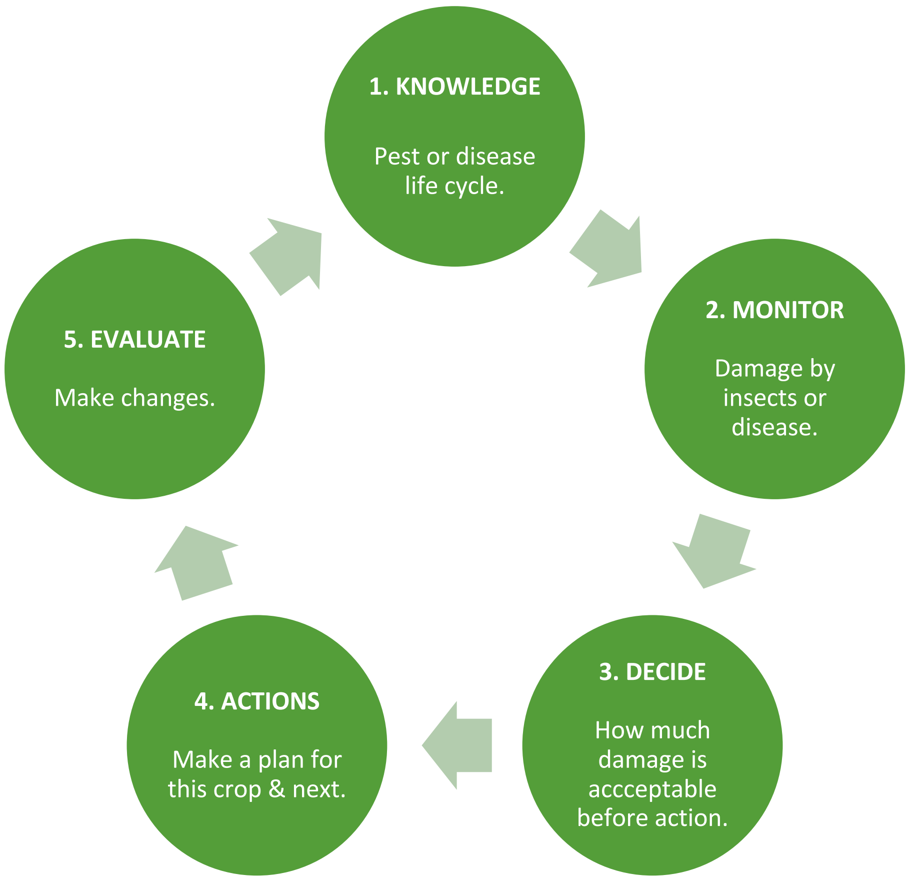


Fig. 4.1 The IPDM cycle, indicating the information needed and the actions required for IPDM to be successful

It is important to remember that in IPDM, pesticides may be used but only as a last resort

EXERCISE 13: What do you already know about IPDM cultural control methods for specific pests and diseases?

In groups, trainees should fill in the table below, for two pests and two diseases from their region, and then share and discuss their answers with the class. An example is given for an insect - diamondback moth on brassicas, and a fungus - *Elsinoe* scab on citrus.

	Crop	What IPDM cultural control methods are possible?			
		For large scale[9]	How it works	For small scale	How it works
Insect/mite pest					
Example: Diamondback moth (DBM)	*Brassicas*	*-Remove weeds in the Brassica family*	*-Reduces DBM populations that maintain populations between crops*	*-Hand picking caterpillars*	*-Removes pest*
1.					
2.					
Diseases					
Example: Citrus scab (Elsinoe fawsetti)	*Citrus*	*-Isolate nurseries from orchards*	*-Prevents spread of fungus.* *-Prune to keep canopy open*	*-Isolate nurseries from orchards* *- Prune to keep canopy open*	*Prevents spread of fungus.*
1.					
2.					

[9] Note, that it is much more difficult to apply IPDM to large-scale cropping, which is why pesticides are more often used at this scale.

4.3 Working through an example of using IPDM

Here is an example of the IPDM process from applied to the green vegetable bug (*Nezara*) on tomato (Fig. 4.2).

Green vegetable bug on tomato

Fig. 4.2 Top left, clockwise: Green vegetable bug nymphs; tomatoes with adult green vegetable bug; bug eggs on a tomato leaf; tomatoes with symptoms of green vegetable bug

KNOWLEDGE

What do we know?

- Identify it - Use your knowledge and the identification processes from Chapters 2 and 3
- Look up the fact sheet; check the colour, its smell and the damage it does. The bug causes white, hard spots where it sucks the fruit (Fig 4.2). See Pacific Pests, Pathogens & Weeds app.
- Life cycle - Where does it lay eggs? Are there any parasites (black eggs)? How long is the life cycle?
- How do you control it?

MONITORING

Checking on the pest damage

- Keep a diary and make notes
  - Is the damage getting worse?
- Go to the garden and check on the bug twice a week (adults and eggs)

  Look at every one to three plants up to the time of fruiting

  Look at every plant during the time of fruit picking

DECIDE

How much damage is acceptable before action?

- Is there more than one bug per plant? From your previous experience (or reading) you know that this will cause crop loss

ACTION

What can you do now and what you can do in the future?

Before planting

Soil - make sure you are planting in healthy soil (see Fact Sheet 468).

Variety - consider using a small fruiting variety that may suffer less damage.

Remove weeds from around the tomatoes.

Location - do not plant next to infested crops or downwind from other tomato crops.

Keep away from alternate hosts, e.g., beans, brassicas, cucurbits.

Biocontrol - plant flowering plants to attracts parasitoids, e.g., parasitic wasps.

Timing - plant when there are fewer pests around.

During crop growth

Keep plants well-watered and with nutrients.

Squash any eggs, nymphs or adults weekly.

Weed throughout the life of the crop.

Plant a trap crop - for example, your reading shows that the bug likes yellow, so plant marigolds, chrysanthemums, or mustard around the tomatoes.

Use homemade pesticide sprays - try chilli and others in Fact Sheet 56.

Protect fruits by bagging.

If homemade pesticides do not work, and the problem persists, only then use commercial sprays - synthetic pyrethroids.

After harvest

Collect the remains of the crop and burn or bury them.

Next crop - keep weeds to a minimum as bugs hide in weeds.

Next crop - use wider spaces between plants, so that bugs cannot hide.

Plant next crop in another place - practise crop rotation.

EVALUATION

Did the plan work? Make changes if needed

Go over the plan for this season and decide if changes are needed for the next season.

If you used sprays, did they work? Were the costs worth it?

EXERCISE 14: Using IPDM- Working out the steps.

The example of the green vegetable bug on tomato shows that, for IPDM to work properly, several important steps need to be taken. These steps are what the plant health doctors need to tell farmers at the PHC. This exercise tests your trainees' knowledge of the IPDM process.

Here are the steps needed for IPDM listed in the **incorrect order**. In pairs or small groups, place the steps in the correct order. Discuss your answers with the class.

INCORRECT ORDER

A. Go to the garden regularly. Look for damage.

B. Was your plan successful or not? Are any changes needed? Is it problem likely to be caused by a pest or a disease? Use the possible/probable approach in Chapter 2.

C. Make a plan of action for the present crop and the next crop: A) before planting (next crop); B) during growth of present crop; and C) after harvest of present crop. If it is a pest, count the pests (can you see natural enemies?). Is the problem getting worse or not? KEEP NOTES.

D. Decide how much damage is acceptable.

E. Knowledge - identify the pest or disease and know its life cycle.

CORRECT ORDER

4.4 Cultural control options for IPDM

The example of the green vegetable bug on tomato in section 4.3 identified a number of management options that can be used against an insect. Now we will look at these in more detail, and also at some that can be used against plant diseases. The methods involve cultural practices, biological control, as well as the use of pesticides, if necessary, as a last resort.

Good cultural practices are a safe and cheap method of disease control. There are many that can be used and, when several are applied together, they can have a very positive influence on insect pest populations or the incidence of diseases.

It is far better to use cultural practices to prevent or manage pests and diseases, than to use chemical methods (pesticides). It means money does not have to be spent on expensive products which may be harmful to the farmer, to beneficial organisms and to the environment. Also, it reduces the risk of insects becoming resistant to pesticides, which are then of no use, or more has to be applied to achieve control.

Healthy soil

Just as healthy people are less likely to get diseases than unhealthy people, healthy plants are far less likely to suffer from pests and diseases than weakened ones. Healthy soil that is rich in well-decomposed organic matter from compost, has all the essential nutrients and is well-drained, is best for most crops (Figure 4.3). There are some exceptions, e.g., rice requires water-logging, but is able to obtain its oxygen from air-filled cells that connect to the shoot, and taro can do the same.

Fig.4.3 Plots of Chinese cabbage in Vanuatu, with and without the addition of chicken manure showing the effect of nutrition on the crop.

If using chicken manure, it MUST be hot-composted first because it may carry harmful bacteria, e.g. *Salmonella*, and it will also ‘burn’ the plants if applied fresh

Soil treatment

Nursery soil may contain pests and diseases, so it should be pasteurised with boiling water or steam to prevent pests and diseases from spreading to the field.

Healthy planting material

Using healthy planting material – seeds, seedlings, roots and cuttings – is perhaps the most important of all the ways of controlling pests and diseases through cultural practices. There are many examples in the Pacific region of problems occurring because the planting material was infected or infested.

Root crops are especially vulnerable because they are vegetatively propagated, and pests commonly occur in or on the propagating material at planting, e.g. virus and root rot diseases of taro, nematode dry rot of yam, fungal scab and viruses of sweet potato, bacterial blight and scale insects on cassava.

There are also pests and diseases of vegetable and fruit crops that are spread with seedlings, e.g. head cabbage seedlings taken from nurseries with diamondback moth, large cabbage moth, and other caterpillars; watermelon seedlings with spots of gummy stem blight; and passionfruit grafted with scions infected with *Passionfruit woodiness virus*.

Seeds, too, can harbour pathogens, and long beans are frequently planted with *Bean common mosaic virus*. This means that disease outbreaks occur early and, consequently, the damage is greater than if the seed or seedlings were healthy to start with.

In some cases, the diseases are so damaging that healthy ‘seed schemes’ have been developed to remove the viruses from planting material by heat and tissue culture therapies. In the process, insects and fungal diseases are also eliminated. Seed schemes for avocado, banana, beans, citrus, grape, potato, strawberry and sweet potato are common throughout the world.

Mixed cropping

Many farmers in the Pacific region use mixed cropping. This is a technique in which two or more different types of crops are cultivated together, either in separate rows or mixed. Its advantage is that if one crop fails, there are other crops that can be harvested. Also, mixed cropping may reduce the spread of pests and diseases. Companion plants are sometimes used as part of the mix, e.g., tomatoes planted with onions and marigold, where the marigolds repel some tomato pests.

Crop rotation

Different crops have different pests and diseases, so those of taro, for instance, do not affect yams, and those of yams do not affect sweet potato, and those of sweet potato do not affect beans or cabbages. Therefore, crops are rotated to avoid the build-up of pests and diseases - in and above the soil - that often occurs when one type of crop is planted continuously.

Crop rotation also helps prevent excessive depletion of soil nutrients. Different crops have different nutrient requirements, so that one that needs less nitrogen can follow a crop that needs more. Legumes in rotation help to increase nitrogen in the soil because the bacteria on their roots 'fix' nitrogen from the air, converting it into compounds that plants take in and use for growth. Crop rotation also improves soil structure and fertility if deep-rooted and shallow-rooted plants are alternated. This can increase yields, maximise land use and add to crop and market diversity.

In Pacific islands, after clearing the land by slashing and burning, a common rotation was taro (or yam), one or two crops of sweet potato, cassava and then a bush fallow, often for up to 20 years, depending on the soil fertility and the pressure of the human population on the land. Modern-day population increase means that the fallow period is becoming shorter and shorter, and other ways of keeping soils fertile must be found. This can be done by adding compost, nutrients or mulch, or by growing legumes such as *Mucuna* beans or green manure legume crops that can be ploughed into the soil to increase nitrogen levels.

There has been a lot of interest in recent years in the effect of brassicas, particularly mustards, in crop rotation. When they are chopped finely to break the cells, and are incorporated into the soil, they release compounds called isothiocyanates that are toxic to fungal and bacterial pathogens. When the brassicas are harvested they can be cut off at the stem base so the root stays in the soil, and breaks down to release the toxins.

To get maximum benefit from crop rotation it has to be done properly. This is where we can help farmers decide on the correct sequence. Sometimes, without knowing, farmers plant vegetable crops that are all in the same family, such as tomato, eggplant, potato and tobacco, or cucumber, pumpkin, watermelon and squash, allowing pests and diseases of these families to build up. Thus it is important for farmers to know which crops are members of the same and different family groupings. Table 4.1 shows the different crops that farmers can use to help them draw up options to carry out effective crop rotation. Marigolds need to be planted as part of a rotation for nematode control.

Table 4.1 Common vegetables that belong to the same plant families or groups.

Cucurbit Family (Cucurbitaceae)	**Cabbage Family (Brassicae)**	**Potato Family (Solanaceae)**	**Root crops (not all in same family)**	**Cereal Family (Poaceae)**	**Legume Family (Fabaceae)**	**Leafy crops (not all in the same family)**
Cucumber	English Cabbage	Egg plant	Carrot	Maize	Long bean	Lettuce
Watermelon	Cauliflower	Potato	Taro		French bean	*Bele* (slippery cabbage)
Pumpkin	Chinese cabbage (Bok choy)	Okra	Yam		Mucuna bean	Spinach
Zucchini	Mustard	Chillies	Sweet Potato		Other beans	
Bitter gourd	Radish	Capsicum	Cassava			
	Broccoli	Tomato				
		Tobacco				

It is also important to rotate in the correct sequence, so that plants can benefit from the previous crop. For example, legumes will leave more nitrogen in the soil so should be followed by a crop that needs a lot of nitrogen, e.g. a leafy crop or maize (Fig. 4.4). Marigolds need to be planted as part of a rotation for nematode control.

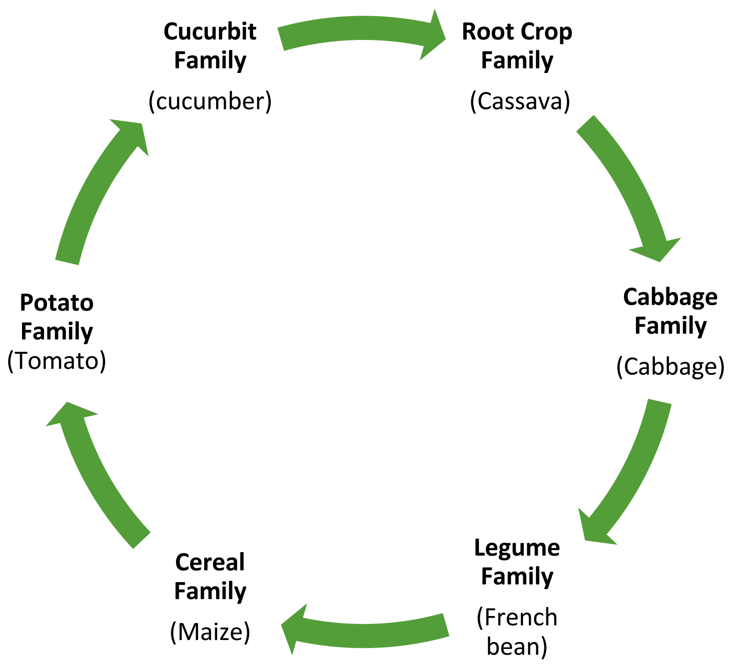


Fig. 4.4 An example of a crop rotation cycle.

EXERCISE 15: Applying crop rotation

In pairs or small groups, trainees should fill in the table below to show which group of crops and examples of each group would be good to use in a crop rotation in different plots. They should give reasons for their answers and discuss them with the rest of the class.

Cycle	Plot 1	Plot 2	Plot 3	Plot 4
1	Leafy crop e.g.			
Reason why you chose this crop rotation:				
2	Solanaceae crop e.g.			
Reason why you chose this crop rotation:				
3	Root crop e.g.			
Reason why you chose this crop rotation:				
4	Legume crop e.g.			
Reason why you chose this crop rotation:				

Isolation of crops

Isolation prevents pests and diseases spreading. Traditionally, taro and yam were grown in relative isolation within forests. It might have been done to hide the plants from evil spirits, or to protect them from theft or the strong winds and rains of the mountains, but the result was the same; severe pests and diseases were kept in check. This was also the time when the population was relatively low, and most people lived in mountainous inland areas. Today, it is different: the majority of people live on the coast, and populations are much higher. There is less forest, and gardens cannot be hidden, so it is much easier for pests and diseases to spread.

Isolation should also apply to nurseries. Nurseries should be far from field plantings to avoid the chance of infection by pests or infestation from diseases (Fig. 4.5).

Fig. 4.5 Bad practice: Chinese cabbage beds close to the nursery where plants are infested with DBM.

Good crop hygiene

Rogueing (removing infected plants) to destroy sources of infestations by insects and mites and infections by diseases (fungi, bacteria, phytoplasmas, viruses and nematodes) can have a huge benefit. It is especially effective if it is done early in the growth of the crop before the problem spreads, and regularly afterwards. It involves burning, burying or hot-composting infected plants before the problem gets any worse.

Removing the remains of the harvested crop is also beneficial. It will reduce fungal growth, spores, bacteria and insects that might otherwise spread to new crops or spread to volunteer (self-grown) plants or weeds, ready to attack the next crop.

Fig. 4.6 Bad practice: Diseased cabbages left in the field will infect the next crop to be planted nearby.

It is important to remove the infected or infested plants when they are first noticed in the field (Fig. 4.6). This is when the method has the greatest impact. Waiting until there are large numbers of insects or diseased plants will often make it too late to control the problem.

Weeds

Early detection and removal of weeds is important for several reasons:

- They can smother the crop, preventing it from getting sunlight
- They take water and nutrients that would otherwise feed the crop
- They can create conditions that favour the rapid increase of pests and diseases, for instance, by creating conditions of high humidity
- They harbour pests and diseases, which spread from the weeds to the crop

It is best to remove or cut down weeds before they flower and seed. If you remove weeds before they flower (i.e. before any seeds are produced), you can put them in a barrel of water and leave them for a few weeks. They make good fertiliser!

Companion planting

Companion planting can be thought of as a method of biological, as well as cultural control. Crops are interplanted or surrounded by other plants ('companions') that repel or attract insects for their benefit or improve the soil. The benefits might not be large, but they can be useful in many ways. It is a method that is probably more useful in backyard gardens and small farms than pest control in large areas, although companion plants can be grown along the edges of crops or between rows. The benefits of companion plants are listed below, with specific examples shown in Table 4.2.

- They may attract beneficial predator insects by providing a nectar source, and they may attract insect-eating birds
- They may attract insects that pollinate crops
- They may produce strong-smelling chemicals that repel or confuse pests
- They may attract pests away from crop plants
- They form a natural break between crops so that pests find it more difficult to travel from crop to crop
- They increase the level of biodiversity in the garden
- They can be used to support each other, e.g. corn stalks can act as support for yams Groups of crops planted together that are mutually beneficial are called 'guilds'

Table 4.2 Examples of companion plants and how they are thought to work.

Companion plant	What does it do?
Coleus (*Solenostemon*)	Planted among taro, possibly as a source of nectar for parasitoid wasps
Marigold *(Tagetes)*	Repels root knot nematodes. It must be planted as a block, not as scattered plants, for several months before the crop is planted
Basil (*Ocimum*)	Repels thrips, flies and mosquitoes
Coriander (*Coriandrum*)	Repels aphids, mites and leaf-eating beetles
Mint (*Mentha spp.)*	Repels aphids, cabbage moths and mice
Plants in the families Umbelliferae (e.g. carrots) and Compositae (e.g. daisies)	Attract hoverflies, lacewings and ladybird beetles; note, ladybird beetles (adults and larvae) as well as the larvae feed on plant-sucking pests
Chives and garlic *(Allium)*	Repels some species of aphids and mites
Chives and mustard	Said to be useful in preventing infection from bacterial wilt

Trap cropping is a variation of companion planting. *Bixa* (the lipstick tree) is an example from Solomon Islands, where it is has been seen to attract *Riptortus* bugs planted near yard long beans. Another example is planting mustard or Chinese cabbage (*bok choy*) alongside cabbages to attract diamondback moth and aphids, *but the plants must be destroyed before the eggs hatch.* In recent years, the FAO has been promoting the 'push-pull system' for the control of the fall armyworm. In this system, maize is intercropped with silverleaf or greenleaf desmodium (*Desmodium uncinatum* or *Desmodium intortum*, respectively). These legume species produce volatiles that repel FAW moths; this is the 'push'. Around the plots of maize, Napier grass (*Pennisetum purpureum*) is planted, a perennial grass that attracts FAW moths; this is the 'pull'.

Timing

Growing crops off-season when there are fewer pests and diseases present is a good strategy, although yields may be affected by sub-optimal environmental conditions. Planting early maturing varieties is a type of this strategy; it works well with, for example, sweet potato, where early maturity is sought by farmers to avoid weevil infestations, and also with yams to avoid lightning/dieback.

Resistant varieties

Some varieties of Pacific island food crops are more resistant to pests and diseases than others. They have been selected by growers over many hundreds, if not thousands, of years. For example, the so-called 'female' taro varieties in Solomon Islands are resistant to Alomae. Some yams are tolerant to lightning/dieback, especially the late-maturing varieties, and there are local, Pacific, varieties of bananas resistant to black Sigatoka disease.

Usually, it is not good to have a crop that is totally resistant to a pest or disease, as this can put pressure on the pest or disease to mutate, so that the crop is no longer resistant. A level of tolerance is better. An example is the Samoan and Papua New Guinea taro breeders' lines that were bred for tolerance to taro leaf blight.

We see similar differences in resistance in more recently introduced crops. For instance, among cocoa varieties there are differences in resistance to black pod and canker. In Papua New Guinea, varieties of cocoa have been bred for tolerance to those diseases and also to vascular streak dieback.

The greatest efforts of plant breeders are to be seen in the vegetable industry, where there are now numerous varieties resistant or tolerant to problematic diseases. For instance, there are tomato varieties that are resistant to root knot nematode, bacterial wilt and late blight; cabbages with tolerance to black rot and club root; and zucchinis resistant to several viruses.

Vegetable seed catalogues of all major companies list pest and disease characteristics of their commercial varieties. Pacific countries should take advantage of this, so that farmers have the very best chance of combatting pest and disease problems.

Biological control

Biological control makes use of the 'natural enemies' that are active all the time, without human influence and mostly without being noticed. There are many types of biological control: predators, parasites (mostly other insects), and also beneficial pathogens - bacteria, fungi, viruses and nematodes. (see Chapter 2, Section 2.3 "What is a pest?".

Fig. 4.7 Syrphids (pale green, slug-like), larvae of hoverflies, and larvae of ladybirds (purple) eating aphids on maize.

Predators that eat pest species are spiders, scorpions, ladybird beetles, lacewings and hoverfly larvae, predatory thrips and predatory mites (Fig. 4.7). They all hunt and kill their prey. Insect-eating birds, lizards and frogs are also useful in controlling pests. If these are present, care should be given to maintaining them. Some farmers keep ducks[10] and chickens that also eat pests.

However, it is the parasitoids – so-called because, unlike parasites, they kill their hosts – that often do most to control pests. The most common parasitoids are species of wasps (Fig. 4.8). Parasitoid activities often go on without farmers noticing them. Sometimes the 'mummies' of aphids can be seen on leaves; these are the dark, dead, swollen bodies of adult aphids, often with holes where parasitoid wasps emerged. But just because parasitoids go about their beneficial acts mostly unseen does not mean that farmers have no influence on the work that they do.

Fig 4.8 Adult *Diadegma* wasp, laying eggs in a larva of diamondback moth.

Pesticides and IPDM

Pesticides used by farmers are likely to have considerable impact as they will kill parasitoids, the natural enemies of pests.

Farmers need to know that if IPDM is to be successful, they should be very careful about pesticide use and, in particular, the type of pesticide used. Not all pesticides are the same. Many are broad-spectrum, which means they kill all insects. After the pesticide decays in the environment, the pest may come back in larger numbers as their natural enemies have been destroyed.

So, before reaching for a pesticide, farmers need to think whether natural enemies might be present. The difficulty in most instances is to know if there are any, as most natural enemies are minute wasps, too small to be seen by the naked eye.

Biocontrol and biological pesticides

The best solution is to avoid broad-spectrum pesticides. Instead, use those that decay rapidly after use or, if appropriate, use a product derived from bacteria, fungi, or viruses, which cause diseases in the pest. These have a specific biological rather than a chemical action and are known as 'biocontrol pesticides' or 'bio-insecticides'. Several have been commercialised to

[10] Indian runner ducks like to eat slugs and snails. These are a good solution for control of the Giant African snail.

maximise biocontrol in vegetables (see Fact Sheet no. 472 in the Pacific Pests, Pathogens & Weeds app).

Bt – *Bacillus thuringienisis*

Bacillus thuringienisis or Bt, is the best example of a commercialised bio-insecticide. Bt produces a protein toxin that kills larvae (caterpillars). The larvae stop eating, become limp and shrunken, then die and decompose. It is useful for the control of hornworms, some armyworms, diamondback moth, and many others. Usually, it is more effective against young caterpillars than against those near maturity.

Bt is sold under the name of AgChem Bt (in Fiji, Tonga and Samoa) but it is also sold as DiPel® or XenTari®. These formulations only infect caterpillars, but other strains can infect beetles (*Bt tenebrionis)* and fly larvae (*Bt israeliensis*).

Spinosad

Spinosad contains chemicals from the soil bacterium, *Saccharopolyspora spinosa*. It is sold under the name of *Success*, and used against a similar range of insects as Bt.

Metarhizium* and *Beauveria

Fungi are also used as biological insecticides. *Metarhizium* causes green muscardine disease. The fungus has been used extensively in parts of the Pacific against the rhinoceros beetle of coconuts, and also against *Papuana* beetle of taro. In other parts of the world it is used against swarms of locust. To a lesser extent, *Beauveria* is used; this causes white muscardine disease of termites, whiteflies and beetles.

Beauveria is being used in the highlands of Papua New Guinea (and elsewhere) against the coffee berry borer weevil *Hypothenermus*.

Note: products such as 'Green muscle' or Green guard', containing strains of *Metarhizium anisopliae* have been used against locusts in East Africa and other parts of the world

Trichoderma

Some fungi are used as biological fungicides. *Trichoderma,* a soil fungus, has been commercialised for use against a number of soil pathogens. It readily colonises the root system of plants, out-competing potential pathogens. To do this, it produces antibiotics against its competitors, as well as parasitises them. There is also evidence that it produces chemicals that increase the resistance of the host plant to root pathogens.

Viruses

Viruses can be highly effective natural control agents of several caterpillar pests but commercialisation has been limited. The naturally occurring nuclear polyhedrosis virus is sold under the name of *Gemstar* but mass production is costly, as it has to be multiplied in living insects. The best example in the Pacific region is the use of *Oryctes rhinoceros nudivirus* for the control of *Oryctes*, the rhinoceros beetle - Pacific strain. Unfortunately, it does not appear to control the Guam strain that is now in some Pacific countries.

Nematodes

There are several *Heterorhabditis* and *Steinernema* species of nematodes, which are used against a variety of agricultural pests. They attack insect larvae, tracking them in soil by following their excretions, carbon dioxide emissions or temperature changes. Once found, the young, called juveniles, enter the insects through natural openings and release a bacterium that kills the insects within one or two days. The nematodes mate, lay eggs and produce many young, which feed off the body of their host, until they are released into the soil, and the cycle starts all over again.

Fig. 4.9 provides a summary of all methods that can be used for management of pest and disease problems.

Management options for pests, diseases and abiotic factors

CULTURAL

1. Healthy soil
2. Healthy planting material
3. Mixed cropping
4. Crop rotation
5. Isolation of crops
6. Crop hygiene
7. Removal of weeds
8. Companion planting
9. Timing
10. Resistant/tolerant varieties
11. Aspect/location

BIOLOGICAL

1. Predators, e.g., insects, spiders, scorpions, ducks, chickens, lizards, snakes, frogs, birds
2. Parasitoids - insects whose larvae are parasites which eventually kill their hosts, e.g., some wasps
3. Biological fungicides, e.g., *Trichoderma, Metarhizium Beauveria*
4. Biological insecticides, e.g., Bt, Spinosad, *Oryctes rhinoceros nudivrius*
5. Nematodes, e.g., *Heterorhabditis, Steinernema*
6. Companion planting

CHEMICAL (PESTICIDES)

Insecticides, fungicides, herbicides etc. (Chapter 5)

1. Home-made
2. Commercial

Fig. 4.9 A summary of all control options for pests, diseases and abiotic factors.

EXERCISE 16: Concept mapping of IPDM

After working through the information on IPDM, your trainees should have a good overview of the concepts. This exercise helps them make the connections between them.

In pairs or small groups, trainees should write each of the following terms (concepts) on a piece of paper or sticky note. They should arrange them and stick them on butcher's paper or brown paper to create a concept map, linking the terms. It is important that they **write the relationship between the terms on the linking lines**. When they have finished, ask them to put their map on the wall and explain the map to the rest of the class.

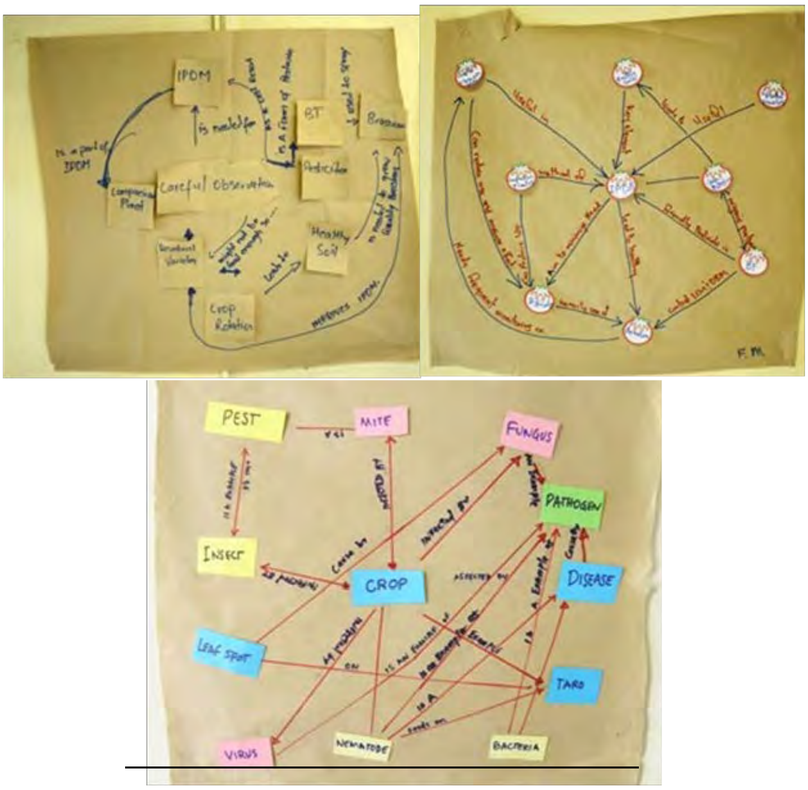


Fig. 4.10 Examples of concept maps from Tonga and Solomon Islands

Here are some suggested terms for a map. You or your trainees can decide to add other terms or change them, depending on the concepts you are teaching

- IPDM
- Companion plants
- Pesticides
- Bt
- Resistant varieties
- Healthy soil
- Brassicas
- Crop rotation
- Careful observation

EXERCISE 17: Summary of cultural practices for IPDM control of some common pests and diseases

In pairs or small groups, trainees should use the resources and information covered in this section to complete the table below. They should use examples they are aware of. Indicate with a tick (✓) which cultural practices they think work to control the pest or disease. They should indicate with a cross (X) if they think it will not work. When finished, trainees should discuss their ideas with the rest of the class.

An example (tomato fruit borer) is provided.

Cause	Example	Crop and part affected	CR*	GH*	F*	GD*	CP*	V*	HPM*	HP*	TC*	BC*
Pests (Insects and mites)	Tomato fruit borer	Tomato fruit	✓	✓	X	X	X	X	X	✓	✓	✓
Nematodes												
Pathogens (fungi, bacteria and viruses)												

*KEY

- CR: Crop rotation
- GH: Good hygiene
- F: Fertiliser/compost/organic matter
- GD: Good drainage
- CP: Companion planting
- V: Resistant variety
- HPM: Healthy planting material
- HP: Hand picking
- TC: Trap crops
- BC: Biological control

END OF SECTION 4 QUIZ: Test your knowledge

Multiple choice. Pick one answer only.

1. In IPDM, pesticides should be used:

A. always
B. never
C. as a last resort
D. only if the farmer can afford them

2. The adult in the picture below is most likely to be:

A. a beetle
B. a wasp
C. a lacewing
D. a fly

3. In order, a companion plant, a bio-insecticide and a beneficial organism are:

A. taro, DBM, *Trichoderma*
B. Chinese cabbage, kocide, ladybird
C. coconut, pyrethrum, *Trichogramma*
D. marigold, *Metarhizium*, spider

4. An example of good crop rotation would be:

A. lettuce, cabbage, broccoli, bean
B. cucumber, squash, potato, cassava
C. potato, tomato, eggplant, capsicum
D. bean, cabbage, cassava, cucumber

5. Rogueing means:

A. using bio-insecticides
B. destroying infected plants
C. using companion plants
D. planting resistant varieties

6. In IPDM, monitoring involves:

A. deciding whether the problem is caused by a pest or a disease
B. using the best pesticide for the pest
C. checking the level of damage and looking for bugs and eggs
D. identifying the pest or disease

7. The correct sequence for applying IPDM is:

A. monitoring, evaluation, making a plan, identification of pest or disease
B. evaluation, monitoring, identification of pest or disease, making a plan
C. making a plan, identification of pest or disease, monitoring, evaluation
D. identification of pest or disease, monitoring, evaluation, making a plan

8. Which plants are all in the same plant family?

A. cabbage, bok choy, broccoli, chilli
B. potato, cassava, taro, sweet potato
C. bitter gourd, pumpkin, cucumber, squash
D. capsicum, chilli, eggplant, bean

9. The best way to control a soil-borne bacterial infection is:

A. to use a resistant variety if it can be obtained
B. to spray with a pesticide
C. to find a virus that attacks the bacteria
D. to add compost to the soil

10. Which of the following is NOT thought to be a characteristic associated with companion planting?

A. companion plants can provide food for parasitoids
B. companion plants may have a smell that repels pests
C. companion plants put copper into the soil
D. companion plants may repel root knot nematodes

CHAPTER 5

Integrated Pest and Disease Management Options 2: Using Pesticides

This chapter covers a range of pesticides and how to use them safely.

What equipment do I need?

- ✓ **Pesticide labels (for Exercise 17)**
- ✓ **PNG videos on Safer use of Pesticides**
- ✓ **Photos of pests and diseases from PNG Highlands (for Exercise 21)**
- ✓ **Knapsack sprayer and nozzles**
- ✓ **Butcher's paper or brown paper**
- ✓ **Marker pens**
- ✓ **Samples from farm or garden**

5.1 Introduction to using pesticides

In Chapter 4, your trainees learned about cultural practices of managing plant pests and diseases within an IPDM system. They also learned that in an IPDM approach, pesticides are used as a last resort because of the many problems with their use. The reality is that large-scale pesticide (chemical) use throughout the world is likely to continue for some time. If pesticides are to be used, it is best not to use those which are broad-spectrum as they kill all harmful insects as well as those that are beneficial. Some pesticides are allowed in organic farming as well. In this chapter we look at a range of pesticides and how to use them safely.

The definition of a pesticide is a substance that is made to kill pests, such as insects, weeds, pathogens, mites, rodents, snails and slugs. Sometimes they are referred to as chemicals. Because they are poisonous, pesticides should be used only in IPDM when cultural controls do not work. Pesticides can be divided into two groups: homemade (Table 5.1) and commercial (Table 5.2). Homemade pesticides are made from materials usually readily available in the home or from local plants. Commercial pesticides MUST be made up according to the manufacturer's instructions.

5.2 Homemade pesticides

Many farmers and people living in urban areas make their own pesticides because it is cheaper to do so. However, there are drawbacks. The recipes, and hence the active ingredients in the sprays, vary a great deal. We have not tested them for the problems that exist in the Pacific region, so we don't know if our recommendations are going to work. For instance, chilli is recommended against caterpillars and other kinds of insects, but the type of chilli to use, whether it is affected by age, how much to use and which caterpillars are controlled are unknowns.

There is also the safety factor. Just because a spray is home-made, does not mean that it is safe to use. Some ingredients are toxic; for example, tobacco contains nicotine, which is poisonous to mammals. There is also the possibility of spreading viruses that may be present in tobacco leaves used as a pesticide. So, take care when these products are being made, and when they are being used.

Treat all homemade pesticides as **poisons**; never assume they are harmless. Be sure to test any homemade spray you make on just a few plants **before** spraying the entire garden

Table 5.1 Homemade pesticides, including some common bought products, where they are used, their active ingredients and their purpose. The list is from Solomon Islands. Where used elsewhere is also indicated.

HOMEMADE PESTICIDES							
Type of pesticide	**Fiji**	**Samoa**	**Solomon Islands**	**Tonga**	**Active Ingredient**	**Purpose**	**Remarks**
Ash	✓	✓	✓	✓	Potassium and calcium carbonates (alkali)	Grasshoppers and beetles	
Baking soda		✓			Sodium bicarbonate (alkali)	Used against powdery mildew fungi, and also against ants	Also used to rid apples of pesticide residue
Beer	✓	✓	✓	✓	Alcohol	Slugs and snails as bait	Also used as fruit fly bait in Australia
Chilli	✓	✓	✓	✓	Capsaicin	Ants, aphids, caterpillars, mealybugs	
Derris	✓		✓		Rotenone	Caterpillars, grasshoppers, aphids, spider mites, planthoppers, beetles	Rotenone is a fish poison
Fu'u (*Barringtonia* species)			✓		Saponins	Caterpillars, aphids and more	Fish poison used in Solomon Islands
Garlic	✓		✓		Allicin	Caterpillars, mites, thrips, and possibly some fungal diseases	
Gliricidia	✓		✓		Dicoumarol (interferes with vitamin K)	Aphids, caterpillars, whitefly, and also a rat poison	May need to mix bark with maize and boil and then allow to ferment
Hot water	✓	✓	✓	✓	Heat	Ants, nematodes in yam cuttings for planting and to sterilise nursery soil	

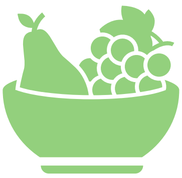
Marigold	✓		✓	✓	α-therthienyl	Insects and is a repellent (planted for control of (root knot) nematodes)	*Tagetes patula, Tagetes erecta,* and *Tagetes minuta*
Milk					Milk fat	Powdery mildew fungi	Use full cream (whole milk) at full strength
Neem	✓	✓	✓		Azadirachtin	Caterpillars, grasshoppers and many more; some fungi and nematodes	Mature seeds have higher active ingredient
Papaya					Papain (enzyme breaks down proteins)	Thrips	
Soap	✓	✓	✓	✓	Sodium stearate (alkali)	Scale insects, mealy bugs, aphids, and mites	
Soursop	✓	✓	✓		Acetogenins	Aphids, caterpillars, (e.g. DBM), planthoppers, grasshoppers	
Tobacco			✓		Nicotine	Caterpillars, aphids and more	
White oil					Smothers pests	Powdery mildew fungi and also many sucking insects, especially scales, aphids, and mites	

5.2.1 Safe handling of home-made pesticides

When handling home-made pesticides:

- Select fresh, healthy plant parts to use as pesticides; reject plants with mould on them.
- Dry plant parts properly for future use. Keep in an airy container (not a plastic container) in a shady place.

- Do not use household cooking utensils or drinking water containers for preparing plant extracts. Clean all tools well after using them.
- Avoid contact with crude extracts during preparation; wear protective clothing when applying. If you do not have rubber gloves, cover your hands in plastic bags.



- Keep plant extracts away from children, house pets and other animals.
- Harvest all mature and ripe fruits on trees before spraying.
- Always test the plant extract on a few infested plants before large-scale spraying.

- Wash your hands after handling the plant extract and wash your clothes as well.
- If there is left-over spray, dispose of it properly (see section 5.3.1).

5.2.2 Preparing home-made pesticides

Homemade pesticides can be used in many different ways to control pests. Review the following recipes with your trainees.

Chilli

Active against ants, aphids, caterpillars, mealybugs.

1. Take 1 cup dry or 2 cups fresh chillies.
2. Crush to a fine paste.
3. Put the paste into a bucket with 1 litre of water and rub with your hands (wear rubber gloves or cover hands with plastic bags). Soak for at least one hour, squeeze and strain.
4. Make up to 1 litre of water.
5. Add 1 teaspoon of grated hand soap.

Soursop or custard apple

Active against aphids, caterpillars, (diamond back moth), plant hoppers, grasshoppers.

1. Boil 500 g of fresh leaves in 2 litres of water until the water is reduced to 0.5 litre.
2. Dilute to a total of 10 litres of water.
3. Strain and add 10 teaspoons of grated hand soap.

OR

1. Take 2 handfuls of seeds and grind to a fine powder.
2. Mix with 4 litres of water and soak overnight.
3. Strain and add 4 teaspoons of grated hand soap.

Tobacco

Active against caterpillars, aphids, beetles

1. Crush 5 large leaves.
2. Add 1 litre of water and leave overnight.
3. Make up to 2 litres with water.
4. Strain and add 4 teaspoons of grated hand soap.

Garlic

Active against caterpillars, mites, thrips, and possibly some fungal diseases

1. Scrape 4 garlic cloves and soak them overnight in a small amount of vegetable oil.
2. Make up to 2 litres with water.
3. Strain and add 4 teaspoons of grated hand soap.

Neem

Active against caterpillars, aphids, grasshoppers, whiteflies, beetles, scale insects (either killing or repelling them). It stops insects from feeding.

Leaves:

1. Put 1 kg of leaves and 5 litres of water in a bucket and leave overnight.
2. Remove the leaves. Retain the water.
3. Pound and squeeze the leaves.
4. Add the 5 litres of water used for soaking the leaves overnight.
5. Strain and add 5 teaspoons of grated hand soap.

Mature seeds:

1. Wash and remove the dry husk.
2. Take 12 handfuls of dry seeds (or use 500 g for each litre of water).
3. Grind them to a fine powder.
4. Mix the powder in 12 litres of water and soak overnight.
5. Strain and add 10 teaspoons of grated hand soap.

Derris

Active against caterpillars, grasshoppers, aphids, spider mites, plant hoppers, beetles. (Note, this is **very toxic** to fish).

1. Take 2 roots of derris (20 cm long and as thick as a small finger) and crush well.
2. Put the crushed roots in a bucket and cover them with water; leave overnight.
3. Make up to 2 litres with water.
4. Strain and add 4 teaspoons of grated hand soap.

Marigold

Active against insects and is a repellent (planted for control of nematodes).

1. Collect 2.5 kg leaves/flowers; pound and mix with enough water to cover them.
2. Strain through a cloth and make up to 18 litres of water; add 4 teaspoons of grated hand soap.

Gliricidia

Active against aphids, caterpillars, whitefly

1. Grind or pound 0.5 kg leaves.
2. Soak overnight in water.
3. Make up to 20 litres with water.
4. Strain and add 5 teaspoons of grated hand soap.

Papaya

Active against thrips Active against insects and is a repellent (planted for control of nematodes).

1. Shake 1 kg of leaves in one litre of water and squeeze through a cloth.
2. Add 4 litres of soap solution (100 g soap/25 litres water).

Soap

Active against scale insects, mealybugs and aphids

Note: Use hand soap, not washing detergent

- Put 5 tablespoons of soap into 4 litres of water

or

- 2 tablespoons of dishwashing liquid in 4 litres of water.

Ash

Active against grasshoppers and beetles

1. Take ash from a fire (make sure it is cool).
2. Beat it to make it fine.
3. Put it in a coarse cloth or a strainer.
4. Shake thinly over each leaf.

Hot water

Active against ants, nematodes in yams, and used to sterilise nursery soil.

Ants – Use hot water to destroy nests, but be careful not to pour hot water onto the roots of small plants that might be growing close to the nests. You will kill the plants!

Soil – Use hot water to sterilise soil: pour it over the soil you have placed in seed boxes or over nursery soil that is spread thinly on the ground.

Yams – Use hot water to kill nematodes in yams with dry rot, before cutting and planting. Dip the whole yam in hot water at 51 degrees for 10 minutes (use a thermometer and clock – do not guess!).

White Oil

Active against powdery mildew fungi and many sucking insects, especially scales.

1. Pour 3 tablespoons (1/3 cup) cooking oil into four litres of water.
2. Add ½ teaspoon detergent soap.
3. Shake well and use.

Milk

Active against powdery mildew fungi

1. Use full-strength milk, diluted to 10% (1 part milk, 9 parts water).
2. Add a few drops of dishwashing liquid as milk does not spread over the leaf surface by itself.

Beer

Active against slugs and snails

1. Place beer in a shallow pan/saucer with edges even with the ground.
2. Snails and slugs will crawl in for a taste and drown.

Baking soda (sodium bicarbonate) (1)

1. Dissolve one or two tablespoons of baking soda in 4.5 litres of water.
2. Spray once a week.

Sodium bicarbonate can be an effective way of controlling fungal growth. It is registered by the US Environmental Protection Agency as a bio-pesticide.

Sodium bicarbonate increases the alkalinity of the surface of the leaves so that is becomes unfavourable for the growth of fungi. It might also leave a protective layer.

Sodium bicarbonate can be used on cabbage, cucumber, lettuce, melon, squash and tomato. It is also useful for most ornamentals, although it is advisable to test a few leaves first before you spray the whole plant, as herbs and other tender-leafed plants may show signs of burning.

Baking soda (sodium bicarbonate) (2)

An insecticide for soft bodied insects such as aphids and a fungicide for vegetables

1. Combine five cups of warm water with:
    - 2 teaspoons baking soda
    - 2 teaspoons dishwashing liquid
    - 1.5 teaspoons of vegetable oil
    - 1.5 teaspoons of natural vinegar

2. Blend until the mixture is white and foamy, then spray it on the plants right away with a hand sprayer. Agitate the sprayer as you go. Try to cover the leaves of your plants and give any bugs a good shower of the spray, so that it covers their exoskeleton and suffocates them.

5.3 Commercial pesticides

As discussed in Chapter 4, pesticides, in particular commercial products, should be used only as a last resort under the IPDM framework. When working with commercial pesticides, trainees must be aware of the dangers, not only to crops but also to those who are applying them and their families. When using commercial pesticides, the trainees should make sure that the labels are read carefully and checked to make sure they are the right product.

Commercial pesticide manufacturers create these products to make a profit. So some manufacturers may try to increase their sales by giving a new name and packaging to a 'new' pesticide, which may not be new at all, but just using the same active ingredients as many older products.

It is important to understand and be aware of the active ingredients in commercial pesticides, so that money is not wasted on gimmick products and more importantly, to avoid contributing to pesticide resistance in crops.

Before going further, test your trainees' prior knowledge of commercial pesticides asking them to complete Exercise 18.

EXERCISE 18: What do you already know about commercial pesticides?

This exercise for commercial pesticides complements the one on homemade pesticides in Table 5.1.

Trainees should describe their use in the *Purpose* column and insert an **F (fungicide), I (insecticide), H (herbicide) or M (molluscicide)** in the column *Type of pesticide*. If they know the active ingredient used, also list this. Check answers in Table 5.2.

Pesticide name	Purpose	Type of pesticide	Active ingredient
Attack			
Sundomil			
Glyphosate			
Kocide			
Confidor			
Orthene			
Agazone			
Suncloprid			
Talendo			
Blitzem			
Steward			
Prevathon			
Others:			

Table 5.2 Common commercial pesticides used in the Pacific Islands (as of 2019).

BOUGHT PESTICIDES							
Common or Trade names	**Fiji**	**Samoa**	**Solomon Islands**	**Tonga**	**Active ingredient**	**Purpose**	**Remarks**
Insecticides & miticides							
Attack	✓	✓	✓	✓	Pirimiphos-methyl/permethrin	Caterpillar, aphids	Broad-spectrum – kills beneficial insects as well
Bt	✓	✓	✓	✓	Bacillus thuringiensis	Larvae of Lepidopterous insects, armyworms, fruit and pod borers	Selective for caterpillars
Match	✓	✓		✓	Lufenuron	DBM in cabbage	Growth inhibitor
Steward	✓	✓		✓	Indoxacarb	Caterpillars, pod borer, armyworm, centre grubs, cutworm, leafroller, leafminers	Low toxicity on non-target insects
Prevathon	✓	✓		✓	Rynaxypyr or chlorantraniliprole	Caterpillars, pod borer, armyworm, centre grubs, cutworm, leafroller, leafminers	Selective for caterpillars
Multiguard	✓	✓		✓	Abamectin	Broad mite, caterpillars	Broad-spectrum – kills beneficial insects as well
Bifenthrin	✓	✓	✓	✓	Bifenthrin	Caterpillar, aphids, leafminers, thrips, mites and taro beetle	Broad-spectrum – kills beneficial insects as well
Confidor	✓	✓	✓	✓	Imidacloprid	Sucking insects like aphids, leafhoppers, thrips, whitefly, mealybugs, scale insects and taro beetle	Broad-spectrum – kills beneficial insects as well as

							taro beetle; toxic to bees
Suncloprid	✓			✓	Imidacloprid	As above	As above
Farmers' Imidacloprid	✓	✓			Imidacloprid	As above	As above
Orthene	✓	✓	✓	✓	Acephate	Chewing and sucking insects like caterpillars, aphids, thrips, leafminers, leafhoppers, cutworm on vegetables and fruits	Broad-spectrum – kills beneficial insects as well
Malathion	✓	✓	✓	✓	Malathion Bactralgel in Samoa	Leafhoppers, aphids, thrips, whitefly, mealybugs and spider mites	Broad-spectrum – kills beneficial insects as well
Karate			✓	✓	Lambda-cyhalothrin	Caterpillars, leafhoppers, aphids, thrips, whitefly, mealybugs and spider mites.	Broad-spectrum – kills beneficial insects as well
Suncis	✓		✓	✓	Deltamethrin	Caterpillar, beetles, thrips, whitefly on fruits and vegetables.	Broad-spectrum – kills beneficial insects as well
Fungicides							
Taratek/Bravo	✓			✓	Chlorothalonil and Thiophanate methyl	Broad-spectrum	Protective and systemic
Manzate	✓	✓	✓	✓	Mancozeb	Broad-spectrum	
Kocide	✓			✓	Copper hydroxide	Broad-spectrum	
Sundomil	✓	✓	✓	✓	Mancozeb	Broad-spectrum	

Talendo				✓	Chlorothalonil/ Thiophanate	Broad-spectrum	Protective and systemic
Kotek	✓	✓	✓	✓	Mancozeb	Broad-spectrum	
Herbicides							
Glyphosate/360/450/ Roundup	✓	✓	✓	✓	Glyphosate	Perennial, woody weeds	Systemic
Agazone	✓	✓	✓	✓	Paraquat	Annual and grass weeds	Contact
Bactericide							
Kocide	✓			✓	Copper hydroxide	Broad-spectrum	
Molluscicide							
Blitzem	✓	✓	✓	✓	Metaldehyde	Snails and slugs	Banning outdoor use is under consideration in Europe.

5.3.1 The pesticide label - an important document

Pesticide labels should provide all the information about how to use the chemical. Trainees should understand that once they have bought a pesticide, they must always **READ, UNDERSTAND** and **FOLLOW** label directions.

The label should have information on:

- the type of product
- what it contains
- the crops it may be used on
- the pests it may be used against
- how it may be applied
- personal protective equipment
- transport
- storage
- disposal after use
- environmental concerns
- what to do in emergencies

Trainees should not be surprised if they can’t find all the information they need on the label: it might be missing! If it is not present, it may be because there was not enough space for all the details

Often the label is divided into three panels or sections laid out in a row or column: left, central and right. BUT NOT ALWAYS! The central panel may be above the other two instead.

Central panel

The central panel contains information on *common and trade names, what is in the product, what it is used for, as well as the risks involved in using it*. The information usually consists of all or some of the following:

- ***Warnings:*** It might catch fire, keep it away from children, it can damage the environment, particularly fish and bees
- ***Trade name:*** The name given by the company, e.g., *Attack* or *Bravo*
- ***Common name:*** A name recognised internationally, e.g., pirimiphos-methyl and permethrin (*Attack*) and chlorothanonil (*Bravo*)

- **Concentration of the active ingredient**: the number of grams per litre, e.g. 475 g/litre pirimiphos-methyl and 25 g/litre permethrin (*Attack*)
- ***What it is:*** Insecticide, fungicide, herbicide, etc.
- ***What it is used for:*** For example: "A broad-spectrum insecticide for use on avocados, citrus, flowers and ornamentals, glasshouse tomatoes ..."
- ***Formulation:*** How the chemical is made, e.g., an emulsifiable concentrate - EC; a wettable powder - WP; granule - G; or dust – D:
  - EC - the chemical is dissolved in a liquid (solvent plus surfactants) that forms *fine droplets* when mixed with water
  - WP - the chemical is made into a solid, finely ground, and then forms a *suspension* when mixed with water
  - G - a mix of chemical, inert substances (called fillers) and binding substances, then made into pellets, e.g. Furidan pellets are put in the top of coconut palms to control *Oryctes.*
  - D - a mix of chemical and inert substances (called fillers)
- ***Net content:*** The total weight (g or kg), or volume (litres) of the pesticide product

Right panel

The right panel contains information on *precautions* and *first aid* if contamination or swallowing occurs. It may contain some of the items listed below:

- ***Hazard class:*** The World Health Organization has a set of hazard classes for health, based on eating or drinking the chemical and its effect on skin (tested on rats).
  - 1a - extremely hazardous
  - 1b - highly hazardous
  - II - moderately hazardous
  - III - slightly hazardous
  - U - unlikely to present acute hazard

The hazards are sometimes shown in the form of pictures at the bottom of the label:

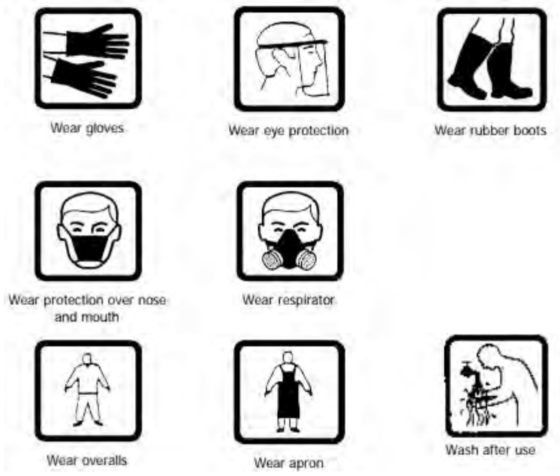


Fig. 5.1 Precautionary advice pictograms published by FAO to reduce risks when handling, applying and storing a pesticide.

- ***Storage:*** Store the product in its original container, tightly closed, and away from heat, food and out of reach of children, preferably in a locked cupboard. Note that in New Zealand, there are different rules depending on the amount of product stored in one place.

- ***Protective clothing:*** This covers the equipment and clothing that should be worn when mixing and applying pesticides, e.g. masks (including respirators) and goggles to protect mouth and eyes, gloves, boots, hat and overalls. After spraying, remove the clothing and wash your hands and face. Wash the clothes used when spraying separately from the normal clothes was. Do not eat, drink or smoke when spraying.

- ***Disposal:*** Notes on how to clean the sprayer and dispose of any remaining chemical residue (usually by spraying on soil at the side of the field, away from humans, livestock and waterways). There are also notes on how to dispose of the pesticide container, either by burying it or sending it to a landfill (Fig. 5.2). Do not re-use the container.

- ***First aid:*** What to do and who to contact if the product is swallowed, skin or hair is contaminated, or the chemical is splashed into the eyes. Usually, a doctor would be called, clothing removed, and skin and eyes flushed with water. Depending on the pesticide, the label will say whether vomiting should be induced or not. If inhaled, victims should be moved to fresh air, and given CPR if the heart stops beating.

> You should always go to the field with another person in case of accidents

- ***Spillage:*** What to do if a spill occurs. Wear protective clothing, cordon off the area, prevent the chemical from entering drains, absorb it with inert material *(soil, sand or sawdust)*, and place it in bins for disposal in a landfill. Wash the contaminated area with water.

- ***Transport:*** How the chemical should be transported, especially whether public vehicles *(buses, etc.)* can be used.

Left panel

This panel gives information on *recommended use and how to apply the pesticide*.

- ***Crops/pests used for:*** A list of pests and diseases for which the chemical is recommended in a country. Most Pacific island countries do not have a registration scheme specifically naming the crops on which the chemical can be used.

- ***How to mix and apply:*** Some chemicals need to be pre-mixed before they are added to the tank of the sprayer and mixed with a larger volume of water. The application of a chemical is usually given - either (i) X g/litre of product, sprayed until run off, or (ii) X kg/ha using Y litres of water (adjusted for young and fully developed crops). When to start spraying is often given, and the interval of application, e.g., apply the chemical every 2-3 weeks.

- ***Re-entry period:*** The period after applying the chemical when it is safe to re-enter the crop.

- ***Pre-harvest interval (commonly called the withholding period):*** The number of days between the last application of a chemical and the crop harvest. *This is very important information. It ensures that the harvest does not have residues that affect its market acceptability.*

- ***Compatibility:*** Two chemicals can sometimes be mixed together and used as one. Some companies will say if specific mixtures are safe (usually their own!).

Fig. 5.2 The incorrect way to discard a pesticide container, thrown to the side of the garden after use.

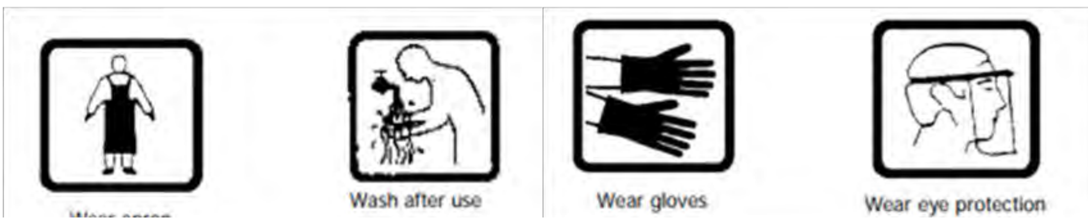
EXERCISE 19: Understanding the pesticide label

Understanding a pesticide label is critically important for the correct and safe use of pesticides. Exercise 19 focuses your trainees on how to understand the label.

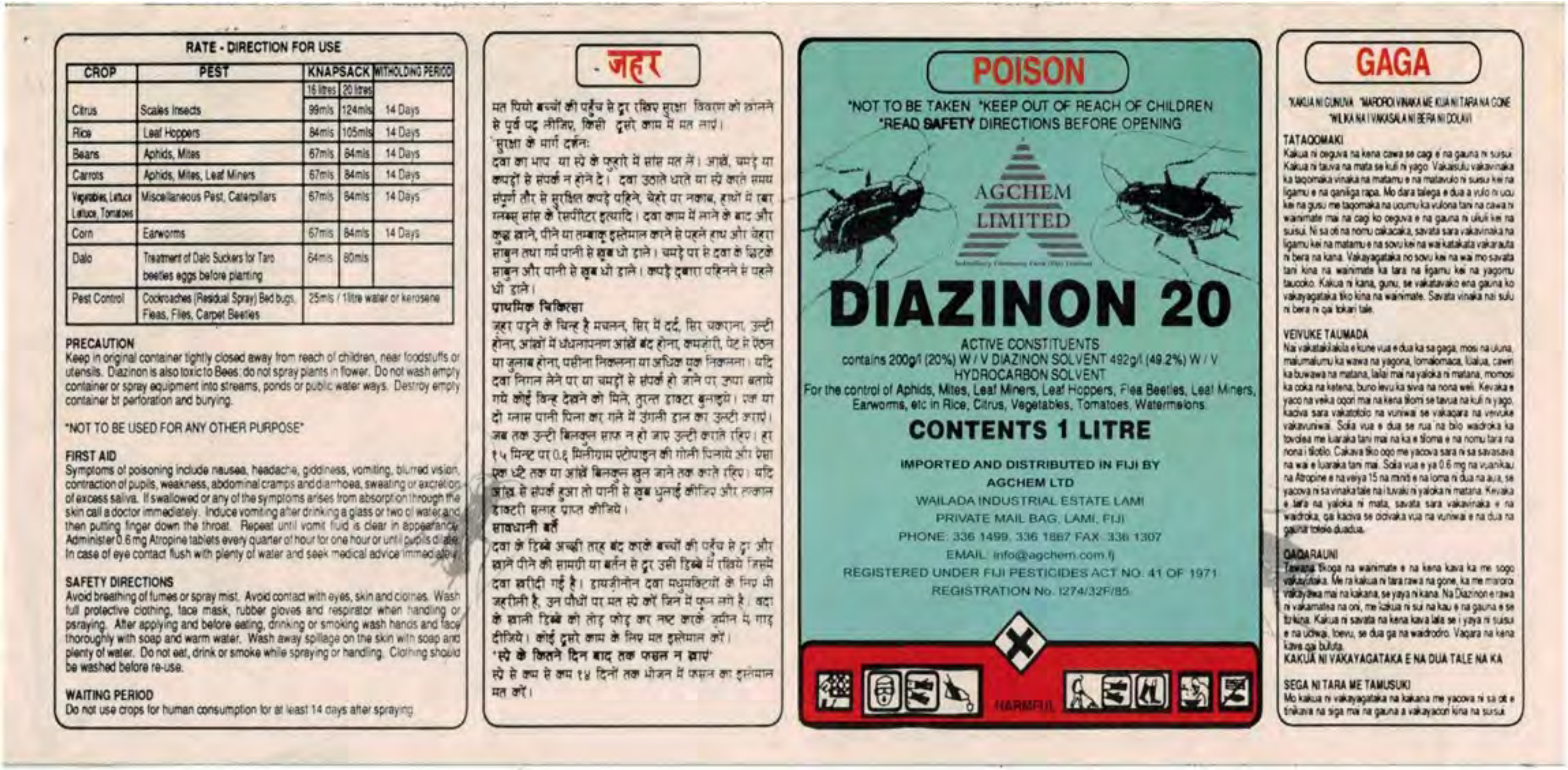
A range of commonly used pesticide labels are on the following pages. Make sure each group (pairs or threes) has a different label to work with. Trainees should carefully read their label and answer the following questions. They should write their answers on brown paper or butcher's paper so that they can be held up and read out to the class. If your trainees cannot find all the answers on one label, they should look at others.

1. What kind of pesticide is it? (i.e. fungicide, insecticide, herbicide etc.)
2. What is the pesticide used for?
3. What is the common name of the pesticide?
4. What is the trade name of the pesticide?
5. Is the label divided into separate panels? If so, what information does each of these panels give you?
   - Centre panel?
   - Left panel?
   - Right panel?
6. What is an emulsifiable concentrate (EC)?
7. What is a sticker?
8. What is a spreader?
9. What is meant by 'compatibility'?
10. What should you avoid doing when spraying, but do immediately after spraying?
11. What clothing is recommended when preparing the spray and spraying?
12. What is the recommended way to store the pesticide?
13. What does 'run-off' mean?
14. Is there a hazard number on the label? What is it and what does it mean?
15. What should you do after spraying and before eating, drinking or smoking?
16. Can you wash the sprayer or empty container in the river? If not, why not?
17. Where are the best places to put the container when it is empty?
18. Is it recommended that you induce vomiting if a person has drunk the pesticide?
19. If you spill the pesticide, what should you do?
20. Can you give livestock feed that has been sprayed with the pesticide?
21. What is meant by the pre-harvest interval (also known as the withholding period)?
22. What do these pictograms mean?

(a) (b) (c) (d)



5.3.2 Pesticide labels



RATE - DIRECTION FOR USE

CROP	PEST	KNAPSACK		WITHOLDING PERIOD
		16 litres	20 litres	
Citrus	Scales Insects	99mls	124mls	14 Days
Rice	Leaf Hoppers	84mls	105mls	14 Days
Beans	Aphids, Mites	67mls	84mls	14 Days
Carrots	Aphids, Mites, Leaf Miners	67mls	84mls	14 Days
Vegetables, Lettuce Lettuce, Tomatoes	Miscellaneous Pest, Caterpillars	67mls	84mls	14 Days
Corn	Earworms	67mls	84mls	14 Days
Dalo	Treatment of Dalo Suckers for Taro beetles eggs before planting	64mls	80mls	
Pest Control	Cockroaches (Residual Spray) Bed bugs, Fleas, Flies, Carpet Beetles	25mls / 1litre water or kerosene		

PRECAUTION
Keep in original container tightly closed away from reach of children, near foodstuffs or utensils. Diazinon is also toxic to Bees: do not spray plants in flower. Do not wash empty container or spray equipment into streams, ponds or public water ways. Destroy empty container bt perforation and burying.

"NOT TO BE USED FOR ANY OTHER PURPOSE"

FIRST AID
Symptoms of poisoning include nausea, headache, giddiness, vomiting, blurred vision, contraction of pupils, weakness, abdominal cramps and diarrhoea, sweating or excretion of excess saliva. If swallowed or any of the symptoms arises from absorption through the skin call a doctor immediately. Induce vomiting after drinking a glass or two of water and then putting finger down the throat. Repeat until vomit fluid is clear in appearance. Administer 0.6 mg Atropine tablets every quarter of hour for one hour or until pupils dilate. In case of eye contact flush with plenty of water and seek medical advice immediately.

SAFETY DIRECTIONS
Avoid breathing of fumes or spray mist. Avoid contact with eyes, skin and clothes. Wash full protective clothing, face mask, rubber gloves and respirator when handling or psraying. After applying and before eating, drinking or smoking wash hands and face thoroughly with soap and warm water. Wash away spillage on the skin with soap and plenty of water. Do not eat, drink or smoke while spraying or handling. Clothing should be washed before re-use.

WAITING PERIOD
Do not use crops for human consumption for at least 14 days after spraying.

जहर

मत पियो बच्चों की पहुँच से दूर रखिए सुरक्षा विवरण को खोलने से पूर्व पढ़ लीजिए, किसी दूसरे काम में मत लाएं।

सुरक्षा के मार्ग दर्शन:
दवा का भाप या स्प्रे के फुहारे में सांस मत लें। आंखें, चमड़े या कपड़ों से संपर्क न होने दें। दवा उठाते धरते या स्प्रे करते समय संपूर्ण तौर से सुरक्षित कपड़े पहिनें, चेहरे पर नकाब, हाथों में रबर ग्लव्स् सांस के रेस्पीरेटर इत्यादि। दवा काम में लाने के बाद और कुछ खाने, पीने या तम्बाकू इस्तेमाल करने से पहले हाथ और चेहरा साबुन तथा गर्म पानी से खूब धो डालें। चमड़े पर से दवा के छिटके साबुन और पानी से खूब धो डालें। कपड़े दुबारा पहिनने से पहले धो डालें।

प्राथमिक चिकित्सा
ज़हर पड़ने के चिन्ह है मचलन, सिर में दर्द, सिर चकराना, उल्टी होना, आंखों में धुंधलापन या आंखें बंद होना, कमज़ोरी, पेट में ऐंठन या जुलाब होना, पसीना निकलना या अधिक थूक निकलना। यदि दवा निगल लेने पर या चमड़ों से संपर्क हो जाने पर ऊपर बताये गये कोई चिन्ह देखने को मिले, तुरन्त डाक्टर बुलाइये। एक या दो ग्लास पानी पिला कर गले में उंगली डाल कर उल्टी कराएं। जब तक उल्टी बिलकुल साफ न हो जाए उल्टी कराते रहिए। हर १५ मिन्ट पर 0.६ मिलीग्राम एट्रोपाइन की गोली पिलायें और ऐसा एक घंटे तक या आंखें बिलकुल खुल जाने तक करते रहिए। यदि आंख से संपर्क हुआ तो पानी से खूब धुलाई कीजिए और तत्काल डाक्टरी सलाह प्राप्त कीजिये।

सावधानी बर्तें
दवा के डिब्बे अच्छी तरह बंद करके बच्चों की पहुँच से दूर और खाने पीने की सामग्री या बर्तन से दूर उसी डिब्बे में रखिये जिसमें दवा खरीदी गई है। डायज़ीनोन दवा मधुमक्खियों के लिए भी जहरीली है, उन पौधों पर मत स्प्रे करें जिन में फूल लगे है। दवा के खाली डिब्बे को तोड़ फोड़ कर नष्ट करके ज़मीन में गाड़ दीजिये। कोई दूसरे काम के लिए मत इस्तेमाल करें।

"स्प्रे के कितने दिन बाद तक फसल न खाएं"
स्प्रे से कम से कम १४ दिनों तक भोजन में फसल का इस्तेमाल मत करें।

POISON

"NOT TO BE TAKEN "KEEP OUT OF REACH OF CHILDREN
"READ **SAFETY** DIRECTIONS BEFORE OPENING

AGCHEM
LIMITED

DIAZINON 20

ACTIVE CONSTITUENTS
contains 200g/l (20%) W / V DIAZINON SOLVENT 492g/l (49.2%) W / V
HYDROCARBON SOLVENT
For the control of Aphids, Mites, Leaf Miners, Leaf Hoppers, Flea Beetles, Leaf Miners, Earworms, etc in Rice, Citrus, Vegetables, Tomatoes, Watermelons.

CONTENTS 1 LITRE

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HARMFUL

GAGA

"KAKUA NI GUNUVA "MAROROI VINAKA ME KUA NI TARA NA GONE
"WILIKA NA I VAKASALA NI BERA NI DOLAVI

TATAQOMAKI
Kakua ni ceguva na kena cawa se cagi e na gauna ni suisui. Kakua ni tauva na mata se kuli ni yago. Vakaisulu vakavinaka ka taqomaka vinaka na matamu e na matavulo ni suisu kei na ligamu e na qaniliga rapa. Mo dara talega e dua a vulo ni ucu kei na gusu me taqomaka na ucumu ka vulona tani na cawa ni wainimate mai na cagi ko ceguva e na gauna ni ululi kei na suisui. Ni sa oti na nomu cakacaka, savata sara vakavinaka na ligamu kei na matamu e na sovu kei na wai katakata vakarauta ni bera na kana. Vakayagataka no sovu kei na wai mo savata tani kina na wainimate ka tara na ligamu kei na yagomu taucoko. Kakua ni kana, gunu, se vakatavako ena gauna ko vakayagataka tiko kina na wainimate. Savata vinaka nai sulu ni bera ni qai tokari tale.

VEIVUKE TAUMADA
Nai vakatakilakila e kune vua e dua ka sa gaga, mosi na uluna, malumalumu ka wawa na yagona, lomalomaca, lialia, cawiri ka buwawa na matana, lailai mai na yaloka ni matana, momosi ka coka na ketena, buno levu ka siva na nona weli. Kevaka e yaco na veika oqori mai na kena tilomi se tavua na kuli ni yago, kaciva sara vakatotolo na vuniwai se vakaqara na veivuke vakavuniwai. Solia vua e dua se rua na bilo waidroka ka tovolea me luaraka tani mai na ka e tiloma e na nomu tara na nona i tilotilo. Cakava tiko ogo me yacova sara ni sa savasava na wai e luaraka tani mai. Solia vua e ya 0.6 mg na vuanikau na Atropine e na veiya 15 na miniti e na loma ni dua na aua, se yacova ni sa vinaka tale na i tuvaki ni yaloka ni matana. Kevaka e tara na yaloka ni mata, savata sara vakavinaka e na waidroka, qai kaciva se cicivaka vua na vuniwai e na dua na gauna totolo duadua.

QAQARAUNI
Tawana tikoga na wainimate e na kena kava ka me sogo vakavinaka. Me ra kakua ni tara rawa na gone, ka me maroroi vakayawa mai na kakana, se yaya ni kana. Na Diazinon e rawa ni vakamatea na oni, me kakua ni sui na kau e na gauna e se tiki kina. Kakua ni savata na kena kava lala se i yaya ni suisui e na uciwai, toevu, se dua ga na waidrodro. Vaqara na kena kava qai buluta.
KAKUA NI VAKAYAGATAKA E NA DUA TALE NA KA

SEGA NI TARA ME TAMUSUKI
Mo kakua ni vakayagataka na kakana me yacova ni sa oti e tinikava na siga mai na gauna a vakayacori kina na suisui.

Precautions

1. Product is poisonous if swallowed.
2. Will irritate the eyes and skin.
3. Facial skin contact may cause temporary facial numbness
4. Always wear protective clothing.

5. Avoid contact with eyes and skin.
6. Do not inhale spray mist.
7. When preparing spray, wear cotton overalls buttoned to the neck and wrist and a washable hat, elbow-length PVC gloves, face and shield.

First Aid

1. Remove contaminated clothing and bathe patient.
2. Wash the patients body thoroughly with plenty of soap and water.
3. Identify, as accurately as possible, the product(s) associated with the exposure. If possible, ask the patient. Store the container, label and leaflet to show to the doctor.
4. If breathing has stopped, provide artificial respiration.
5. No specific antidote. Treat symptomatically

Directions for Storage

1. Store in a cool place.
2. Do not store the product in the rooms of your home.

Spillage and Disposal

1. For small spills, take up with sand or other absorbent material and place into containers for later disposal.
2. Do not reuse container.
3. Wash contaminated area with soap and water.
4. Dispose of container into an approved sanitary landfill.

Tataqomaki

1. Ena rawa niko gaga ke gunuvi.
2. E na milamila na matamu se na yagomu ke tauva na wainimate oqo.
3. Ena rawa ni nunu na matamu ke terega na wainimate.
4. Me daramaki na sulu ni tataqomaki.
5. Kakua ni tauva na mata se kuli ni yago.
6. Kakua ni ceguva na cawa ni suisui.
7. Ena gauna ni uliuli, mo daramaka nai sulu me taqomaka na yagomu kei na ligamu, vaka qa ni liga rapa kei na i tataqomaki ni mata.

Veivuke Taumada

1. Luvata na i sulu sa terega na wainimate ka sili.
2. Me vakasilimi vinaka e na sovu kei na wai.
3. Raica na Vuniwai ke yaco e dua na leqa ka kauta vua e dua na i lavelave ni wainimate.
4. Ke sa tasogo na nona i cegu, me soli vua nai cegu ni veivuke taumada.

Kena Maroroi

1. Maroroi ena dua na vanua vinaka.
2. Ka kua ni maroroi ena dua na rumu ni nomu vale.

Kena Vakarusai

1. Buluta ena nuku ke tasova vakalailai na wainimate o qo, qai takiva kina dua na vokete me vakarusai.
2. Ka kua ni vakayagataka tale na kava lala.
3. Savata vinaka e na sovu kei na wai na vanua e tasova kina na wainimate.
4. Buluta na kava lala e na dua na vanua digitaki vinaka.

सावधानियां

1. उत्पाद अगर निगल लिया हो तो जहरीला है।
2. आँखो और त्वचा मे जलन होगा।
3. चेहरे की त्वचा के संपर्क के कारण स्तब्ध हो सकता है।
4. संवेदनशील मज़दूरो को सुरक्षित कपड़ो का उपयोग करना चाहिए।
5. आँखो और त्वचा के संपर्क से बचे।
6. स्प्रे की धुंध को साँस से मत मिलने दे।
7. स्प्रे की तैयारी; कपास चौगा पहीने गर्दन और कलाई तक, टोपी, कोहिनो तक लमबे ग्लवस, चे पर मास्क और कवच पहीने।

प्राथमिक चिकित्सा

1. दूषित कपड़े निकाले और साबुन पानी से मरीज़ का शरीर अच्छी तरह से धो ले।
2. अगर मरीज़ डॉक्टर के पास जाए तो उत्पाद का लेबल लेकर जाए ताकी उसे पता चल सके इस उत्पाद के विशय मे।
3. अगर साँस लेना बंद हो जाए तो कृत्रिम श्वसन लेना चाहिए।
4. कोई विशिष्ट मारक नही है तो लाक्षणिक उपचार करे।

सुरक्षित स्थान

1. उत्पाद को ठंडे जगह पर रखो।
2. अपने घर के कमरे मे उत्पाद को मत रखो।

छलकना और निपटान

1. उत्पाद छलक गया हो तो रेत या बाद से कंटेनर मे रख दे और फिर बाद मे निपटान करे।
2. कंटेनर का उपयोग दुबारा मत करे।
3. साबुन और पानी से दूषित क्षेत्र धो ले।
4. एक अनुमोदित सैनिटरी लैंडफिल मे कंटेनर के निपटान करे।

CAUTION

NOT TO BE TAKEN
KEEP OUT OF REACH OF CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING OR USING

AGCHEM LIMITED

HORTIGUARD

Composition of Content

Active Ingredient:

Abamectin	1.8%
Inert Ingredients	98.2%
Total	100%

For Agricultural use to control Leaf miners, Mites, Aphids and Thrips on Ornamental plants, Lawns and Crops like Capsicum, Eggplant Cottons, Citrus, Cabbage, Strawberries, and Tomatoes.

Contents 1L

Application Method

Crops	Crops - Pest/ Disease	Dosage (Per 100L water or as indicated)	Application Direction and Minimum Time between Last Application and Harvest or Feeding (F)	
			Days	Unless otherwise indicated dilutions are for high volume application.
Apples and Pears	Red spider mite and European red mite	35ml + 250ml spray oil (1000 - 2000 ml/ha + 0.25% spray oil)	7	Apply as a full spray when pest is noticed and repeat when necessary. Resistance to various pesticides may be encountered.
Cabbage	Diamond back moth, Pieris Rapae	22 -23ml		Add 2000 - 3000 times of water and spray.
Tomatoes Capsicum Eggplant	American leaf miner	60ml (300 - 1200ml/ha)	3	Apply at first signs of infestation as a full cover spray. Repeat application every 7 days or as needed to maintain control.
	Red spider mite	60ml (300 - 1200ml/ha)	3	Apply when pest is noticed and repeat when necessary. Resistance to various pesticides is evident. Full cover application.
Citrus	Thrips	10 -20ml + 300ml light or medium narrow range mineral oil	7	Apply at first signs of thrip presence. Use higher dosage rate when climatic conditions are favourable for thrip infestation. Apply as a light cover spray. Repeat when necessary. Do NOT apply more than 3 sprays or 2 consecutive sprays per season.

AGCHEM LIMITED

Imported & Distributed by:
AGCHEM LIMITED
Lot 5, Wailada Industrial Estate, Lami
Private Mail Bag, Lami Fiji Islands
Phone: 336 1499, 336 1867 Fax: 336 1307
Email: info@agchem.com.fj

SUNDAT

Manufacturer:
Sundat (S) PTE Limited
26 Gul Crescent, Singapore.

Registered Under the Fiji Pesticide Act No. 41 of 1971.

Registered No. I 776/221 F/85


Precautions
1. Product is poisonous if swallowed.
2. Will irritate the eyes and skin.
3. Facial skin contact may cause temporary facial numbness.
4. Sensitive workers should use protective clothing.
5. Avoid contact with eyes and skin.
6. Do not inhale spray mist.
7. When preparing spray, wear cotton overalls buttoned to the neck and wrist and a washable hat, elbow- length PVC gloves, face and shield.
First Aid
1. Remove contaminated clothing and bathe the patient.
2. Wash the patient body thoroughly with plenty of soap water.
3. Identify, as accurately as possible, the product(s) associated with exposure. If possible, ask the patient. Store the container, label and leaflet to show to the doctor.
4. If breathing has stopped, provide artificial respiration.
5. No specific antidote. Treat symptomatically.
Directions for Storage
1. Store in a cool place.
2. Do not store the product in the rooms of your home.
Spillage and Disposal
1. For small spills, take up with sand or other absorbent material and place into containers for later disposal.
2. Do not reuse container.
3. Wash contaminated area with soap and water.
4. Dispose of container into an approved sanitary landfill.
Tatagomaki
1. Ena rawa niko gaga ke gunuvi.
2. Ena milamila na matamu se na yagomu ke tauva na wainimate oqo.
3. Ena rawa ni nunu na matamu ke terega na wainimate .
4. Me daramaki nai sulu ni tataqomaki.
5. Kakua ni tauva na mata se kuli ni yago.
6. Kakua ni ceguva na cawa ni suisui.
7. Ena gauna ni uliuli, mo daramaka nai sulu me taqomaka na yagomu kei na ligamu, vakaqaniliga rapa kei na tataqomaki ni mata.
Veivuke Taumada
1. Luvata na i sulu sa terega na wainimate ka silivakavinaka.
2. Me vakasilimi vinaka e na sovu kei na wai.
3. Raica na Vuniwai ke yaco e dua na leqa ka kauta vua e dua na i lavelave ni wainimate.
4. Ke sa tasogo na nona i cegu, me soli vua nai cegu ni veivuke taumada.
Kena Maroroi
1. Maroroi e na dua na vanua vinaka.
2. Kakua ni maroroi e na dua na rumu ni nomu vale.
Kena Vakarusai
1. Buluta e na nuku ke tasova vakalailai na wainimate oqo, qai takiva kina dua na vokete me vakarusai.
2. Kakua ni vakayagataka tale na kava lala.
3. Savata vinaka ena sovu kei na wai na vanua e tasova kina na wainimate.
CAUTION
NOT TO BE TAKEN
KEEP OUT OF REACH OF CHILDREN
READ LABEL CAREFULLY BEFORE OPENING
AGCHEM
BIFENTHRIN 8 SC
Composition Content
Active ingredient: Bifenthrin.............................. 80 g/l (8%) % w/v
Inert ingredients.............................. 92% w/v
Total.............................. 100% w/v
Insecticide
A systemic Pyrethroid Insecticide and Acaricide with a board spectrum of activity which has a rapid knockdown and a long residual action
Content: 1 Litre
WHO III
Compatibility
Not compatible with alkaline materials.
Application Method
Crops | Pest | Knapsack Rate 16l | 20l | Withholding Period
Vegetables | Caterpillars, Aphids, Leafminers, White Fly, Thrips Mites | 15-20mls | 20-25mls | 3 Days
Rose Ornamentals | Caterpillars | 32mls | 40mls |
Dalo | Dalo Beetles | 40mls | 50mls | Start treatment once at planting and 3 months later at 100mls / plants
Household Pests | Spiders | 30-65mls/10L Water | Use the higher rate in situations where pest pressure in high, when a rapid knock down and/or maximum residual protection is desired. The lower rate may be used for follow up treatments
Cockroaches, Fleas Ants, Flies, Ticks, Paper-Nest Wasps, African-Black Beetles, Stem Weevils Mosquitoes | 65-125mls/10L Water
Imported & Distributed by:
AGCHEM LIMITED
Lot 5, Wailada Industrial Estate, Lami
Private Mail Bag, Lami Fiji Islands
Phone: 336 1499, 336 1867 Fax: 336 1307
Email: info@agchem.com.fj
Manufacturer:
SUNDAT (S) PTE Ltd
26 Gul Crescent, Singapore 629532
Registered under Pesticide Act No. 41 of 1971
Registration No. I562/211F/85

APPLICATION EQUIPMENT
Through coverage of grasses and weeds with spray of medium fine droplets is required for optimum control. Because contamination of propal with small amounts of certain pesticides results in injury to rice. Clean equipment with detergent solution and rinse with clean water before filling the tank. To avoid possible injury to other crops later, flush the sprayer with clean water immediately after each application. Can be applied with knapsack sprayers or motorized sprayers.

OPERATIONS CONDITIONS
Do not apply when wind velocities 5 to 10 miles per hour and cause poor plant coverage or spray to nearby susceptible crops. A slight cross – wind during spraying is desirable to equalize distribution. Fields may be treated when grasses and weeds are either fry or wet with dew. Rain within 3 to 6 Hours after application may reduce effectiveness, is most effective when applied in warm to hot weather. For best results it should be applied in day temperature to 23 – 26 degrees (74 – 80F)

DRIFT HAZARD TO OTHER CROPS
Propal injure most crops except cereal grains and perennial grasses. Avoid drift or accidental application on other crops such as cotton, soy bean, corn, safflower, seeding legumes, vegetables, orchards, vineyards, gardens, shrubs and ornamentals.

WARNING
Do not mix propal with carbamate or organophosphate insecticides nor apply chemicals within 10 days if using propal. Store in original containers, tightly closed in a safe place away from food stuff, seeds, fertilizers or other pesticides. Wash out empty containers and dispose with the chemical or used container.

NOT TO BE USED FOR ANY OTHER PURPOSE

SAFTEY DIRECTION
Avoid contact with eyes and skin. Avoid breathing spray mist. Wear rubber gloves and protective clothing when handling or spraying. Wash hands and exposed parts of the body after used and before eating, smoking or drinking. Do not eat or smoke while spraying.

FIRST AID
If swallowed, drink a glass or two of water then induce vomiting by putting a finger down the throat. Repeat until the vomit fluid is clear. Call a doctor immediately. In case of eye contact flush with plenty of water and seeks medical advise at once. If spilt on skin, wash immediately with soap and water.

IMPORTED AND DISTRIBUTED BY:
AGCHEM LTD.
LOT 5, WAILDA INDUSTRIAL ESTATE, LAMI
PRIVATE MAIL BAG, LAMI, FIJI
PHONE: 3361499, 3361867 FAX: 3361307
EMAIL: info@agchem.com.fj
REGISTERED UNDER THE PRETICIDE
ACT 41 OF 1971 (FIJI)
REGISTERED No. 1309 11F/85

NOTICE TO BUYER
Seller makes no warranty of any kind expressed or implied concerning the use of this product. Buyers assumes all risk of the use in handling whether in accordance with directions or not

AGCHEM LIMITED

QARAUNA

-MAROROYA VINAKA ME KUA NI RA TARA NA GONE
-REREVAKI KEVAKA E TILOMI
-WILIKA NA I VAKASALA NI BERA NI DOLAVI
-E WAINIMATE KAMA TOTOLO. KUA NI DOLAVA TU SE MO VAKAYAGATAKA SE NA LOMA NI 30 NA I YATE MAI NA DUA NI BUKA SE YAMEYAME

LEQA NI YACOVI IRA NA KA TEI TALE SO:
E rawa me vakacacana na porpal na veika tei tale e so, vakavo wale ga na veika me vaka na sila, raisi kei na witi kei na co bula tudei e na loma ni veigauna kece. Tovolea me kua ni vuka na kena cawa se me vakayagataki cala e na vetei tale e so me vaka na vauvau, soya bean, sila, sunflower sore ni legumes, kakana draudrau, loga ni vuanikau, loga ni viani, ilei, veico tubu lelevu kei na kau tei me i ukuku ni lomanibai.

NA VEIVUKE TAUMADA:
Kevaka e sa gunuvi, solia vua e dua se rua na bilo wai droka qai tovolea me lauraka tani tale mai. Oqo e rawa ni caka ena nomu tara na rona i tilotilo. Vakarautaka tale me yacova ni sa makare na wai ka lauraka tani mai. Kaciva sara vakatotolo na vuniwai. Kevaka e sikava se tauva na yaloka ni mata, suya tani mai qai kauta vakatotolo vua na vuniwai.

TATAQOMAKIA:
Me kakua sara ni tara na mata kei na kuli ni yago. Kakua talega ni ceguvi na kena cawa se cagi ni vakayacori tiko na suisui. Me sava vinaka na liga kei na veitiki ni yago e sega ni vakaisulutaki, e na gauna sa vakayagataki oti kina. Kakua ni kana se vakalavako e na gauna ni suisui. Sava vinaka na i sulu ni bera ni daramki tale. Kevaka e tara na kuli ni yago, savata sara vakatotolo e na sovu kei na wai.

REREVAKAI:
Kakua ni waka vata na propal kei na dua tale na wainimate ni suisui. Mo kakua talega ni vakayagataka kina na Propal vakavo ke sa oti e 10 na siga mai na gauna ko vakayagataka kina. Me sogo vinaka ni maroroi vata na sore ni tei, vakabulabula ni qele se waimate tale eso. Savata vinaka na kena kava sa lala. Tukituka kina e so an qara buluta. Kakua ni ko biuta e na toevu. sala ni wai se viritaka tu vakaveitalia.

ME KAKUA NI VAKAYAGATAKI E NA DUA TALE NA KA.

CAUTION

***KEEP OUT OF REACH OF CHILDREN *READ SAFTEY DIRECTIONS BEFORE OPENING *HARMFUL IF SWALLOWED *HIGHLY INFLAMABLE. DO NOT OPEN WITHIN 30 FEET OF FIRE OR FLAME.**

AGCHEM LIMITED

PROPAL

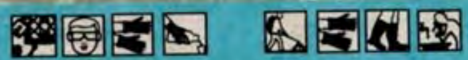
Contains 360g/litre Propanil

CONTENTS 1 LITRE

For control of barnyard and other grasses in rice

GENERAL: Preparation of a good seed bed helps in obtaining a uniform germination of rice and grasses and obtaining optimum results. With irrigated crops a temporary flooding will assist in making the grass more susceptible to the application of propal will not be controlled.

DIRECTIONS FOR USE: For best results apply when grasses are succulent and actively growing.
RATE: up to 4 leaf stage of weed.
USE: 10 TO 11.5 Litres propal in sufficient water to cover 1 Ha. Or 7 to 8 pints propal in sufficient water to cover 1 Acre.
Knapsack Spraying: 13.5 liters (3 gal) tank use 340mls (12 fl ozs) per knapsack and apply 30 knapsacks per Ha.
Motor Blowers: 13.5 liters (3 gal) tank use 510mls (18 fl ozs) and apply 20 tanks per HA or 8 tanks per acre. Grasses from early 4 leaf to 5 stage can be controlled by 17 L/HA (1.5 gallons of product per acre) when idle conditions exist. Spraying at this later growth stage or earlier stages under adverse conditions, may give inferior results. The spraying of good – seeded crops is not recommended.



सावधान

Sundothrin 25 EC Insecticide.

GENERAL INSTRUCTIONS

APPLICATION
Sundothrin 25 EC is a contact spray. Through, even coverage is essential.

EQUIPMENT Ground Spray:
Standard low volume boom or high volume equipment may be used.

COMPATIBILITY
Sundothrin 25 EC may be mixed with most formulations of fungicides and insecticides such as dimethoate, methamidophos, pirimicarb, methomyl liquid, mancozeb, metalaxyl, and chlorothalonil, where these products are required for additional insect control or control of diseases. Sundothrin 25 EC may also be mixed with X-77 Sticker.

MIXING
Add the required quantity of Sundothrin 25 EC to the spray thank with agitators in motion. Where other products are to be mixed, add these after Sundothrin is mixed in the tank.

PROTECTION OF LIVESTOCK
- Dangerous to bees. Do NOT spray on any plants in flower while bees are foraging.
- Some repellent effect may be apparent for approximately 2 days.

PROTECTION OF WILDLIFE, FISH, CRUSTACEA AND ENVIRONMENT
- Dangerous to fish. Do not contaminate dams, ponds, waterways or drains with chemical or used container.

STORAGE AND DISPOSAL, PROTECTION OF OTHERS
Store in original container tightly closed and in a cool, well ventilated area. Do not store for prolonged periods in direct sunlight. Triple rinse containers before disposal and add rinsing to tank mix or disposal pit. Destroy empty empty containers by breaking, crushing or puncturing them. Bury containers to the depth of 50cm or more at a municipal or private sanitary land fill type tip that does not burn its refuse.

SAFETY DIRECTIONS
Product is harmful if absorbed by skin contact, inhaled or swallowed. Facial skin contact may cause temporary facial numbness. Avoid contact with eyes and skin. When preparing spray wear elbow-length PVC gloves and face shield. If product spills on skin, immediately wash area with soap and water. After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water. After each days work wash contaminated clothing, gloves and face shield.

FIRST AID
If skin contact occurs, remove contaminated clothing and wash skin thoroughly with clean water. Remove patient from contaminated area. If splashed in eye wash thoroughly in clean running water for least 13 minutes. If swallowed rush patient to nearest health centre or doctor. Apply artificial respiration if not breathing.

AGCHEM LIMITED

Manufactured by:
SUNDAT(S) PTE LTD
26 GUL CRESCENT
SINGAPORE 2262

IMPORTED AND DISTRIBUTED BY:
AGCHEM LIMITED
LOT 5, WAILADA INDUSTRIAL SUB-DIVISION LAMI
PRIVATE MAIL BAG, LAMI, FIJI
PHONE: 336 1499, 336 1867 FAX: 336 1307
REGISTERED UNDER THE FIJI PESTICIDE ACT No.41 OF 1971
REGISTRATION No. 1512/112F/85

HARMFUL

NOT TO BE TAKEN

KEEP OUT OF REACH OF CHILDREN

READ SAFETY DIRECTIONS BEFORE OPENING

SUNDOTHRIN

25 EC INSECTICIDE

Active Ingredient: contains 250g/litre (25%) Permethrin as an Emulsifiable concentrate

For the control of Cluster Caterpillars, Diamondback moth, Large cabbage moth, Cabbage Aphids, Army worms, Bean Pods Borer, House hold Pest and Tick, Fleas, Lice, Mites in Domestic Animals.

A SYNTHETIC PYRETHROID INSECTICIDE

NOT TO BE USED FOR ANY PURPOSE OR IN ANY MANNER CONTRARY TO THIS LABEL UNLESS AUTHORITIES UNDER APPROPRIATE LEGISLATION.

PRECAUTIONS

Wear rubber gloves, face shield and protective clothing when handling the chemical.

HARMFUL

Crop/ SITUATION	PESTS	KNAPSACK RATE		WITHHOLDING PERIOD	CRITICAL COMMENT
		16L	20L		
Beans	Army worm, Bean Pod Borer and Cluster Caterpillar	13-16 mls	17-20 mls	7 days	Start applying when the flower buds appear and repeat at 7-10 to day intervals until the pods are fully formed.
English Cabbages, Chinese Cabbages, Cauliflower and Broccoli	Diamondback moth , Large Cabbage moth, Cluster caterpillar and Cabbage aphids	17-22 mls	21-26 mls	3 days	Apply at the first appearance of the insects and required amount of x77 sticking agent to the spray tank.
Maize	Army worm	17-22 mls	21-26 mls	5 days	Spray when the insects first appear and repeat as necessary. Pay special attention at the tips of the ears for presence of the insect Larvae.
Tobacco	Army worm and Cluster Caterpillar	17-22 mls Mistblower 45-60 mls in 10L tank.	21-26 mls	5 days	Spray when the insects first appear and repeat as necessary. Pay special attention at the tips of the ears for presence of the insect larvae.
Household and industrial areas	Cockroaches, silverfish, cloth moth, ants, fleas, bedbugs, mosquitoes, act.	20 mls in 10 litres of water. Use 5 litres of the mixture to 100 square metre area.			Spray the mixture to the point of run-off. Remove all foodstuff, clothing and bedding before spraying in house. Do not enter treated areas until fully dry.

ADVICE TO PHYSICIAN
No antidote is available and treatment should be symptomatic. Chemical pneumonitis is resulting from aspiration of the solvent into lungs is a hazards that occurs when liquid formulations are used. Do not induce vomiting. Empty the stomach only on the advice of a Physician and only with equipment that will not cause aspiration into lungs. If convulsions occur diazepam (10-20mg for an adult) should be administered slowly, intravenously or rectally and repeated if necessary.

FIRST AID
If Swallowed cause vomiting by giving a glass or two of water and then poking finger down the throat. Call doctor immediayely.
[illegible]
[illegible]

VEIQARAVI TANUMADA
Ke gunuvi me sagai me lualua ni gunuvi oti e dua na bilo wai oqo ni tarai na rona i tilotilo. Laki raica e dua na Vuniwai.

PRECAUTIONS
Wear rubber gloves, face shield and protective clothing when handling the chemical.
[illegible]
[illegible]

TATAQOMAKI
Daramaka na qa ni liga rapa. Taqomaka na yaogmu ena i sulu vakarautaki ni ko vakayagataka na wai ni mate.

CONTENTS 1 LITRE

Suncis 25 EC Insecticide.

GENERAL INSTRUCTIONS

APPLICATION

Suncis 25 EC is a contact spray. Through, even coverage is essential.

EQUIPMENT Ground Spray

Standard low volume boom or high volume equipment may be used.

COMPATIBILITY

Suncis 25 EC may be mixed with most formulations of fungicides and insecticides such as dimethoate, methamidophos, pirimicarb, methomyl liquid, mancozed, metalaxyl, and chlorothalonil, where these products are required for additional insect control or control of diseases. Suncis 25 EC may also be mixed with X - 77 Sticker.

MIXING

Add the required quantity of Suncis 25 EC to the spray tank with agitators in motion. Where other products are to be mixed, add these after Suncis is mixed in the tank.

PROTECTION OF LIVESTOCK

. Dangerous to bees. Do NOT spray on any plants in flower while bees are foraging.

. Some repellent effect may be apparent for approximately 2 days.

PROTECTION OF WILDLIFE, FISH, CRUSTACES AND ENVIRONMENT

. Dangerous to fish. Do not contaminate dams, ponds, water ways or drain with chemical or used container.

STORAGE AND DISPOSAL, PROTECTION OF OTHERS

Store in original container tightly closed and in a cool, well ventilated area Do not store for prolonged periods in direct sunlight. Triple rinse containers before disposal and add rinsing to tank mix or disposal pit Destroy empty containers by breaking, crushing or puncturing them. Bury containers to a depth of 50cm or more at a municipal or private sanitary land fill type tip that does not burn its refuse.

Manufactured by:
SUNDAT (S) PTE LTD
26 GL CRESCENT
SINGAPORE 2262

IMPORTED AND DISTRIBUTED IN FIJI BY
AGCHEM LTD
WAILADA INDUSTRIAL ESTATE LAMI
PRIVATE MAIL BAG, LAMI, FIJI
PHONE : 336 1499, 336 1867 FAX 336 1307
REGISTERED UNDER THE PESTICIDE ACT No. 41 OF 1997 (FIJI) REGISTERED\RED No. 144/129F/85

AGCHEM LIMITED

HARMFUL

GAGA
ME KAKAU NI GUNOVI
ME MAROROI LAVI BRA NA
GONE WILIKA VINAKA, NA NANORO
NI BERA NIKO DOLAVA

NOT TO BE TAKEN
KEEP OUT OF REACH CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING

Suncis

25 EC INSECTICIDE

A synthetic pyrethoid insecticide for the control of caterpillars, beetles, thrips, white butterfly, diamondback moth on a broad range of fruit and vegetables. It is fast acting light stable and has moderate persistence on plants.

Active Ingredient

Deltamethrin 2.5%
Inert Ingredients 97.5%

NOT TO BE USED ANY PURPOSE OR IN ANY MANNER CONTRARY TO THIS LABEL UNLESS AUTHORITIES UNDER APPROPRIATE LEGISLATION

PRECAUTIONS

Wear rubber gloves, face shield and protective colthing when handing the chemical.

HARMFUL

Crop	Pest	Knapsac Rate		Withholding Period
Cabbage	Diamondback Moth	16L 7mls	20L 8 mls	7 Days
Tomato	Tomato Fruitworm Looper Caterpiller	7mls	8mls	3 Days
Ornamental	Looper Caterpiller Tomato Fruitworm Thrips	7mls	6mls	
Beans	Looper Caterpiller	6mls	8mls	3 Days
Cucumber Squash Water Melon	Aphids	16mls	20mls	3 Days
Maize Sweetcorn	Greasy Cutworm Corn Earthworm	8mls	10mls	7 Days

SAFETY DIRECTIONS

Product is harmful if absorbed by skin contact, inhaled or swalloed. Facial skin contact may cause temporary facial numbness, Avoid contact with eyes and skin. When preparing spray wear elbow-length PVC gloves and face shield. If product spills on skin, immediately wash area with soap and water. After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water. After each days work wash contaminated clothing, gloves and faces shield.

FIRST AID

If skin contact occurs, remove contaminated clothing and wash skin thoroughly with clean water. Remove patient from contaminated area. If splashed in eye wash thoroughly in clean running water for at least 13 minutes. If swallowed rush to nearest health center or doctor. Apply artifical respiration if not breathing.

ADVICE TO PHYSICIAN

No antidote is available and treatment should be symptomatic. Chemical pneumonitis is resulting from aspiration of the solvent into lungs is a hazards that occurs when liquid formulations are used Do not induce vomiting. Empty the stomach only on the advice of a Physician and only with equipment that will not cause aspiration into lungs. If convuisions occur diazepam (10-20mg for an adult) should be administered slowly, intravenously or rectally and repeated if necessary.

FIRST AID

If Swallowed cause vomiting by giving a glass or two of water and then poking finger down the throat.

VEIQARAVI TAUMADA

Ke gunuvi me sagai me lualuâ ni gunvi oti e dua na bilo wai ôqo me tarai na nona i tilotilo. Laki raica e dua na Vuniwai.

PRECAUTIONS

Wear rubber gloves, face sheild and protective clothing when handling the chemical.

TATAQOMAKI

Daramaka na qa ni liga rapa. Taqomaka na yaogmu ena i sulu vakarautaki ni ko vakayagataka na wai mate.

CONTENTS
500ml

Biological Insecticide

AgChem Bt.

500grams

GENERAL INSTRUCTIONS:

AgChem Bt is a highly effective biological insecticide for the control of caterpillar larvae of certain Lepidopterous Insects in vegetable crops.
Crops should be scouted for early signs of infestations.
Larvae must eat deposits of AgChem Bt to be effected. Best results are obtained on small insects.
Thorough coverage of the plants is necessary. Treat both sides of the leaves.
Under heavy insect pressure shorten the spray interval to 3days instead of 7 days, and increase volumes of spray to improve coverage.

Use 10grams of AgChem Bt in a 20l knapsack. X-77 Sticker is recommended on hard to wet plants like Cabbages.
Withholding period Nil.

Crop	Pest	16L Knapsack	20L Knapsack
Fruiting Vegetables Such as eggplant Pepper & Tomato	Loopers Tomato Fruitworm Variegated Cutworm Saltmarsh caterpillar Hornworm Armyworms	Bt 8 grams X-77 16ml	Bt 10 grams X-77 20ml
Leafy & Cole Crops Such as Broccoli, Brussels Sprout Cabbage, Cauliflower, Celery Chinese Cabbage, Collard, Endive, Kale, Kohirabi, Lettuce (Head & Leaf), Mustard, Greens, Parsley & Spinach	Looper Imported Cabbage worm Diamond Backmoth Armyworms	Bt 8 grams X-77 16ml	Bt 10 grams X-77 20ml
Legume Vegetables Such as Bean, Pea, Lentil & Soybean	Looper Green Cloverworm Velvetbean Caterpillar Podworm Armyworms Soybean Looper Saltmarsh caterpillar	Bt 8 grams X-77 16ml	Bt 10 grams X-77 20ml

AGCHEM LIMITED
Subsidiary Company Lane (Fiji) Limited

Imported and Distributed by
Agchem Limited.
Factory: Lot 5, Wailada Industrial Estate.
Postal: Private Mail Bag, lami, Fiji.
Phone Bus: 336 1499, 336 1867
Fax: (679) 336 1307
Email: info@agchem.com
REGISTERED UNDER THE FIJI PESTICIDE ACT NO.41 OF 1971
REGISTRATION NUMBER: I 695/87 C/85

ACTIVE INGREDIENT:
Active Ingredient of 32,000 IU/mg Bt WP is extremely low hazard to human being, but avoid over exposure.
Formulation Toxicity:
Acute Oral in rats: LD_{50}>5000

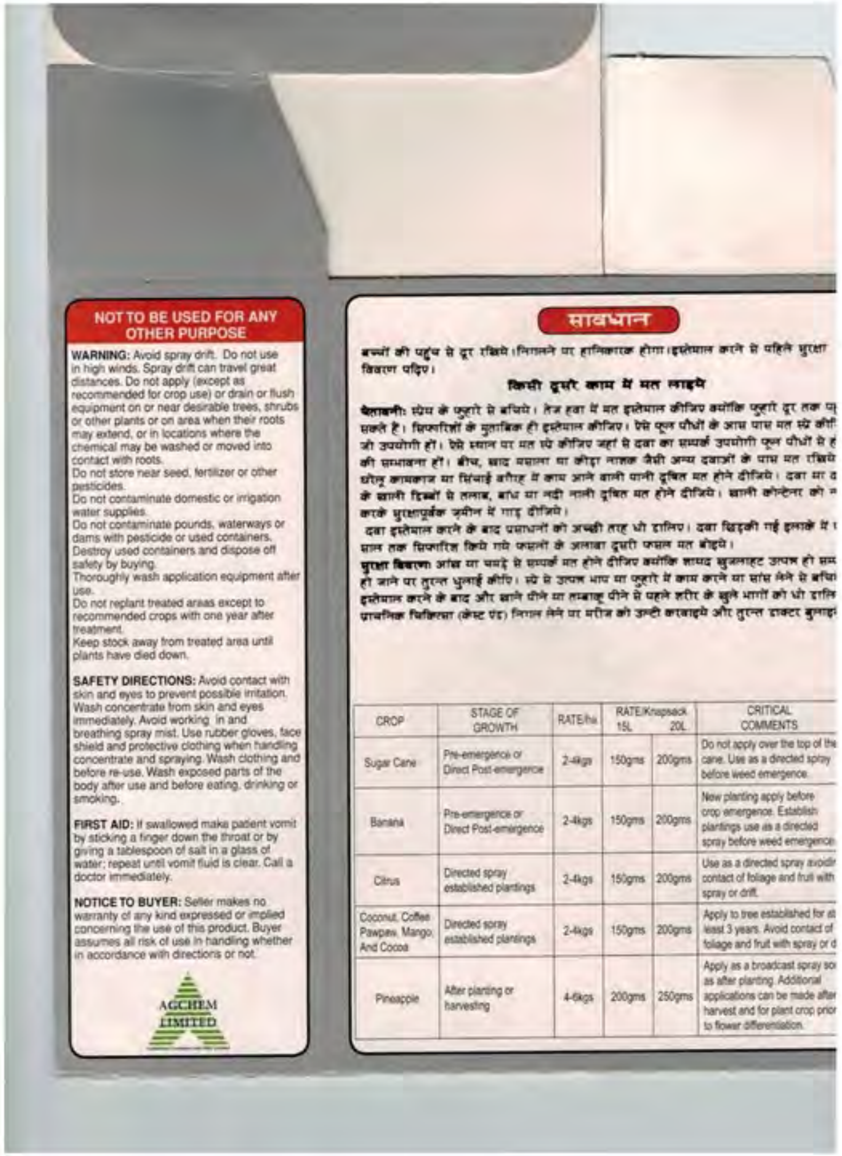
acute dermal in rats: LD_{50}>2000

HARMFUL


AGCHEM LIMITED
Manzate Evolution
ECOTOXI
Manzate®
Evolution™
FUNGICIDE
ACTIVE INGREDIENT:
750g/kg MANCOZEB
in the form of a water dispersible granule
For the control of certain diseases in fruit, vegetable and ornamental crops.
Registered pursuant to the ACVM Act 1997 No. P7514
See www.foodsafety.govt.nz for registration conditions.
Approved pursuant to the HSNO Act 1996 Code HSR000808
Net Contents : 1 Kg
United Phosphorus NZ Ltd
PO Box 158, Auckland New Zealand 1140
सावधान
AGCHEM LIMITED
IMPORTED AND DISTRIBUTED BY:
AGCHEM LTD.


QARAUNA
E TABU NI RA TARA NA GONE.
WILIKA VINAKA NA I VAKASALA NI BERA NI VAKAYAGATAKI.
TATAQOMAKI
E rawa ni votivoti kina na mata, ucu, tilotilo kei na kuli ni yago. E rawa ni veivakacacani ke ceguvi se tilomi. Kakua ni ceguva na kuvu se cawa ni wainimate. Kakua ni veitaratara kei na kuli ni yago, mata kei na i sulu. Me maroroi laivi mai na buka waqa se kama.
VEIVUKE TAUMADA
Savata vinaka e na wai na kuli ni yago se mata ke tara na wainimate. Raica na tabana ni bula ke tara na mata.
VEIKA BIBI
E gaga e na ika ka tabu ni vakayagataki e na tobu ni ika se drano. Kakua ni vakayagataka e na vanua e rawa ni vakadrodroi tani yani kina. Kakua ni vanataka ni draki cagicagi. Kakua ni benuca na ucilwai me sava kina na i yaya ni suisui se sova kina na i vovo ni wainimate.
NA MENZATE EVOLUTION E I TATAROVI NI VEI MATE OQO:
Pinati: Peanut rust, cercospora leaf spot.
Pateta: Early and late blight.
Tomata: Early and Late blight, grey leaf mold and anthracnose.
Kiukaba: Gummy stem blight anthracnose and cercospora leaf spots.
Bean: Rust.
Maqo: Anthracnose.
VAKARAU NI WAINIMATE:
NA I WALEWALE NI KENA VANATAKI
Ke sa vanataki qo, cegu me oti e 7 – 10 na siga qai vanataka tale ke gadrevi.
GAUNA YALATAKI:
Waraki me oti e 7 na siga na kena vanataki.
AGCHEM LIMITED


AGCHEM LIMITED
DIURON DF
HERBICIDE
QARAUNA
*MAROROYA E NA DUA NA VANUA KA RA SEGA NI YACOVA NA GONE LALAI
* REREVAKI KEVAKA E GUNUVI. WILIKA VINAKA NA I VAKASALA NI BERA NI DOLAVI.
ME KAKUA NI VAKAYAGATAKI E NA DUA TALE NA KA.
VAKSALA: Kakua ni liwavi iko na cagi ni wainimate. Kakua ni vakayagtaki e na gauna cagicagi. E na rawa ni kauta vakayawa na cagi. Kakua ni vakyagataki e na i tei (vakavo kevaka evakakina), salasala ni wai, yaya ni cakacaka, vanua ka tei kina na vunikau, se dua ga na vanua e yacova yani na waka ni kau se ena vanua ka rawa ni drodro kina na wai ka na waki vata kei na wainimate.
Kakua ni maroroi volekata na sore ni kau, vakabulabula ni qele, se na wainimate ni manumanu meca ni kau. Kakua ni biu ena wai ni gunu, se wai vakayagataki ena i teitei. Kakua ni biu e na uciwai, tobu ni wai ena wainimate, se biu ki na kava laia ni wainimate. Me biu laivi na kava ka daumaka me bulu.
Savata vinaka na i yaya ni vanavana ni sa vakayagataki oti. Kakua ni teivaki na vanua e vana vakavo kevaka e vakasalataki vakakina ni oti e dua na yabaki, mai na gauna a vana kina.
DUSIDUSI NI TATAQOMAKI: Qarauna me kua ni veitaratara kei na kuli kei na yaloka ni mata. Ke mani yaco me tauva na tiki ni yago e rua oqori., savata sara vakatotolo, kua ni ceguva na kena kabu se cawa e na gauna ko suisui tiko kina. Vakayagataka na qaniliga rapa, na i ubi ni mata kei na i sulu vavaku ni tataqomaki e na gauna ko suisui kina. Savata sara vakavinaka na i sulu ni bera ni ko vakayagataka tale. Savata sara vakavinaka na veitiki ni yagomu ka sega ni vakaiubi ni oti na suisui, vakabibi ni bera ni ko kana, gunu se vakatavako.
VEIVUKE TOTOLO DUADUA: Ke sa mani gunuvi se tilomi, saga me lua ko koya e yacovi koya e na nomu i qaqalo se solia vua e dua na taki masima kei dua na bilo wai. Tomana me yacova ni savasava na wai ni lua ka kaciva sara vakatotolo na Vuniwai.
Packed & Distributed by :
Agchem Limited.
Lot 5, Wailada Industrial Estate, Lami, Fiji.
PHONE: 336 1499, 336 1867 FAX: 336 1307
E-mail: info@agchem.com
REGISTERED UNDER THE PESTICIDE ACT 41 OF 1971 (FIJI)
REGISTERED No. W98/8F/45
AGCHEM LIMITED
WARNING
KEEP OUT OF REACH OF CHILDREN. HARMFUL IF SWALLOWE
READ SAFETY DIRECTION BEFORE OPENING
DIURON DF
HERBICIDE
FOR SELECTIVE WEED CONTROL IN SUGARCANE, PINEAPPLE, PAWPAW, CITRUS, RUBBER, COCONUT COCOA, TEA AND BANANA
ACTIVE CONSTITUENT: 80% W/W DIURON
FOR TOTAL WEED CONTROL AROUND BUILDINGS, INDUSTRIAL INSTALLATIONS, FENCE LINES & DRAINAGE & IRRIGATION DITCHES
CONTENTS 1 KG. NETT
HARMFUL


NOT TO BE USED FOR ANY OTHER PURPOSE
WARNING: Avoid spray drift. Do not use in high winds. Spray drift can travel great distances. Do not apply (except as recommended for crop use) or drain or flush equipment on or near desirable trees, shrubs or other plants or on area when their roots may extend, or in locations where the chemical may be washed or moved into contact with roots.
Do not store near seed, fertilizer or other pesticides.
Do not contaminate domestic or irrigation water supplies.
Do not contaminate pounds, waterways or dams with pesticide or used containers.
Destroy used containers and dispose off safety by buying.
Thoroughly wash application equipment after use.
Do not replant treated areas except to recommended crops with one year after treatment.
Keep stock away from treated area until plants have died down.
SAFETY DIRECTIONS: Avoid contact with skin and eyes to prevent possible irritation. Wash concentrate from skin and eyes immediately. Avoid working in and breathing spray mist. Use rubber gloves, face shield and protective clothing when handling concentrate and spraying. Wash clothing and before re-use. Wash exposed parts of the body after use and before eating, drinking or smoking.
FIRST AID: If swallowed make patient vomit by sticking a finger down the throat or by giving a tablespoon of salt in a glass of water; repeat until vomit fluid is clear. Call a doctor immediately.
NOTICE TO BUYER: Seller makes no warranty of any kind expressed or implied concerning the use of this product. Buyer assumes all risk of use in handling whether in accordance with directions or not.
AGCHEM LIMITED
सावधान
बच्चों की पहुंच से दूर रखिये। निगलने पर हानिकारक होगा। इस्तेमाल करने से पहिले सुरक्षा विवरण पढ़िए।
किसी दूसरे काम में मत लाइये

CROP	STAGE OF GROWTH	RATE/ha	RATE/Knapsack 15L	20L	CRITICAL COMMENTS
Sugar Cane	Pre-emergence or Direct Post-emergence	2-4kgs	150gms	200gms	Do not apply over the top of the cane. Use as a directed spray before weed emergence.
Banana	Pre-emergence or Direct Post-emergence	2-4kgs	150gms	200gms	New planting apply before crop emergence. Establish plantings use as a directed spray before weed emergence
Citrus	Directed spray established plantings	2-4kgs	150gms	200gms	Use as a directed spray avoidi contact of foliage and fruit with spray or drift.
Coconut, Coffee Pawpaw, Mango, And Cocoa	Directed spray established plantings	2-4kgs	150gms	200gms	Apply to tree established for at least 3 years. Avoid contact of foliage and fruit with spray or d
Pineapple	After planting or harvesting	4-6kgs	200gms	250gms	Apply as a broadcast spray so as after planting. Additional applications can be made after harvest and for plant crop prior to flower differentiation.

PINEAPPLE SPRAY

GROWTH REGULATOR

POISON

KEEP OUT OF REACH OF CHILDREN

Active Ingredient Composition:
2-Chloroethylphosphonic acid...48%w/v
Inert ingredient.........................52%w/v

Precautions:

1. Product is poisonous if absorbed by skin contact or swallowed.
2. Repeated minor exposure may have cumulative poisoning effect.
3. Avoid contact with eyes and skin.
4. Do not inhale spray mist.
5. When preparing spray and using the prepared spray, wear cotton overalls buttoned to the neck and wrist, a washable hat, elbow-length PVC gloves, face shield or goggles

Directions for Storage:

1. Store in cool place
2. Avoid direct sunlight
3. Do not store the product in the rooms of your home

Induce Flowering in Pineapples

WATER	BORAX	UREA	PINEAPPLESPRAY
16LTR	80grm	320grm	32mls
20LTR	100grm	400grm	40mls
50LTR	250grm	1000grm	100mls

Application Method:

CROP	USES	RATE
Pineapple	Enhance colouring of fruit	2 to 4L / 500 to 1000 L water per ha

Qarauna

E rawa ni vakavu gaga ke gunuvi se me drodrova ka curuma na kuli ni yago.
Qarauna me kakua ni terega na kuli ni yago se na yaloka ni mata.
Me kakua ni ceguvi na kena cawa.
Na gauna e vakayagataki tiko kina na wainimate me daramaki tiko na i sulu rakorako me vaka na tarausese balavu kei na sote liga balavu, na i sala, qaniliga rapa, kei na mata lloilo.

Veivuke Taumada

Ke takavi iko na wainimate, me luva sara na i sulu, ke me sisili sara vakavinaka ena wai kei na sovu ni bera ni qai qarai na veivuke vaka vuniwai.
Ke terega na mata, me sava e na wai (wadrawadra ena wai) me 15 na miniti ni bera ni qarai na veivuke vaka vuniwai.
Ke vaka e ceguvi na cawa ni wainimate, me vakagalala taki kina dua na vanua lala me cegu cagi bulabula kina, ia ke sa tasogo na nona i cegu me garavi ena veigaravi me vakasukai kina vua na i cegu, ka me qarai sara vakatotolo na veivuke vaka vuniwai.

Kena Maroroi

Me maroroi ena dua na vanua ka me kakua ni ra tara na gonelalai, ka me kakua ni maroroi tiko e loma ni nomu vale. Me kakua ni vaka cilavi siga se biu ena dua na vanua katakata, ka me tawa tiko ga ena kena bola dina. Me kakua ni vakayagataki tale na kena bola lala ena dua tale na i naki, ka me lamuti ka buluti sara vakavinaka ni sa lala.

आपातकाल और पराथमकि चकितिसा

आंखों के लिए:
या कम से कम पंद्रह मनिट के लिए पानी और नमकीन घोल के साथ आंखो सचिाई. तत्काल चकितिसा ध्यान दे

त्वचा के लिए:
तुरंत दूषति कपड़े नकिाल दे. साबुन पानी और शराब के साथ दूषति क्षेत्रों धो लो.

साँस लेना के लिए:
ताजा हवा के लिए जोखमि क्षेत्र से तुरंत हटा दे. कृत्रमि श्वसन दे जब श्वास बंद कर दयिा है, हवा की तरह, रक्त का दबाव बनाए रखने और प्रशासन ऑक्सीजन दे यहाँ जब अभी भी उपलब्ध है. तत्काल चकितिसा ध्यान दे

अगर नगिल लयिा:
अगर व्यक्ति सतर्क है और श्वसन उदास नहीं है, ipecac के सरिप, और पानी देना. तत्काल चकितिसा ध्यान दे

Emergency & First Aid Procedures

For Eyes:
Irrigate eyes with water or saline solution for at least 15 minutes. Get medical attention immediately.

For Skin:
Remove contaminated clothing immediately. Wash contaminated areas with soap and water followed by alcohol. Get medical attention immediately.

For Inhalation:
Remove from exposure area to fresh air immediately. If breathing has stopped give artificial respiration, maintain airway and blood pressure and administer oxygen if available. Get medical attention

For Ingestion:
If person is alert and respiration is not depressed.give syrup of IPECAC. followed by water (if vomiting occurs, keep head below hips to prevent aspiration. Treat respiratory difficulty with artificial respiration and oxygen

1 LITRE

IMPORTED AND DISTRIBUTED IN FIJI BY
AGCHEM LTD
WAILADA INDUSTRIAL ESTATE LAMI
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REGISTERED UNDER FIJI PESTICIDES ACT NO. 41 OF 1971
REGISTRATION No. M120/242D/85

AGCHEM LIMITED

SUNDAT (S) PTE LTD

WARNING

ACTIVE INGREDIENT:
600 g/Kg of Metsulfuron as the Methyl Ester in the form of water dispersible granule.

PRECAUTIONS

PLEASE READ THIS LABEL BEFORE OPENING OR USE.
May cause eye and mild skin irritation. Very toxic to aquatic organisms and to many plant species.

STORAGE: keep out of reach of children. Store in the original, tightly closed container, in a secure place away from foodstuffs, seeds, fertilisers, insecticides or fungicides used for crop protection.

PERSONAL PROTECTION: Avoid contact with eyes and skin. Avoid inhalation of dust or spray mist. When mixing or applying, wear overalls, boots, gloves and eye protection. Do not eat, drink or smoke while using. Remove protective clothing and wash hands and face thoroughly before meals and after work.

EQUIPMENT: apply with well-maintained and calibrated spray equipment.

DISPOSAL: dispose of this product only by using in accordance with this label, or at a suitable landfill. Do not burn. Dispose of packaging to a suitable landfill. Do not use packaging for any other purpose.

ENVIRONMENTAL: use this product carefully. Do not contaminate aquatic environments with product, spray drift or packaging. Spray drift or equipment contamination may cause serious damage to desirable plants, so do not drain or flush equipment near to desirable trees or other plants, or on areas where their roots may extend to.

FIRST AID: if swallowed do not induce vomiting. If splashed in eyes, wash out immediately with running water for several minutes. If skin or hair contact occurs, remove contaminated clothing and wash with soap and running water. For advice, call the National Poisons Centre or a Doctor immediately.

WEED	KNAPSACK RATE		MIST BLOWER RATE	APPLICATION COMMENTS
	16L	20L	10L	. Bottle Cap Measures 1 gram . The addition of X-77 Sticker or Input penetrant at rate of 100ml/100litres (1ml/1litre) is essential in order to get a good result.
WEDELIA, BROADLEAF WEEDS, GUAVA	16gms	20gms	30gms	

MANUFACTURED BY:
Orion Crop Protection Ltd.
Unit 1, 15 Sir Gil Simpson Drive, Harewood, Christchurch 8053.
PACKED AND DISTRIBUTED BY:
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REGISTERED UNDER THE PESTICIDE ACT No. 41 OF 1971
REGISTRATION NUMBER: W 486/192 F/85

सावधान

मत पियें
बच्चों की पहुंच से दूर रखिये
खोलने से पहले सुरक्षा विवरण पढ़िए

चेतावनी
फुहारों की धारा से बचिये और जब हवा चलती हो तो मत इस्तेमाल करें। फुहारों की धारा बहुत दूर तक जा सकती है। यह दवा उन पौधों के नज़दीक में नहीं काम में लाना चाहिये जैसे, टमाटर, करेला, पेशन फ्रूट, टमाटर, धान, सजावट या फसलों के पेड़। यदि पेड़ धीरे हो यह पानी बरसने वाला हो तो मत स्प्रे करें, जो घास पर सूख से अच्छा असर पड़ता है। बीज, छोटे पौधों, खाद इन्सेक्टीसाइड और फंगीसाइड से दूर रखिये। इस दवा से स्प्रे किये गये पौधों जानवरों के लिए आकर्षक हो सकते हैं, जानवरों को ऐसी जगह से तब तक दूर रखिये जब तक पौधे मर ना जाये अन्य किसी काम के लिए मत इस्तेमाल करिये।

सुरक्षा के आदेश
कपड़े और आखों में मत लगने दीजिए। धूल या फुहारों को सांस के द्वारा अन्दर मत जाने दीजिये। इस्तेमाल करने के बाद और भोजन करने, पानी या तम्बाकू पीने से पहले हाथों और शरीर के खुले भागों को धो लेना चाहिए। स्प्रे करते समय न तो भोजन करना चाहिए न ही पानी या तम्बाकू पीना चाहिए। रबर, जूता, फेस शील्ड और बचाव के लिए कपड़े पहन कर स्प्रे कीजिए। दुबारा इस्तेमाल करने से पहले कपड़े धो लेना चाहिए।
(१) तालाब, नाली या रुके हुए पानी को पेस्टीसाइड या काम में लाये गई कोन्टेनर्स से मत दूषित होने दीजिए।
(२) खाली कन्टेनर्स को सुरक्षा पूर्वक मिट्टी में गाड़ कर नष्ट कर दीजिए।
(३) स्प्रे करते समय कुछ मत खाये पीये या तम्बाकू पिये।

फर्स्ट एड
यदि कोई निगल ले तो मरीज़ को एक या दो गिलास पानी पिला कर गले में उंगली डाल कर उल्टी कराइये। उल्टी कराते रहे जब तक कि सब कुछ न निकल जाये। डाक्टर को तुरन्त बुलाइये यदि आंख में लग जाये तो साफ पानी में खूब धोना चाहिये और डाक्टर की सलाह तुरन्त लेनी चाहिए। दूषित कपड़ों को निकाल देना चाहिये और बदन को अच्छी तरह धोना चाहिये।

POISON

KEEP OUT OF REACH OF CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING OR USING
For the control of certain grass weeds in broadleaf crops as per Directions for Use table

AGCHEM LIMITED

WEDELIA ERADICATOR

A HERBICIDE for the control of wedelia, broadleaf weeds, wild ginger, guava and a range of other scrub weeds in pasture, waste areas and in forestry sites prior to planting.

80 Grams

HARMFUL

GAGA

QARAUNA
WILIKA VAKAVINAKA NA I VAKASALA NI BERA NI VAKAYAGATAKI.
Rawa ni vakavuna na milamila ni Mata kei na Kuli ni yag
rawa ni vakavu leqa vei ira na veikabula e wai kei na vei
eso. Me qarauni sara vakavinaka na kena vakayagataki

KENA MAROROI
Maroroi vakavinaka me ra kakua ni tara na gone lalai. M
tikoga ena kena bola dina ka me sogolati vakavinaka. M
ni biu vata kei na Kakana, na i tei, na i vakabulabula ni c
wainimate ni manumanu, na waimnimate ni tatarovi ni m

I TATAQOMAKI
Qarauna me kakua ni terega na mata kei na kuli ni yagc
kakua talega ni ceguvi na kuvu ni wainimate se na cawa
daramaka na i sulu ni tataqomaki ena gauna e vakayag
wainimate oqoka. Kakua ni ko kana, gunu, se vakatava
ena gauna e vakayagataki tiko kina na wainimate oqo. I
sulu ni tataqomaki ka mo sasavui sara vakavinaka ni ot
ka ni se bera niko kana.

KENA VAKARUSAI
Me na buluti na bola lala ni wainimate ena dua na vanu
vakamatau. Me kakua ni vakayagataki tale na bola lala
ena dua tale na ka.
VEIKABULA TALE ESO: Me qarauni na kena vakayaga
wainimate. Me kakua ni vakadukdukalitaki na uciwai, to
ni wai ka ni rawa ni vakavu mate vei ira na manumanu
talega ni vakavu leqa vei ira na kau eso ka me qarauni
sova kina na wai e dau sava kina na i yaya ni cakcaka
kina na cakacaka. Qo me dau laurai me yawaka mai na
yacova yani na waka ni kau ka ni rawa ni vakamatea n
na waka ni kau.

VEIVUKE TAUMADA
Kevaka e tilomi me kakua ni sagai me lauraka mai. Ke
me sava sara na mata ena wai, ka wadrawadra vakala
bera ni qarai na veiqaravi nei Vuniwai. Ke tasova ena y
luva laivi na i sulu ni cakacaka ka sisili vakavinaka ena
ni bera ni laurai ko Vuniwai.

5.4 Applying pesticides – the important steps in spraying

- Do not spray on windy days
- Take another person with you when spraying in case of an accident, a spill or poisoning
- Always wear proper protective clothing

5.4.1 Before spraying

The nozzle

Check you have the correct nozzle for the pesticide you are going to use. The nozzle is the most important part of the sprayer.

What does the nozzle do?

- **Nozzles break liquids into droplets.**
- **Nozzles send liquids out in a pattern.**
  The pattern for killing weeds is quite different from the pattern for spraying pests and pathogens.
- **Nozzles control the width of the spray.**
- **Some sprayers have a pressure control knob inside, which regulates the pressure of the spray.**

Check you have the correct nozzle for the pesticide you are going to use.

Types of nozzles

- Flat fan or anvil (also known as flood) for herbicides
- Hollow cone for insecticides or fungicides

Fig. 5.3 Types of spray pattern produced by a hollow cone, a flat fan and an anvil nozzle.

Before using the nozzle

1. Check that the nozzle is clean.
2. Remove the nozzle from the sprayer and wash in water.
3. Tap to unblock.
4. If still blocked, use a piece of grass to unblock (Fig. 5.4). Never use a nail!

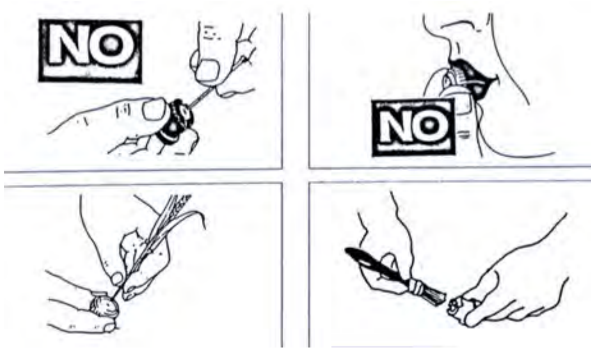


Fig. 5.4 How to clean a nozzle. Use a piece of grass rather than a nail.

Spraying herbicides

- Use a flat fan or anvil (also known as a flood) nozzle (Fig. 5.3)
- The pressure should be low
- Apply as a 'light rain'
- The droplets fall on the TOP of the leaves

- The droplets are larger than those of insecticides or fungicides, lowering the chance of drift and damage to crops

Spraying insecticides and fungicides

- Use a hollow cone nozzle (Fig. 5.3)
- The pressure should be high
- Apply as a mist
- The droplets are small forming a cloud
- They give better coverage as they flow AROUND the plant

The sprayer

- Check the straps. Are they worn? If they are, replace them
- Check the tank. Are there leaks? Put water in the sprayer, check when upright, on the side and upside down. Do not use if there are any leaks
- Check the handle. Open and close the trigger; it should start to spray and stop quickly
- Consult the PNG videos on ‘Safe Use of Pesticides’ for personal protective equipment (PPE) and maintenance of the sprayer

Personal protective equipment (PPE)

Remember that pesticides are poisons, so you must protect yourself when spraying. Ideally, you should wear the following:

- Lightweight overalls
- Gloves
- Boots
- Goggles, face mask and a cap

If you don’t have all these, protect yourself with a **long-sleeved shirt and long trousers** used only for spraying, and boots and gloves. Wear the shirt over the gloves, and the trousers over the boots.

Making up sprays

Do not guess! Read the label, making sure that the concentration of spray is correct.

Example 1: Spraying cabbages with lambda cyhalothrin (the name of the product is *KARATE).*

The label tells you to add **10 mls *Karate* per 10 litres (L) of water** and apply at the rate of **400–500 ml per ha** (Fig. 5.5).

You have a 15 L knapsack sprayer, so you need 15 mls – about 3 teaspoons of *Karate*.

How much *Karate* spray should you spray on the cabbages?

1. Pace out the length and width of a bed of cabbages. Let's say the length is 25 m and the width is 4 m. The area is 100 m^2.

2. To find out how much *Karate* is needed for a 100 m^2 bed:
   - Divide the rate of Karate/ha by the number of m^2/ha and multiply by the area of the bed. Use the higher rate of 500 ml/ha.
   - 500/10000 x 100 = 5 ml.
   - Look at the label, this tells you to mix *Karate* at 10 ml/10 L water. So, for 5 ml you need 5 L water. This is the amount for a 100 m^2 bed.
   - Now, spray the 100 m^2 bed with 5 L **water**. (We use water first to test that you are walking at the right speed to deliver the right amount of spray).

Check:

- ✓ Did you spray more or less than 5 L?
- ✓ If you sprayed more, repeat with water at a slower pace.
- ✓ If you sprayed less, repeat with water at a faster pace.

3. When you have the correct pace, refill the tank with 15 L of water, add 15 ml *Karate*, shake the tank, and spray the cabbages on all the beds at the pace you selected from your tests.

   Now, spray the 100 m^2 bed with 5 L **water**. We use water first to make sure no *Karate* is wasted or overused.

Fig. 5.5 Amount of *Karate* per ha and rate per L in knapsack sprayer.

Example 2: Spraying tomatoes with chlorothalonil. The name of the product is *Eko*

The label tells you to add **34 ml of *Eko* per 20 L of water** (Fig. 5.6). But the label does not say how much *Eko* per ha. **Usually, for tomatoes, this is 1.8–2.3 L/ha.**

You have a 15 L knapsack sprayer, so you need 25 ml - about five Coca-Cola tops of *Eko*.

How much *Karate* spray should you spray on the tomatoes?

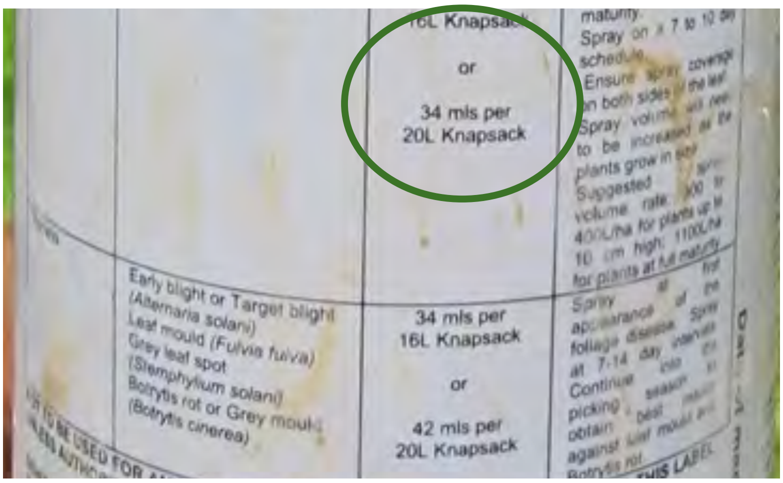


Fig. 5.6 Amount of *Eko* per 16 and 20 litre knapsack sprayers.

1. Pace out the length and width of a bed of tomatoes. Let's say the length is 25 m and the width is 4 m. The area is 100 m^2.

2. To find out how much *Eko* is needed for a 100 m^2 bed, do the following:
   - Divide Rate Eko/ha by number of m^2/ha and multiply by the area of the bed. Use the lower rate of 1800 ml/ha.
   - 1800/10000 x 100 = 18 ml.
   - Look at the label. This tells you to mix *Eko* at 34 ml/20 L water. So, for 18 ml you need 10.6 L water. This is the amount for a 100 m^2 bed.
   - Now, spray the 100 m^2 bed with 10.6 L **water**. (We use water first to test that you are walking at the right speed to deliver the right amount of spray).
   - Now, spray the 100 m^2 bed with 10.6 L of water.

Check:

- ✓ Did you spray more or less than 10.6 L?
- ✓ If you sprayed more, repeat with water at a slower pace.
- ✓ If you sprayed less, repeat with water at a faster pace.

3. When you have the correct pace, refill the tank with 15 L of water, add 25 ml *Eko* (five *Coca-Cola* tops), shake the tank, and spray the tomatoes on all the beds at the

pace you selected from your tests. Later, when the plants are mature, increase the amount per bed to 14 L (this is the higher rate of 2300 ml/ha (see above).

A quick practical method for calibration

If extension staff and farmers find the methods of calibration too complicated, then do the following:

i) add water to the hydraulic knapsack sprayers (according to the volume of each machine)
ii) add insecticide or fungicide to the water according to the volume of sprayer and the size of bottle top chosen (Figs. 5.7, 5.8 and Table 5.3)
iii) spray crops to just before run-off as shown in the following section (5.4.2 and Fig. 5.10)

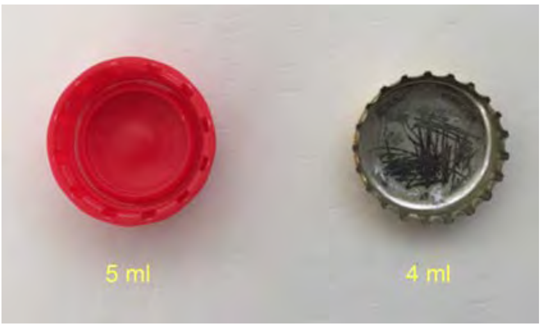


Fig. 5.7 Measuring pesticides (liquids): 5 ml Coca-Cola bottle top (left); 4 ml beer top (right).

The amounts of *KARATE* and *Eko* to add are given in Table 5.3.

Table 5.3 The number of bottle tops of *Karate* or *Eko* (capacity 5 ml or 4 ml) to add to three knapsack sprayers (10, 15 and 20 L water) to formulate the pesticides according to the manufacturer's instructions.

Volume of knapsack sprayer (L)	Total no. mls *Karate*	No. Coca-Cola 'tops'	No. beer 'tops'	Total no. mls *Eko*	No. Coca-Cola 'tops'	No. beer 'tops'
10	10	2	2 1/2	17	3 1/2	4
15	15	3	4	25	5	6
20	20	4	5	34	7	8

If you are using a pesticide that is a powder, then use the tops (lids) as either 2.5 g or 2 g measures. Calculate the number of tops required depending on:

i) the size of the top
ii) the volume of the knapsack
iii) the concentration indicated on the pesticide label (Fig. 5.8).

Fig. 5.8 Measuring pesticides (powders): 2.5 g (Coca-Cola bottle top (left); 2 g beer bottle top (right)

5.4.2 During spraying

Trainees should know that it is important to spray at the right time and during the right weather conditions. If this is not done, the crops will not be treated effectively, and there is a danger to health.

When is it best to spray?

Spray either early in the morning or late in the afternoon, when the wind is less strong. If it is windy, do not spray. If the wind is only light, spray down wind.

Always use a spray shield to prevent chemical drift!

For small plants (near the ground), e.g. cabbages, your sprayer should be fitted with a hollow cone nozzle, and you should spray 50 cm above the crop (Fig. 5.9).

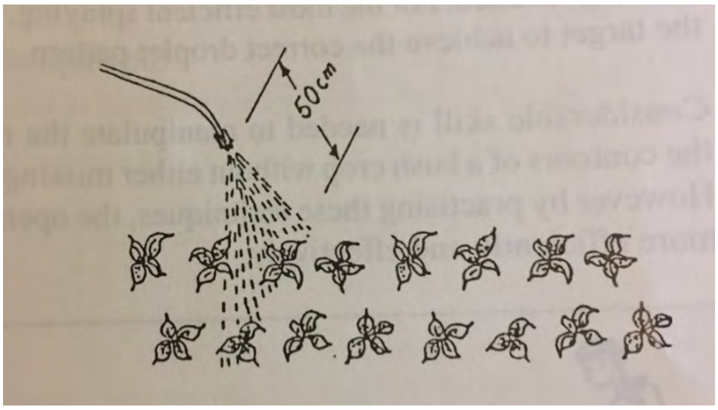


Fig. 5.9 How to spray cabbages or any low-growing plants from above. Keep the nozzle 50 cm above the crop.

When you have finished spraying, look at the leaves to check the way the droplets have landed. You want small droplets covering all the leaf. If you spray too much, the droplets come together and fall off the leaf (Fig. 5.10).

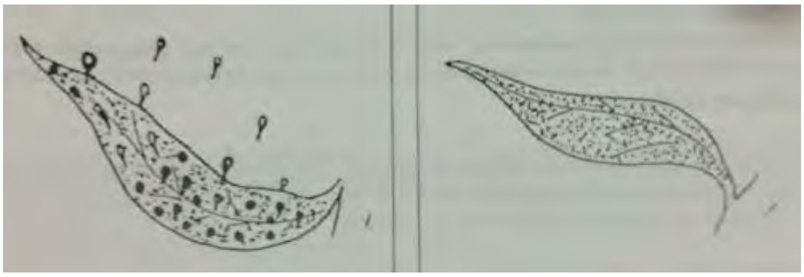


Fig. 5.10 Pattern of droplets on a leaf sprayed with too much pesticide run-off (left) and the correct amount (right)

For taller plants, e.g. tomatoes, your sprayer should be fitted with a hollow cone nozzle, and you should angle the lance sideways, moving it up and down and around the plants so that the spray covers both sides of all the leaves. Keep the nozzle about 50 cm from the plants as you spray (Fig. 5.11).

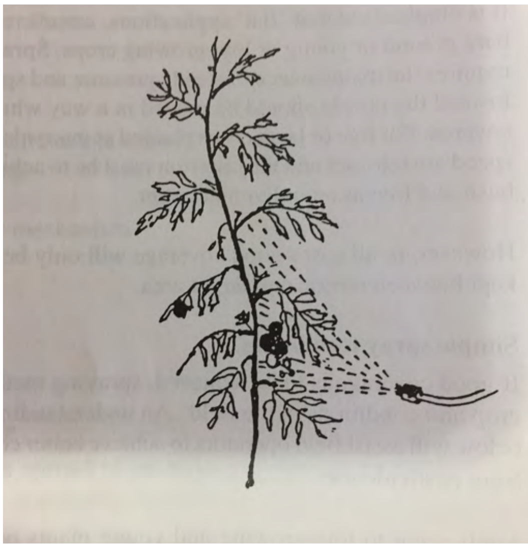


Fig. 5.11 How to spray tomatoes or any other bush from the side. Keep the nozzle 50 cm from the crop

If an accident happens, refer to the label. In case of a spill, cover the chemical with sand, sawdust or soil, and bury it away from the house at the edge of the garden or field

5.4.3 After spraying

- Clean the tank immediately after use so that the chemical does not dry on the inside
- Open the tank, remove the strainer, fill with 1.5 L of water, replace the cap and shake
- Pour onto an area that has been sprayed, or the ground nearby
- Add another 1.5 L of water and spray to clean the hose, lance and nozzle

After spraying, remove your clothes and shower. Wash the clothes separately from other clothing. And DO NOT eat or drink after spraying until you have washed.

EXERCISE 20: Making up a pesticide for spraying

Trainees should use the following information to determine how much pesticide is needed

- The pesticide label (*Eko*) tells you that you should apply *Eko* in **400 L of water per ha**.
- *Eko* is made up at **34 ml per 20 L sprayer** (see Fig. 5.6).
- The farmer has a **5 square chain tomato field**.
- Area: 5 square chains is equivalent to 0.2 ha (**25 sq chains = 1 ha, 5/25**)
- Spacing**: 0.5 m x 1 m.**
- The farmer has a **15 L** knapsack.

By themselves, trainees should answer the questions below:

1. **How many knapsack sprayers are needed to spray 1 ha of tomato?**

2. **How much (*Eko*) chemical will you need to spray 1 ha of tomato?**

3. **What advice would you give the farmer about the amount of chemical (*Eko*) … that he/she will use?**

4. **Check your answer with a partner and then discuss with the whole class.**

EXERCISE 21: Important factors in spraying

In pairs or small groups, trainees should write down at least four important things that they need to know before, during and after spraying. Discuss answers with the class.

Before spraying	1. 2. 3. 4.
During spraying	1. 2. 3. 4.
After spraying	1. 2. 3. 4.

5.5 Pesticides and organic farming

Organic farmers have a restricted range of pesticides they can use. This is because these farmers and their certifying bodies believe that many bought and even some home-made pesticides are harmful to humans, animals and the environment. Hence, some of the pesticides may not be as effective as bought ones, and not all have been scientifically tested.

Organic certification is carefully regulated. The Pacific Organic Standards (2008) are available at **https://lrd.spc.int/organic-pasifika-publications/cat_view/364-pacific-organic/369-pacific-organic-standard**. This document provides excellent information on organic farming in the Pacific region.

Some of the pesticide and growth regulators allowed in organic farming are listed and detailed in Table 5.4.

Table 5.4 Pesticides and growth regulator inputs allowed in organic farming.

Input	Purpose	Remarks
Chitin	Nematicide	
Coffee grounds	Insect repellent	Have a strong smell
Corn gluten meal	Pre-emergent herbicide	
Milk, casein	Fungicide	For powdery mildews
Gelatine	Insecticide	
Lecithin	Fungicide	
Vinegar	Herbicide, bactericide, fungicide	
Neem	Insecticide	
Castor oil	Rodenticide, insecticide, insect repellent, bird repellent	Care should be taken; it is very toxic
Grapefruit seed oil	Fungicide	
Chilli	Insecticide	
***Tithonia* (African sunflower)**		
Marigold (*Tagetes* species)	Insecticide and repellent of root knot nematodes	
Papain (from *Papaya*)	Thrips	
Jatropha	Insecticide, molluscicide	
Pongamia glabra	Insecticide	
Propolis	Insecticide	
Pyrethrum (Chrysanthemum cinerariaefolium)	Insecticide	The synergist (carrier) piperonyl butoxide used in commercial pesticides must not be used
Quassia (Quassia amara)	Insecticide	
Derris elliptica, Lonchocarpus spp., Tephrosia spp.) Rotenone	Insecticide	Studies show a (unconfirmed) link between rotenone and Parkinson's disease so use should be limited, and safety measures observed

Ryania (Ryania speciosa)	Insecticide	
Sabadilla	Insecticide	
Seaweed	Root diseases of sunflower and tomato	
Tobacco tea	Insecticide	Safety measures need be taken to reduce skin contact. Pure nicotine must not be used
Mineral clays (e.g. bentonite, vermiculite, perlite, zeolite)	Insecticide	Form a barrier to attack on the plant – used in orchards
Copper salts (e.g. sulphate, hydroxide, oxychloride, octanoate)	Fungicide, bactericide	Maximum 8 kg/ha copper per year (on a rolling average basis)
Light mineral oils (paraffin)	Insecticide, herbicide, fungicide	
Diatomaceous earth	Insecticide	
Lime sulfur (calcium polysulfide)	Fungicide	
Potassium bicarbonate	Fungicide	
Potassium permanganate	Fungicide, molluscicide, bactericide	
Quicklime silicates (e.g. sodium silicate, quartz)	Fungicide, molluscicide, bactericide	
Sodium bicarbonate	General post-harvest insecticide and fungicide for banana	
Sulfur	Insecticide, miticide, fungicide	
Fungal and bacterial preparations (e.g. *Bacillus thuringiensis*, Bt)	Insecticide	Used against caterpillars
Iron phosphate	molluscicide	
Calcium hydroxide	Fungicide, herbicide, bactericide	

Salt (sodium chloride)	Molluscicide, herbicide, insecticide, bactericide	
Sodium carbonate (washing soda)	Insecticide	Scale insects, mealy bugs, aphids, and mites
Soft soap	Insecticide	Scale insects, mealy bugs, aphids, and mites
Pheromones (in traps and dispensers only)	Insect traps	Traps for fruit-fly and substances as required by regulations are permitted

5.6 Pesticide resistance management

Some pests develop resistance to pesticides. This happens when the same pesticide is used repeatedly against the same pest in a crop. It is due to random genetic mutations that occur within the pest population; by chance, some of these mutations allow individuals to survive exposure to the pesticide and they multiply quickly, as there is little competition (Fig. 5.12). Soon, they become the dominant type.

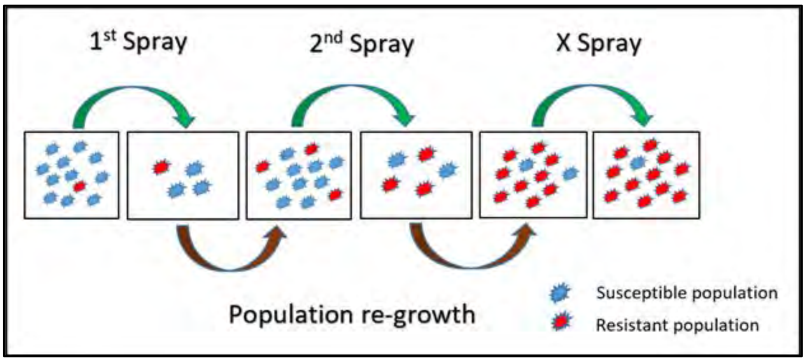


Fig. 5.12 Diagram showing how insect pest resistance to pesticides builds up.

Insecticides are grouped according to how they kill pests, i.e. their mode of action (MoA). The chances of a pest population becoming resistant to a pesticide can be reduced by making sure that a pesticide with the same MoA is not used repeatedly against successive generations of the pest. We must ensure that the pesticides used have different MoAs, as well as being the least harmful to natural enemies.

The 'Groups' mentioned in Fig. 5.13 (6, 11, 22 or 28 and 15) identify pesticides based on their chemical characteristics and the way in which they kill insects (ie their MoA). The trade names and common names are: Multiguard (abamectin); Ag Chem Bt (*Bacillus thuringiensis*); Prevathon (chlorantraniliprole); Steward (indoxacarb); and Match (lufenuron).

A critical feature of the approach is that insecticides that kill insects in different ways are rotated to slow the development of resistance. Fig. 5.13 shows how this strategy can be implemented to reduce the probability of the diamondback moth (DBM), a pest of cabbages, developing resistance to pesticides. In lowland regions of the Pacific islands, DBM can complete a generation (from egg to adult) in approximately 18 days. To make sure that successive generations are not exposed to the same type of insecticides, different insecticides should be used in the 'windows', as indicated in Fig. 5.13. In this strategy, Bt is used at the leafy stage, as this is the most sensitive stage of the crop. Bt has the added advantage that it is harmless to natural enemies.

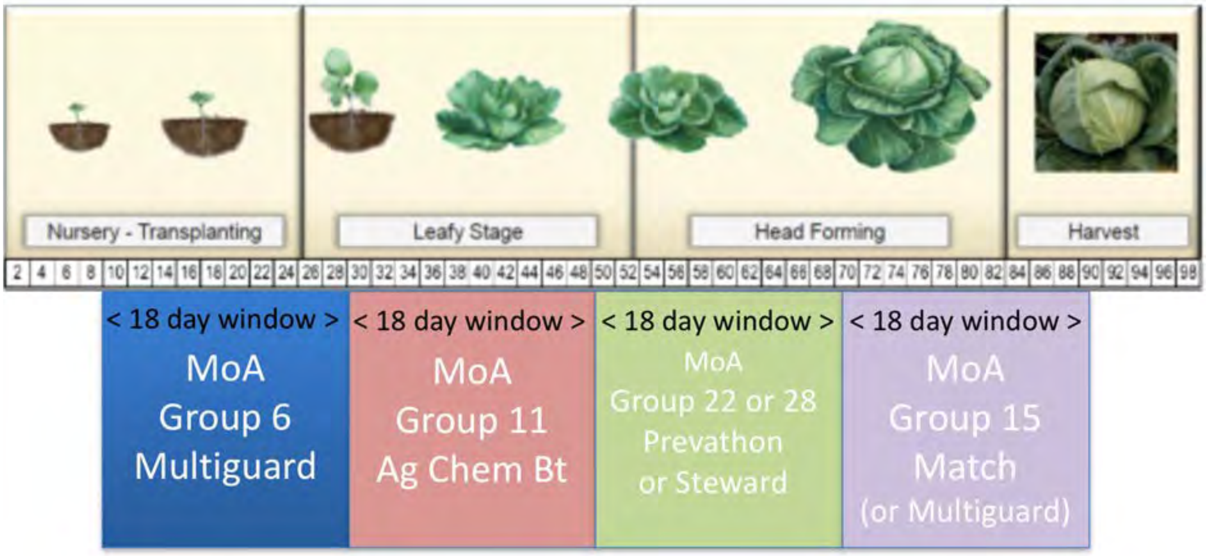


Fig. 5.13 Insecticide resistance management strategy for diamondback moth in the Pacific region, using pesticides with different ways of killing the pest (MoAs). Group 6 – avermectins (affect nerves (chloride channels)); Group 11 - *Bacillus thuringiensis* products (affect mid-gut of caterpillars); Group 15 - benzolureas (affect chitin synthesis in cuticle); Group 22 - oxadiazines (affect nerves (sodium channels)); Group 28 – diamides (affect muscle).

EXERCISE 22: Advantages and disadvantages of using pesticides

Trainees have now covered Chapters 4 and 5 on management of pests and diseases through cultural control and use of pesticides.

In pairs or small groups, they should discuss and write down what they now know about the advantages and disadvantages of using pesticides, compared with other methods included in IPDM.

An example is given below.

Advantages of using pesticides	Disadvantages of using pesticides	Safer alternatives
Example: • *They are cheap* •	• *They are toxic to beneficial insects* •	• *Crop rotation* •

EXERCISE 23: Using trainees' knowledge to identify and develop a management strategy for a farmer

Now that your trainees have studied the identification, diagnosis and management of pests and diseases, they need to put their knowledge into practice. Practice and experience are essential; becoming a competent plant health doctor is complicated and takes work! This is an important exercise, as it prepares your trainees for plant health clinics and is a good introduction to Chapter 6: Running a plant health clinic.

This exercise is in five parts. Allow your trainees plenty of time to work on it.

1. Identify and diagnose the problem
2. Ask the farmer questions about the problem
3. Manage the problem – make a plan
4. Completing the prescription form
5. Discuss and reflect

Trainees should work in pairs. Allocate two of the photos from Papua New Guinea highlands to each pair. The pictures show samples of problems a farmer might bring to a plant health clinic. The crops are:

- tomato (3 photos)
- zucchini (2 photos)
- Chinese cabbage (1 photo)
- cabbage - caterpillars (2 photos)
- cabbage - yellow spots (2 photos)

Part 1 – Identifying and diagnosing the problem

Trainees should now work through the process of identification and diagnosis of the problem in their photos. They should use all the information from the manual, Fact Sheets in the Pacific Pests, Pathogens & Weeds app, as well as their own experience.

Remind trainees to use the identification and diagnosing process in Chapter 2:

1. Is it A, B, or C? (Abiotic, Biotic or Confused)
2. Possible and Probable?
3. They should check with the feact sheets in the Pacific Pests, Pathogens & Weeds app ***only after they have done steps 1 and 2.***

Exercise 23 (PART 1)

TOMATO (i)

Exercise 23 (PART 1)

TOMATO (ii)

Exercise 23 (PART 1)

TOMATO (iii)

Exercise 23 (PART 1)

ZUCCHINI (i)

Exercise 23 (PART 1)

ZUCCHINI (ii)

Exercise 23 (PART 1)

CHINESE CABBAGE

Exercise 23 (PART 1)

CABBAGE (i)

Exercise 23 (PART 1)

CABBAGE (ii)

Exercise 23 (PART 1)

CABBAGE (iii) Black rot

Exercise 23 (PART 1)

CABBAGE (iii) Black rot (close up)

PART 2– Asking the farmer questions about the problem

As well as examining the sample, at a clinic, plant doctors will need to ask the farmer questions to provide more detail and information about the pest or disease.

1. Trainees should make a list of questions they would ask the farmer.
2. Each pair should now show the class their photos, read out their questions and discuss their diagnosis.

Part 3 – Managing the problem - making a plan

Next, trainees should discuss and write down all the different ways the problem could be managed, using:

- Biological control
  - Are there any natural enemies that are important to preserve which might be killed with some pesticides?
- Cultural control – what can be done?
  - Before planting
  - During growth
  - After harvest
- Resistant varieties
  - These can only be recommended if they are known to be available in the country
- Chemical control
  - Homemade pesticides
  - Commercial pesticides

Part 4 – Completing the prescription form

Trainees should now complete the plant health clinic prescription form. They can make up the farmer's details. Stress that they should fill in **ALL** parts, using clear handwriting.

Part 5 – Discussion and reflection

Discuss and reflect on the exercise as a class. What worked well? What is difficult to do? What can be done better? What training is still needed?

This exercise should now be repeated using real samples from a garden or field. Practice is essential!

The Plant Health Clinic Prescription Form

CLINIC

Date: ☐ Fiji ☐ Samoa ☐ Solomon Islands ☐ Tonga Code:

FARMER

Family Name: Given Names: Sex: M☐ F☐

Village/Settlement: Province: Mobile:

Clinic visit: 1st ☐ 2nd ☐ 3rd ☐ other: Age: < 29 ☐ 30-55 ☐ > 56 ☐ Sample: Yes☐ No☐

CROP

Crop: Estimate planted area (m^2):

Variety: Estimate no. of plants:

Seed source: Estimate no. of plants damaged: Few ☐ Many ☐ All ☐

Previous crop: Plant problem: Common ☐ New ☐

Crop stage: Weather: Normal ☐ Wet ☐ Dry ☐ Unusual ☐

DESCRIBE WHAT YOU SEE (if no sample, write what the farmer tells you)

WHAT CONTROL MEASURES HAS THE FARMER TRIED?

WHAT DO YOU THINK THE PROBLEM IS?

YOUR RECOMMENDATIONS

What can the farmer do now?

Cultural control Chemical control

What can the farmer do in future (when growing the same crop)?

Cultural control Chemical control

Before planting: Any resistance varieties?

During growth

After harvest:

Photo(s) taken: Yes ☐ No ☐ Sample sent to lab? Yes ☐No ☐

Plant doctor: Signature: Mobile no.:

END OF CHAPTER 5 QUIZ: Test your knowledge

Multiple choice. Pick one answer only.

1. **Which of the following are all fungicides?**
   A. Manzate, milk, baking soda, malathion
   B. Sundomil, Kotek, Kocide, Talendo
   C. Glyphosate, neem, Blitzem, pyrethrum
   D. Confidor, Orthene, Bt, Manzate

2. A sprayer nozzle suitable for fungicides should:
   A. be an anvil type and the spray should form a light rain.
   B. be a flat type and the spray should form a mist.
   C. be a hollow cone type and the spray should form a mist.
   D. be a flat type and the spray should form a cloud.

3. A pesticide label says that it should be made up at a concentration of 10 ml pesticide to 10 L water. The concentration of the pesticide is:
   A. 10%.
   B. 1%.
   C. 0.1%.
   D. 0.01%.

4. A farmer has 10 ha of a crop to be sprayed. The pesticide label tells her that the spray should be 30 ml pesticide per 20 L water and the crop should receive 400 L per ha. How many ml of the pesticide should she use to make up the spray to spray the whole crop properly?
   A. 4000 ml
   B. 600 ml
   C. 6000 ml
   D. 2400 ml

5. Buildup of insecticide resistance in a pest can be prevented by:
   A. alternating the spraying between an insecticide and a fungicide.
   B. spraying early in the morning.
   C. using the correct type of nozzle for spraying.
   D. making sure the same type of insecticide is not used all the time.

6. Which of these pesticides are not allowed in organic farming?

A. copper fungicides
B. tobacco
C. castor oil
D. glyphosate

7. Which action should you NOT do if you accidently spill some pesticide?

A. cover the area with sand.
B. make sure you wash yourself and your clothes thoroughly.
C. get the dog to lick it up.
D. keep children away from the spill.

8. Pesticide resistance in insects is caused by:

A. a genetic mutation that is passed on to new generations of the insect.
B. a fungicide being used by mistake.
C. a virus getting into the insect.
D. using the wrong crop rotation.

9. Which of the following information is NOT usually found on a pesticide label?

A. the type of product
B. which pests are resistant to it
C. what it contains
D. what crops it may be used on

10. An emulsifiable concentrate:

A. is the same as a wettable powder.
B. is incompatible with all other pesticides.
C. cannot be mixed with water.
D. forms a milky liquid when mixed with water.

11. A pesticide withholding period means:

A. how long before it is safe to enter the crop after spraying.
B. the period during which animals are not allowed to graze on the crop at any time.
C. the number of days between the last application of a pesticide and crop harvest.
D. how long before a pesticide is allowed into a country.

12. Copper can be used to control:

A. phytoplasmas and viruses.
B. nematodes and mites.
C. snails and insects.
D. bacteria and fungi.

13. **Pests in a small farm or garden are best controlled by:**
   A. ignoring them.
   B. using pesticides as soon as they are seen.
   C. encouraging beneficial insects and spiders.
   D. using insecticides and fungicides weekly.

14. **Pesticides allowed in organic farming:**
   A. come only from plants.
   B. are the same as commercial pesticides only weaker.
   C. are controlled under organic standards.
   D. Are always safe.

CHAPTER 6

Running a Plant Health Clinic (PHC)

This chapter covers the whole process of planning, conducting and reflecting on a plant health clinic.

What equipment do I need?

STATIONERY

- ✓ Prescriptions forms
- ✓ Farmer feedback forms
- ✓ Notebooks, marking pens, pens and pencils
- ✓ Labels
- ✓ Butchers or brown paper

ON PHONE OR TABLET

- ✓ Camera
- ✓ CommCare app
- ✓ Pacific Pests, Pathogens & Weeds app
- ✓ WhatsApp (see Chapter 3)

EQUIPMENT

- ✓ Knife/scissors
- ✓ Hand lens
- ✓ Bottles for insect capture
- ✓ Water and bucket for washing roots
- ✓ Plastic bags to keep samples fresh for discussion and reflection after the clinic
- ✓ Newspapers for wrapping samples for identification
- ✓ Cardboard (paper) box
- ✓ Uniforms
- ✓ Isopropyl alcohol for preserving insects.

Do not use a Stanley knife blade or scalpel – they are dangerous and snap easily

OTHER ESSENTIALS

- ✓ Tarpaulin
- ✓ Table and chairs
- ✓ Banner
- ✓ Samples from the field
- ✓ Samples brought in by farmers
- ✓ Materials for wrapping and sending away 'unknowns':
    - o newspaper
    - o 70% alcohol or isopropyl alcohol
    - o small glass tube
    - o toilet or tissue paper
    - o self-sealing plastic bags
    - o dry silica gel or calcium chloride

6.1 Introduction to running a plant health clinic

Fig. 6.1 Clinics in action in Fiji (left) and Samoa (right)

There are a number of important points for plant health doctors to think about when preparing for and running a plant health clinic successfully, as well as reviewing and reflecting on it afterwards.

If there is time, it is a good idea to run a practice clinic with extension staff (and research and biosecurity staff if resources allow), especially if there has not been a plant health clinic in the area before.

Exercises 24,25, 26 and 27 are designed to take your trainees through the whole process of running a clinic in class before the actual clinic takes place. These exercises cover the topics listed below.

1. What do we need for a successful plant health clinic?
2. How to use WhatsApp as a plant doctor
3. Filling out the prescription form
4. The CommCare app
5. The farmer feedback form

Preparation needs to be done several days in advance of the clinic
Good awareness is essential!
Without it, farmers will not come, or they will not bring samples

EXERCISE 24: What do we need to run a successful plant health clinic?

This exercise helps your trainees think about everything they will need for a successful clinic

In pairs or threes, on butchers' paper or brown paper, trainees should use a marker pen to divide the paper into three columns and write 'before', 'during' and 'after' as headings. Ask trainees to brainstorm and write down in each column all their ideas about running a clinic before, during and afterwards, *without looking at the answers in the manual.*

When ready, one group should give their ideas, starting with 'before'. After that group has spoken, the other groups should just add anything that has been left out (otherwise it will take too long, be repetitive and people might get bored.) An example is given for you.

What do we need?		
Before the clinic	During the clinic	After the clinic
Identify a good location for farmers	*Pacific Pest, Diseases & Weeds app*	*Samples brought by farmers*

Now, trainees should read the checklist at the beginning of this chapter **very carefully** and add anything they may have missed to their list.

EXERCISE 25: WhatsApp - How to use it

Trainees should have already joined their country WhatsApp group as described in Chapter 3

WhatsApp is very useful for Unknowns or Confused samples seen during the clinic. Trainees should take a picture of a pest or disease and send it to their WhatsApp group. It is important that trainees send photos that are in focus. They should give their name, place of work and information about the crop and problem.

Ask trainees:

- What do you think the problem is?
- If you received a reply, is it what you thought it was?
- If not, what is it?
- Was this helpful? Why or why not?
- Share your photos and any feedback from WhatsApp with the class. Note: it may take time to get feedback from WhatsApp.

Trainees should share their photos and any feedback from WhatsApp with the class. Note: it may take time to get feedback from WhatsApp.

EXERCISE 26: Role play - filling out the Prescription Form

This exercise builds on Exercise 21 in Chapter 5, and gives trainees more practice on what they will do in the clinics.

Trainees should form pairs, where each pair is made up of one experienced plant health doctor and one with less experience (where possible). Provide each group with a sample or ask the trainees to go outside and collect samples of:

- A pest
- A disease
- An unknown or confused problem

If they cannot find a good sample, trainees can use one of the photos in the manual or one from the Pacific Pests, Pathogens & Weeds app.

Provide each group with a copy of the **Prescription Form** to fill in and a **Farmer Feedback Form (in appendix)** (Exercise 28).

Modelling the process

To start with, you or someone who has experience with plant health clinics, should model the process of working with a farmer to show the trainees what to do. You role-play the 'doctor' and choose a trainee to role-play the 'farmer'. The 'doctor' should interview the 'farmer' and the other trainees should observe.

Clearly model all the steps of being a doctor. Explain what you are doing as you work through the identification and diagnosis steps carefully (see Chapter 2).

1. Is it A, B or C? (Abiotic, Biotic or Confused)
2. What are the possible and probable causes?
3. Make a diagnosis
4. Check with the Pacific Pests, Pathogens & Weeds app
5. Decide on possible recommendations for treatment, both straight away and into the future
6. Fill in the Prescription Form

Now ask your trainees to play the roles of doctor and farmer.

After this, swap roles and work through another sample together. Continue until everyone has had a turn playing both doctor and farmer.

Emphasise that doctors should not go straight to the
Pacific Pests, Pathogens & Weeds app!

When you have finished, ask trainees to discuss their experience of the role play.

- How easy or difficult was the process of making the diagnosis?
- What was easy about filling in the form?
- What did they find difficult?
- Were they able to make a diagnosis and give a recommendation? Yes/No.
- If NO, why not?

Now ask the person who played the farmer to complete the **Farmer Feedback form** (see Exercise 28).

The Farmer Feedback form will be used at a real clinic. After each interview, the person who played the role of the farmer should give feedback to the plant health doctor on the diagnosis process and their ideas on management.

Remember to tell trainees that handwriting must always be neat on prescription forms so that others can read it. If you know your handwriting is not neat, print carefully!

EXERCISE 27: Using the CommCare Prescription Form

CommCare is an app that can be used on a smartphone instead of the prescription form to record the farmer's data. The advantages of CommCare are:

- *the prescription forms can be filled in off-line and sent later when there is a wi-fi connection available*
- *the results of the interview can be entered straight away*
- *it is quick to fill in*
- *typing avoids handwriting by plant health doctors that may be difficult to read*
- *a single doctor can interview more farmers in a shorter period*

Features of CommCare are:

- *it incorporates multimedia – supports video, audio messages, images, GPS, and signature capture*
- *It creates an Excel spreadsheet automatically*
- *it has unlimited data storage – uses a secure cloud server*
- *it supports multiple languages*
- *it supports two-way SMS messaging – it sends and receives messages to your intended audience*

Demonstrate to the class how the CommCare form works.

Trainees should download the CommCare app to their smartphones or tablets, then fill in the form using, a sample of a pest or disease that you give them.

Note, farmers will still need a copy of the Prescription Form. If the CommCare app is used at a 'real' PHC, there needs to be two plant health doctors for each farmer, one filling out the CommCare app, the other filling in the Prescription Form, so a copy can be given to each farmer.

EXERCISE 28: Filling in the Farmer Feedback form

The Farmer Feedback form (also in the appendix) is an important part of PHC improvement, as well as for monitoring and evaluation (M&E) purposes. It is used to obtain immediate feedback from farmers after they have seen the plant health doctor at the clinic. The clinic manager or another person (especially someone who speaks the farmer's language) needs to interview each farmer and complete the form. ***The manager needs to make sure that the interviewer understands exactly what information is to be collected, and how it will be used, and by whom.***

After the clinic, the manager collects and collates all the feedback forms and presents the information during the reflection session after the clinic (see Exercise 30).

Farmer Feedback Form

1) **Did the plant health doctor diagnose your problem? (please circle)**

Yes No Not sure

Why?

____

2) **Do you think you can carry out what the doctor said you should do?**

Yes No Not sure

Why?

____

3. Was the clinic useful?

Yes No

Why?

____

4. Do you have any suggestions on how to improve the plant health clinic?

____

5. Would you recommend the clinic to other farmers?

Yes No

Why?

____

6. If there is another clinic in your area would you come again?

Yes No Maybe

EXERCISE 29: Preparing for many farmers attending the clinic with the same problem

It is important that all farmers see a plant health doctor, even if they have the same problem as other farmers

Often, a number of farmers will bring the same problem to the clinic. If there is time after the farmers have received their prescription from the doctor, it would be very useful to gather them together and ask one of the doctors to give them a short talk about the problem. This will give the farmers the opportunity to talk to each other about the problem and what they are doing about it.

Trainees should prepare by making sure they are aware of the major pests and diseases in their area (see Exercise 7 in Chapter 2), although sometimes new problems can spring up quickly, especially when weather conditions change. Other extension staff should be contacted if necessary, to find out.

Either in a group or as a whole class, give your trainees the names of pests or diseases that are likely to be a problem in the area where the clinic is to be held. If possible, samples from the field should be used. The trainees should research these using the Pacific Pests, Pathogens & Weeds app to make sure they understand:

- The symptoms
- The diagnosis
- Recommendations for control now and in the future

Trainees should discuss how they will approach these problems with the farmers.

6.2 Checklists for running a plant health clinic (PHC)

Throughout Chapters 2-5, your trainees have explored how to identify, diagnose and manage plant pests and diseases. Now they are ready to apply their knowledge to run a real PHC with their local farmers. To do this properly requires careful planning so that the clinics will run well and be of real benefit to farmers.

An excellent way to make sure a clinic is well planned is to use a checklist for each aspect. This way, nothing is forgotten and the responsibility for planning a clinic can be shared within the Plant Health Doctor team.

Use the checklist in Table 6.1 to check each aspect of planning for before, during and after a PHC. Sections 6.2.1 to 6.2.6 provide additional detail for planning for each of the checkpoints in Table 6.1. Also see the Plant Health Clinic Procedure Check List in Appendix 5.

Table 6.1 A checklist for before, during and after running a Plant Health Clinic. Tick off each task as they are completed.

<table>
<tr><th colspan="2">Checklists for Plant Health Clinics</th></tr>
<tr><td colspan="2">General preparation for PHCs</td></tr>
<tr><td></td><td>Clinic timing
How often should they be held?
Make a strategic PHC plan for your country
Always plan subsequent clinics in advance, so you can announce the next date at your current clinic
Samples
Clinics run best when farmers bring samples that are kept for reference. Discuss with your team how you are going to collect, label, manage, store and follow up with any samples before planning a PHC
Staff
Are there enough staff appointed to the PHC team to effectively run clinics in the field and conduct the administration before and after them?
Recording PHC data
Create a database before ever conducting a PHC. Make sure all staff in your team understand its importance and know how to use it</td></tr>
<tr><td colspan="2">Before the clinic</td></tr>
<tr><td></td><td>Location - Is it:
Accessible?
Visible?
Conveniently timed?
Awareness:
Radio
TV</td></tr>
</table>

	- Phone calls - Emails - Encourage whole plant samples to be brought - Give farmers plenty of notice **Budget:** - Stationary - Advertisement - Other materials **Staff:** - Clinic manager - Data entry - Plant protection officers (extensions, research, biosecurity) - Country's WhatsApp community on stand-by
At the clinic	
	Setting up: - Table, chairs, tarpaulin - Banner and pull-ups advertising the clinic - Access to wi-fi, if possible - A decision on what to do with 'unknowns' **Plant health doctors - what is needed?** - Materials for assessing samples, recording data, providing prescriptions (see detailed list in section 6.2.3)
Steps to ensure a successful PHC	
	Farmer registration and direction: - Make sure farmer's samples are processed appropriately - Ensure farmer interviews and prescriptions are completed timely and accurately

	• Have the farmers complete a feedback interview • Provide farmers with factsheets, leaflets, other information sheets or resources
What to do with unknowns.	
	• Tell the clinic manager if you have an unknown. He or she should ask other plant health doctors who might be able to identify it • Make sure unknowns are assessed by one or more plant health doctors • Ask the WhatsApp community for help • Make sure the clinic manager follows up with SPC or other research/biosecurity divisions for identification • Do not forget about unknowns! If you tell farmers you will follow up after the clinic to help them, do not forget to get an answer for them. **If there is no follow-up, farmers will not come to future clinics**
Immediately after the clinic.	
	• Enter all the data from the prescription forms in the database if you are not using the CommCare app. • Collate Farmer Feedback forms (the clinic manager usually does this) • Follow up on any unknowns that have not been solved. • **Review and reflection:** o What went well? o What could have been better? o What changes will you make the next time? o Make notes to record changes that will be made next time

6.2.1 General preparation for plant health clinics

How often should clinics be held?

How often you hold a clinic depends on your country's implementation plan, availability of staff, and resources. Ideally, a clinic should be run at least once a month. Always announce at the clinic when you will hold the next one in the same location.

Samples

Encourage farmers to bring samples of unhealthy plants, preferably with early symptoms. Farmers should try to bring the whole plant, including the roots.

Each sample should be given a code on a piece of card which is the same as the code in the top right-hand corner of the prescription sheet. If more than one sample is brought in, the letter A, B, etc. should be added to the code on both the card and the form.

After the clinic, the plants should be put into a bag with the correct sample code and be discussed in the reflection time after the clinic. Then they should be disposed of safely to avoid spreading pests and diseases.

Check that the sample has a card with the correct code that matches the prescription form when it is put in the bag.

Recording plant clinic data

Clinic data will be entered into a database (e.g., Excel). The data can supply information on clinic use, such as the ratio of men and women attending and the frequency of submission of particular pests and diseases. It also checks on the quality of advice given by extension staff. Staff who need further training or information can be identified by looking at the data. This is an important element in the M&E part of the plant health system. It means that, over time, a set of data regarding plant health clinics can be built up and used for monitoring and research. If possible, avoid the need to add data manually, and instead use the CommCare app which fills an Excel spreadsheet automatically and so avoids mistakes (see Exercise 27).

Staff

A clinic manager (usually from extension services) should be appointed in charge of the clinic. Where possible, there should be at least two plant health doctors for each farmer to process queries efficiently and share their thoughts on diagnosis and advice.

6.2.2 Before the clinic

Location

Clinics should be held in accessible places such as markets and other places that farmers visit regularly, and held at times that are convenient to farmers. Extension offices in agriculture department buildings are not good venues; they are busy places and often too far for farmers to reach easily. The clinic site should be made clearly visible, using banners.

Awareness

Good awareness is essential. Plan awareness and announcements through radio, banners, TV, phone calls, texts, WhatsApp, email, word of mouth and other means. Decide when to start, and how many times to repeat the message. Farmers should be reminded to bring samples of unhealthy plants, and also insects that are damaging their crops. They should bring as much plant material as possible *including the root.* Just bringing part of a small leaf is not useful for a satisfactory diagnosis.

Budget

Check that the estimated budget is sufficient to cover all expenses (stationery, materials, travel, etc.) for the clinic.

Staff

Appoint a clinic manager who is in charge of setting up, running, closing the clinic and collating and presenting the farmer feedback data.

Invite staff from other agriculture divisions who directly work in plant protection. They do not need to attend the clinic, but make sure that they are standing by on the day to give advice if needed.

Ensure that the plant doctors are members of their country WhatsApp group (Chapter 3). Alert the WhatsApp community that there is a clinic taking place and ask them to stand by so they can help in sample identification.

6.2.3 At the clinics - steps to ensure success

Farmer registration and direction[11]

1. At the registration table, greet the farmer.
2. Direct farmers to the waiting area where they can have some refreshments (if provided) and look at useful material, such as:
    - fact sheets
    - posters
    - leaflets
    - newspapers
    - nutrition information
    - video on safe use of pesticides from Papua New Guinea
3. Take a photo of the farmer's samples.
4. Direct the farmer to the doctor's table when the previous farmer has finished.

TIP: The manager or another extension officer could give the farmers a short tour and talk about the information on the posters.

[11] The clinic manager may prefer not to have a separate registration desk and let the plant health doctors complete the full form as well as photograph the samples. If so, make sure labelling is carefully done to match: (i) the sample; (ii) photos; and (iii) the Prescription Form

Giving the farmer advice

1. When the farmer comes to the doctor's table, welcome him or her and ask the questions on the Prescription Form
2. Fill in the first part of the Prescription Form, if not already completed
3. Examine the sample (if the farmer has brought one), discuss the problem, ask the farmer relevant questions, and try to diagnose it using the diagnosis process you have practised
4. Suggest recommendations to the farmer, and check if he/she understands them and is able to carry them out
5. Fill in the rest of the Prescription Form and give the top copy to the farmer
6. Ask the farmer to go to the person who is doing the farmer feedback interview
7. Label the farmer's samples and any photos taken of the samples with the same code as that on the Prescription Form
8. Put the samples in a bag. Make sure this is done and the samples are taken back to the extension office for the reflection after the clinic

Remember: If a lot of farmers come with the same problem, let the manager know. He or she can arrange to gather them together and talk to them in a group (Exercise 29).

If needed, trainers should translate the prescription and farmer feedback forms into the national language but a copy in English is needed for data entry

6.2.4 What to do with unknowns

Sometimes a plant doctor will find it very difficult to make a diagnosis for the farmer. Before the clinic, the plant health doctors should make sure they know what to do if they have an unknown problem, or if they are confused. Read Chapter 3 again for online help. If a doctor cannot diagnose a sample and cannot make a recommendation, then they need to tell the farmer, not make up an answer. It is much worse to give farmers the wrong information than to tell them, "I don't know, but I will find out and get back to you."

Plant health doctors should record the word “unknown” on the Prescription Form and take the farmer’s phone number to follow-up.

What to do if plant doctors have an unknown sample at a clinic:

- Tell the clinic manager if there is an unknown. He/she can ask if any of the other doctors can make a diagnosis. It may have already been brought in and diagnosed by another doctor
- If it is still unknown, send a photo via WhatsApp to the experts, who will be standing by while the clinic is in progress
- The clinic team may need to arrange a visit to the farm
- In the section on the Prescription Form: ‘WHAT DO YOU THINK CAUSES THE PROBLEM?’, write ‘Unknown’ and tell the farmer the team will find out what the problem is. Do not leave it blank! Remember, never write a diagnosis if unsure of the problem. It is always best for a doctor to say if they don’t know.
- After the clinic, the manager may decide to send the sample to the research/biosecurity division for identification. The process for this is described in Exercise 31.
- Make sure the advice is followed up with the farmer when there is a positive diagnosis. **Never promise you will help the farmer and then do nothing about it!**

Important reminders for plant health doctors

- Fill out the form neatly and clearly, print if necessary
- Tell the clinic manager immediately if there is an unknown
- Tell the farmer if you don’t know, rather than guess
- If there is no solution at the clinic, tell the farmer it will be followed up and get back to him or her as soon as possible

6.2.5 After the clinic

Data entry

Good quality accurate data allows the plant health team to draw conclusions from the clinics, update a country's information about pests and diseases, and make improvements. The clinic manager or another Extension officer is responsible for entering the data from the prescription forms into an Excel spreadsheet (if the CommCare form is not being used).

Follow-up with farmers

The clinic manager is responsible for making sure the clinic team follows up on unknowns, i.e. letting the farmers know the results of diagnoses made by experts from biosecurity or elsewhere. The results must be added to the spreadsheet.

In addition, recommendations that were not given to the farmer at the time, but which were identified in discussions during the reflection with other plant health doctors, should be given to farmers over the phone. These, too, should be added to the spreadsheet.

The **clinic manager** is responsible for making sure that follow-up data are entered into the system to fill in the gaps. For example: If a sample that was sent away for diagnosis comes back from the laboratory, the officer responsible needs to add it to a spreadsheet, as well as communicating with the farmer.

Note: if the CommCare app is used, the information entered can be automatically entered into an Excel spreadsheet which you can access.

Review and reflection

After the clinic, plant doctors need to come together, as well as follow up with the farmers, and collect data that will show how successful the clinic was. This is a very important part of the whole PHC process. It is where the plant health doctors share their experiences of the clinic held that day, think about what went well, what was learned and what needs to be improved or changed next time.

Exercises 30-35 allow trainees to reflect on what they have learned during their training and their experience at the clinic. It will help identify any areas that require additional training so that they are confident in their ability to run successful plant health clinics into the future.

It is also very important to make a summary for the clinic. It does not take much time but is necessary for record keeping, and for sending to senior officers, the media and others who are interested in these clinics. To make it easier for you, there is a photosheet[12] summary that can be used as a model (Fig. 6.2). Trainees can practise this in Exercise 35.

[12]The photo sheet concept was suggested by Dr Eric Boa, University of Aberdeen.

SAMUSU - ALEIPATA, SAMOA

Ministry of Agriculture & Fisheries

4th October 2018

This Plant Health Clinic was held at Samusu – Aleipata, a village towards the far east of Apia, in conjunction with the regional team to test the training manual. It started at 10am and concluded at 1pm. About 18 farmers attended; a third were women. Farmers came from Samusu, Lalomanu, and Salani. All the farmers brought samples and many brought more than one sample from different crops; there were 40 problems diagnosed.

The problems included bacterial wilt on tomato and capsicum; root-knot nematode on tomato and cabbage; LCM on cabbage; possibly Pythium rot on taro; white flies and sooty-mould on broccoli; root rot (possibly nematodes) on banana; fruit piercing moth on tomato fruits; fruit fly and rot on cucumber.

Plant doctors from MAF were Christian T, Faalelei T, Mu V, Kuini T, Tamoe T, Aleni U, Latatuli L, Tommy T and Leafa G; from the regional team; Ratu Toloi V (Fiji) Tevita T and Emeline A (Tonga), Rosemary A (Solomon Islands), Mani M (Pacific Community) under the supervision of Dr. Grahame Jackson (PestNet) and Dr. Caroline Smith (University of Tasmania). Sailo Pao was the clinic manager.

Prepared and reported by the Ministry of Agriculture and Fisheries. For more information, contact Sailo Pao, Crops Division, Nu'u Research Station. Mob: 7230442 Email: sailop.pao@maf.gov.ws; Plant Health Clinics are held as part of a sub-regional ICM/IPDM project (HORT/2016/185) – *Responding to emerging pest and disease threats to horticulture in the Pacific islands*, with support from the Australian Centre for International Agricultural Research, Canberra.

Fig. 6.2 An example of a plant health clinic photosheet summary to be used as a model for future plant health clinics.

EXERCISE 30: Reflection on the clinic process

On butcher's or brown paper, trainees should discuss what went well and what did not go well. Encourage them to share all their experiences, not just their successes. This is how they will learn.

Trainees should record their discussion using this table and share with the class. An example is provided.

What went well?	What didn't go so well?	What training is still needed?	What improvements will be made at the next clinic?
A lot of farmers came	*Only a few women came*	*Diagnosis*	*Make sure awareness targets women in particular.* *More diagnosis practice before next clinic*

EXERCISE 31: Farmer feedback data

The clinic manager will collate all the Farmer Feedback forms and present the results. This will let the team know what the farmers thought about the clinic, which will also help to plan for the future.

Discuss the results.

1. What do the results tell your trainees about how well they ran the clinic?
2. What should be done to improve next time?
3. Does the feedback form provide enough information about the farmers' experience at the clinic?
4. Does the form need improving? If so, how?

EXERCISE 32: Reflection on diagnosis and recommendations

This exercise is one of the most important to do after the clinic. In a safe learning environment, your trainees will come together with farmers' samples and copies of the completed Prescription Forms to discuss their descriptions, diagnoses and recommendations.

Trainees should form groups of two or three and go through samples from the clinic. They should discuss:

- Their diagnoses of a pest, a disease and a 'confused' sample brought by farmers to the clinic
- Any differences of opinion
- What they told the farmers to do in i) the short term and ii) the long term
- Any samples that could not be identified ('unknowns')
- How they informed (or will inform) the farmers about the unknowns

Each group should select **one sample** and report their findings to the class using the template below, either as a PowerPoint or on paper. The discussion afterwards should focus on the process of the diagnosis and the recommendations. Any changes should be discussed with reasons

Farmer and location: **Crop:** **Symptoms:** **Diagnosis:**	**Insert photo if available**

What farmer can do NOW	E.g. Cultural control	E.g. Chemical control
What farmer can do in the future	E.g. Cultural control	E.g. Chemical control

EXERCISE 33: Sending samples for identification

This exercise shows trainees how to send unknown samples to experts for identification.

If no one is able to identify their sample, it will need to be sent to an expert for examination, either locally or overseas. Samples of pests and diseases should be placed on three tables labelled 1-3: 1 - for pests; 2 - for diseases excluding viruses; 3 - for viruses. Trainees can work though the procedure for each type of pest and disease, then move to the next table, so that they have experience preparing samples for different types of pests and diseases.

Details of the methods can also be found on the PestNet website (www.pestnet.org).

You will need the following for this exercise:

- ✓ Paper for labels
- ✓ Pencils
- ✓ Plastic bags
- ✓ Newspaper
- ✓ Sticky tape
- ✓ Alcohol (if not ethanol, then isopropyl alcohol)
- ✓ Small bottles
- ✓ Envelopes
- ✓ Camera for taking photographs of samples
- ✓ Silica gel and calcium chloride (if available)

Before going to a table, each group should write a note to put inside the parcel containing:

- crop/plant name
- code given at the clinic
- doctor's names and address
- code, same as on the prescription form
- date and location of the clinic
- farmer's name and phone number
- farmer's village
- a short description of the problem and any other useful information they think will be useful

Table 1: Processing damaged or diseased plant samples

1. Collect the samples showing a full range of symptoms.
2. Take a photo of the samples
3. Make a parcel of the specimens with newspaper.
4. Attach the second label to the front of the parcel. If possible, seal the label with sticky tape to protect it.

Table 2: Processing insects and mites

1. Take a photo of the samples
2. For small insects – thrips, aphids, hoppers as well as mites, preserve in alcohol. 70% alcohol is best, but probably not easy to find. So, use isopropyl alcohol which should be available at the local chemist.
3. Place a small amount of alcohol in a bottle.
4. Carefully pick up the insect, or cut out a piece of the plant that contains the insects or mites, and place it in the bottle with alcohol.
5. Add a label (as detailed above) to the bottle. It is important that all labels are written in pencil, as ethanol removes ink.
6. Make sure that the tube/bottle does not leak!
7. Place in plastic bag, and tie the opening.
8. For larger specimens, wrap them carefully in paper envelopes and place them in a secure box so that they are not crushed. Use this method for Lepidoptera (butterflies and moths): do not put them in alcohol.

If you are sending a scale insect or mealybug do not attempt to remove it from the leaf or twig on which it is feeding. Do not put butterflies and moths into alcohol as the scales will fall off. Instead, fold in paper envelopes.

Table 3: Processing samples caused by viruses

Trainees are unlikely to process samples infected by viruses as special equipment is needed. However, you might wish to explain how it is done for their interest.

1. Take a photo of the samples
2. Cut out the area of the leaf that shows symptoms of virus.
3. Place this on a clean wooden board, or a tile or thick paper and cut out strips 10 mm wide, using a clean scalpel or a clean sharp knife (wipe it first with alcohol or bleach).
4. Cut across the leaf pieces, making strips 1 x 10 mm wide.
5. Place these, loosely packed, in a screw-capped tube (about 30 ml) half-filled with silica gel (blue) or calcium chloride. (If you do not have either, then dry the samples in an air-conditioned room).

6. If the samples is not crisp dry after 24 hours, transfer it to a new tube of drying agent.
7. When dry, fix the second label with clear tape on the outside of the tube.

Note, if the silica gel is pink, it means the sample is not yet dry. It needs to be re-dried at 150°C for 3–4 hours until the silica gel is blue. Be careful to wait until the silica gel is cool as it retains heat for some time.

EXERCISE 34: Plant health doctor self-evaluation form

Now it is time for your trainees to evaluate themselves as plant health doctors. This is anonymous, but it will help the extension service to monitor how well the program is running and what further training may be needed.

On a sheet of A4 or brown paper, trainees should give their answers to the questions below. In questions 1, 2 and 3, 1 is the lowest level of confidence and 5 is the highest. They should circle the number that they think best fits their level of confidence.

1. How confident are you in your abilities to make correct disease diagnoses?

1 2 3 4 5

2. How confident are you in your ability to correctly diagnose pest problems?

1 2 3 4 5

3. How confident are you in your ability to make correct recommendations?

1 2 3 4 5

4. Do you feel you need more training?

Yes/No

5. If 'Yes' what training is needed? Please specify (e.g. IT, diagnosis, filling out the prescription forms, interviewing farmers, etc.)

Collate and report the results from the class.

Discuss:

What does this say about your trainees' level of confidence and ability to conduct a plant health clinic? How can you and your trainees continue to improve?

EXERCISE 35: Making a plant health clinic photosheet summary

It is very important to make a clinic summary. It does not take much time but is necessary for record keeping, and for sending to senior officers, the media and others who are interested in these clinics. Use the template below. This can be done in Word or Acrobat Pro. Following the template, provide the location and date, the number of farmers, the number of men and women, where they came from, the problems they brought to the clinic, the diagnoses made, and the names of the plant health doctors. Contact details of the organisation hosting the clinic should also be added. See the example in Fig. 6.2

XX COUNTRY

XX (major administrative area)

XX (PLACE ORGANISATION) PLANT CLINIC

XX (organisation) | DATE

INSERT PHOTO 1	INSERT PHOTO 2
INSERT PHOTO3	INSERT PHOTO 4
INSERT PHOTO 5	INSERT PHOTO 6

This plant clinic was held at XX and organised by XX. The XX (clinic) is located XX km N/S/E/W from XX town.
N farmers participated at the clinic; there were N men and N women).
N samples were received.
Some of the key problems presented were XX.
The plant doctors were XX.
[Other information]: You could add if any specimens were sent for identification.

Prepared and reported by XX, Organisation. For more information contact XX (person, phone number, email, etc.).
Photos by XX (if a different person).

Plant clinics are held as part of the ACIAR project: Responding to emerging pest and disease threats to horticulture in the Pacific islands.

END OF CHAPTER 6 QUIZ: Test your knowledge

Multiple choice. Pick one answer only.

1. Plant health clinics are important parts of:

A. a country's food security
B. a country's plant health system
C. the agricultural extension system
D. all of the above

2. The best place to hold a clinic is:

A. where many farmers gather, e.g., a market
B. at the research station
C. on a farm
D. at the university

3. Important advice for farmers when raising awareness about a forthcoming clinic is:

A. to bring the whole plant, including roots
B. to bring a few leaves
C. to bring a soil sample
D. to bring your phone

4. If you do not know what the problem is, you should:

A. leave that part of the prescription form blank
B. tell the farmer something, even if you are not sure
C. ask if anyone else knows what the problem is
D. send the farmer away

5. Look at the steps below for identifying a disease sample. They are in the wrong order.

1. make a parcel for the specimens with newspaper
2. write a label and put the specimen in a plastic bag with a few drops of water and seal the bag
3. collect samples showing a full range of symptoms

The correct order to do these steps in is:

A. 1, 2, 3,
B. 3, 2, 1
C. 2, 1, 3
D. 1, 3, 2

6. Insect samples to be sent away for identification are best preserved in:

A. methanol
B. isopropyl alcohol
C. 70% alcohol
D. beer

7. A plant doctor suspects a farmer's sample has a bacterial wilt. She can test this by:

A. smelling it to see if it smells rotten
B. cutting the stem and dipping the end of it in water and looking for milky streams
C. finding the bacteria under a microscope
D. looking for spots on the leaves

8. The most important items to take to a clinic are:

A. chairs
B. kava
C. uniforms
D. prescription forms

9. After a clinic, a plant health doctor must always:

A. follow up with a farmer if the farmer has been told that will happen
B. reflect on and review the clinic data and plan to improve for next time
C. collect all the samples for looking at later with the other plant health doctors
D. do all of the above

10. A farmer brings yams that have died and gone black. The farmer tells the plant health doctor they have been damaged by lightning. The doctor thinks the problem is anthracnose. The doctor should help the farmer straight away by:

A. agreeing that lightning might be the cause but also offering other ideas of the cause, and suggesting what the farmer could do
B. offering to visit the farm
C. telling the farmer he or she cannot be helped at the clinic
D. asking the farmer to bring in more samples

6.4 The Big Quiz

Now that your trainees have completed all the plant health clinic training in Chapters 2-6, they can test their knowledge with one final test, The Big Quiz! You can also make up your own questions. When they have all finished, go through the answers. You do not need to ask what marks the trainees got; they will have learned the correct answers by going through the test as a class. Make sure you discuss any answers they are not sure about. Then explain that if there is anything they are still not sure about, they should read the manual again and/or ask for help.

THE BIG QUIZ

1. A plant health system should include:

A. plant health clinics, extension staff, research staff, ministries of agriculture staff
B. biosecurity staff, research staff, hospital staff, quarantine staff
C. plant health doctors, vets, extension staff, research staff
D. media, tourism, agriculture, horticulture

2. Which of the following are all insecticides?

A. Manzate, milk, baking soda, Taratek
B. Sundomil, Attack, Multiguard, Confidor
C. Glyphosate, neem, Blitzem, pyrethrum
D. Confidor, Orthene, Bt, Taratek

3. A sprayer nozzle suitable for fungicide should:

A. be an anvil type and the spray should form a light rain
B. be a flat type and the spray should form a light rain
C. be a hollow cone type and the spray should form a mist
D. be a flat type and the spray should form a cloud

4. A pesticide label says that it should be made up at a concentration of 1 ml pesticide to 10 L water. The concentration of the pesticide is:

A. 10%
B. 1%
C. 0.1%
D. 0.01%

5. A farmer has 10 ha of a crop to be sprayed. The pesticide label tells her that the spray should be 30 ml pesticide per 20 L water and the crop should receive 500 L per ha. How many ml of the pesticide should she use to make up the spray to cover the whole crop properly?

A. 3000 ml
B. 4000 ml
C. 6000 ml
D. 7500 ml

6. Build-up of pesticide resistance in a pest can be prevented by:

A. alternating the spraying between an insecticide and a fungicide
B. spraying early in the morning
C. using the correct type of nozzle for spraying
D. making sure the same type of pesticide is not used all the time

7. Which action should you NOT do if you accidently spill some pesticide?

A. cover the area with sand
B. make sure you wash yourself and your clothes thoroughly
C. keep children away from the spill
D. leave it to evaporate away

8. Pesticide resistance in insects is caused by:

A. a genetic mutation that is passed on to new generations of the insect
B. using the wrong crop rotation.
C. a herbicide being used by mistake.
D. a virus getting into the insect.

9. Which of the following information is NOT usually found on a pesticide label?

A. the type of product
B. which pests are resistant to it
C. what it contains
D. what crops it may be used on

10. A wettable powder:

A. is the same as an emulsifiable concentrate
B. is incompatible with all other pesticides
C. can be mixed with water.
D. forms a milky liquid when mixed with water

11. A pesticide withholding period:

A. is the period before it is safe to enter the crop after spraying
B. is the period when animals are not allowed to graze on the crop at any time
C. is the number of days between the last application of a pesticide and crop harvest
D. is the period before a pesticide is allowed into a country from overseas

12. **In IPDM, pesticides should be used:**
    A. always, as a prevention
    B. never
    C. as a last resort
    D. only if the farmer can afford them

13. **The adult insect in the picture below is most likely to be:**
    A. a beetle
    B. a wasp
    C. a lacewing
    D. a fly

14. **In order, a companion plant, a biological insecticide and a beneficial organism are:**
    A. taro, DBM, Trichoderma
    B. Chinese cabbage, kocide, ladybird
    C. coconut, pyrethrum, trichogramma
    D. marigold, metarhizium, spider

15. **An example of a good crop rotation would be:**
    A. lettuce, cabbage, broccoli, bean
    B. cucumber, squash, potato, cassava
    C. potato, tomato, eggplant, capsicum
    D. bean, cabbage, cassava, cucumber

16. **A plant health doctor is faced with an unknown pest or disease at the clinic. What should s/he do first?**
    A. send a picture to WhatsApp
    B. make up something; it's better than the farmer thinking they don't know
    C. see if anyone else in the clinic knows
    D. tell the farmer to go away

17. In IPDM, monitoring involves:

A. deciding whether the problem is caused by a pest or a disease
B. using the best pesticide for the pest
C. checking the level of damage and looking for bugs and eggs
D. identifying the pest or disease

18. The correct sequence for applying IPDM is:

A. monitoring, evaluation, making a plan, identification of pest or disease
B. evaluation, monitoring, identification of pest or disease, making a plan
C. making a plan, identification of pest or disease, monitoring, evaluation
D. identification of pest or disease, monitoring, evaluation, making a plan

19. Which plants are all in the same plant family?

A. cabbage, bok choy, broccoli, chilli
B. potato, cassava, taro, sweet potato
C. bitter gourd, pumpkin, cucumber, pineapple
D. capsicum, chilli, eggplant, potato

20. The best way to control a soil borne bacterial infection is:

A. use a resistant variety if it can be obtained
B. spray with a pesticide
C. use a virus that attacks the bacteria
D. add compost to the soil

21. Which of the following is NOT thought to be associated with companion planting:

A. companion plants can provide food for parasitoids
B. companion plants may have a smell that repels pests
C. companion plants always add large amounts of potassium to the soil
D. companion plants may repel root knot nematodes

22. In order, abiotic and biotic factors that cause damage on plants are:

A. fungi and mites
B. birds and drought
C. potassium deficiency and bacteria
D. phytoplasmas and poor soil

23. Typical symptoms on plants caused by bacteria are:

A. leaf spots, angular or round, with or without haloes
B. wilt and yellowing at the edges of leaves
C. rusty spots and mosaics
D. dieback and the leaves go purple

24. A common disease of tomatoes in the Pacific region is:

A. witches' broom
B. tobacco mosaic
C. early blight
D. ring spot

25. The smallest of these pathogens is:

A. a virus
B. phytoplasma
C. a bacterium
D. a fungal spore

26. A plant doctor finds a plant with symptoms of wilt. The most unlikely cause would be:

A. bacteria in the soil
B. rust fungus
C. nematodes
D. stalk borers

27. Pests with eight legs are not:

A. mites
B. insects
C. scorpions
D. spiders

28. Which of these diseases is caused by a fungus?

A. bunchy top on banana
B. blossom end rot on tomato
C. scale on sweet potato
D. damping off on cabbage seedlings

29. A plant doctor finds a cabbage with a lot of holes in the leaves. Which are not likely causes?

A. Diamondback moth
B. large cabbage moth
C. leaf spot
D. snails

30. A virus can be spread by:

A. bacteria
B. fertiliser
C. rhinoceros beetles
D. aphids

31. Two insects with simple life cycles are:

A. aphids and katydids
B. butterflies and bugs
C. grasshoppers and ants
D. bees and moths

32. Plant health clinics are important parts of:

A. a country's food security
B. a country's plant health system
C. the agricultural extension system
D. all of the above

33. The best place to hold a clinic is:

A. where many farmers gather, e.g. a market
B. at the research station
C. on a farm
D. at the university

34. Important advice for farmers when you are raising awareness about a forthcoming clinic is:

A. to bring a whole sample if possible
B. to bring a few leaves
C. to bring a soil sample
D. to bring your phone

35. If you do not know what the problem is, it is best to:

A. leave that part of the prescription form blank
B. tell the farmer something, even if you are not sure
C. send the farmer away
D. ask if anyone else knows what the problem is

36. Look at the steps below for identifying a disease sample.

1. make a parcel for the specimens with newspaper
2. write a label and put the specimen in a plastic bag with a water and seal the bag
3. collect samples showing a full range of symptoms

The correct order to do these steps in is:

A. 1, 2, 3,
B. 3, 2, 1
C. 2, 1, 3
D. 1, 3, 2

37. Insect samples to be sent away for identification are best preserved in:

A. beer
B. methanol
C. isopropyl alcohol
D. 70% alcohol

38. A plant doctor suspects a farmer's sample has a bacterial wilt. She can test this by:

A. smelling it to see if it smells rotten
B. looking for spots on the leaves
C. placing the end of the stem under water and looking for milky streams
D. finding the bacteria under a microscope

39. The most important items to take to a clinic are:

A. chairs
B. kava
C. uniforms
D. prescription forms

40. After a clinic, a plant health doctor must always:

A. follow up with a farmer if the farmer has been told that will happen
B. reflect on and review the clinic data and plan to improve for the next clinic
C. collect all the samples for looking at later with the other plant health doctors
D. do all of the above

41. A farmer tells the plant health doctor he thinks his crops have been damaged by an evil spirit. The doctor should help the farmer by:

A. agreeing this might be the case and offering other ideas of what the farmer could do
B. sending the farmer to a priest
C. telling the farmer he cannot be helped at a plant health clinic
D. asking the farmer to bring in more samples

42. Which Pacific countries now have the Guam strain of the rhinoceros beetle?

A. Samoa
B. Tonga
C. Fiji
D. Guam, Palau, Papua New Guinea, Solomon Islands

43. Good soil is likely to have a pH of around:

A. 1
B. 3
C. 7
D. 9

44. Which of these home-made pesticides is particularly harmful to fish?

A. chilli
B. gliricidia
C. neem
D. derris

45. What are the pests in this photo?

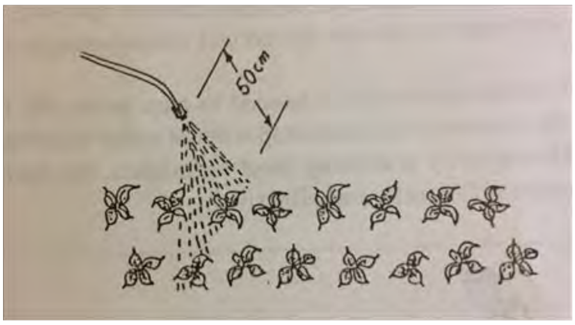
A. Rhinoceros beetles on mango
B. green vegetable bugs on tomato
C. black ticks on pumpkin
D. aphids on guava

46. What is the difference between a parasite and a parasitoid?

A. there isn't one: they are the same
B. a parasite does not kill its hosts; a parasitoid does
C. a parasitoid can't be seen with the naked eye; parasites can
D. parasites have complex life cycles whereas those of parasitoids are simple

47. The picture below shows you how:

A. to spray low-growing crops
B. far apart crops should be
C. to use a mist sprayer
D. to water your plants in a drought



48. A farmer brings a plant with large irregular spots on the leaves. It is most likely to be:

A. a wilt
B. a deficiency disease
C. a fungal disease
D. something I know nothing about

49. You want to teach your trainees to think about how plant diseases relate to people going hungry. The best teaching strategy is probably:

A. a cause and effects diagram
B. a picture of a hungry child
C. a role play
D. a concept map

50. Which symptoms are often confused?

A. a powdery mildew and a leaf spot
B. a virus and a deficiency disease
C. a bacterial leaf spot and a bacterial wilt
D. overwatering and copper deficiency

---- End of Quiz ----

Congratulations to the trainer and the trainees in completing the plant health doctor training!

Now – practise, practise, practise!!

CHAPTER 7

Resources for Trainers

To be an effective trainer, you should ensure you are familiar with the manual content before planning and carrying out PHC training. The resources in Chapter 7 provide some background on being a good trainer, and guide you through the important material in the manual for you to use in your preparation.

7.1 Being a good plant health clinic trainer

Good training of plant health doctors is essential for plant health clinics to be effective. Good trainers are confident about both ***what*** to teach and ***how*** to teach, and they work to develop a non-threatening and stimulating learning environment.

Become confident about *what* to teach

Good trainers continually build on their understanding of pests and diseases, and how to go about diagnosing and controlling them. There is no substitute for practical experience and lifelong learning. You should try to spend a lot of time in gardens and farms with your hand lens and the Pacific Pests, Pathogens & Weeds app on your phone to become familiar with plant pests and diseases as they actually appear in the field, as well as talking to farmers and Extension staff. This is the best way to develop experience and expertise in diagnosis.

Visits to the field will help you decide whether a problem is caused by a pest or disease or has another cause (poor soil, nutrient deficiencies, dry conditions, water logging, etc.), in other words, whether it is A, B or C, as in section 2.2 of the manual. Finding out what others think about the problem and what they have done about it is also very helpful and important.

Become confident about *how* to teach

Even if you have excellent knowledge of plant pests and diseases, to help others learn you need to understand something about how learning takes place. It is not enough to just give a lecture with slides. Some people might learn well that way, but others do not. All human beings naturally enjoy learning to make sense of their world but, unlike children, adult learners already have a lot of knowledge and skills to share with each other, and usually they learn best when they are interested and motivated. Adults expect to be able to learn from each other, as well as the trainer, and respect each other's experience, self-worth and knowledge.

Usually, adults learn best in small groups, so they can discuss ideas together, but there should also be time for people to work alone, or for you to teach the whole class together. The exercises in the manual use a range of teaching strategies designed to help your trainees to become actively engaged in their learning.

7.2 Developing a non-threatening and stimulating learning environment

Good trainers work hard to develop strong relationships with their plant health doctor trainees. This has a major impact on your trainees' ability to learn and become confident. Learning takes place best in a *safe, non-judgemental* and *supportive* learning environment, where people do not feel foolish if they don't understand something or make mistakes. Rather, they see that making mistakes is an important part of learning, and they should not be afraid to share their mistakes and failures as well as their successes. Neither you nor your trainees should worry about admitting when you don't know or understand something. None of us knows everything, however long we have been working; there is always something new to learn! But you should make an effort to find out what you don't know. Think of yourself as a lifelong learner, always looking for opportunities to learn more.

As you go through the training program, try to become aware of the diversity of the trainees in your class – their backgrounds, gender, age, the languages they speak, their own knowledge and experience, and how they like to learn best.

7.3 Reflecting on your work

Trainers will always improve if they take the time to reflect on their teaching and learning. Feedback from trainees can be in the form of listening to their discussions and answers, and making sure you ask plenty of questions to check their understanding. The learning/teaching process is a cycle that never ends, the aim is to reflect on what has been learned, and to know what to do for continuous improvement.

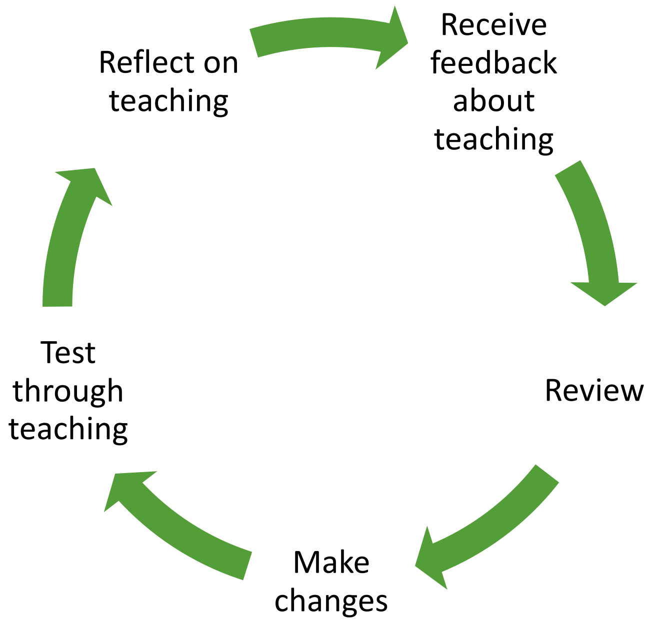


Fig. 7.1 The reflective learning cycle – it never ends!

7.4 What trainers say about the qualities of a good trainer

When they were asked to list the qualities of a good trainer, the regional trainers reviewing and testing the manual came up with the qualities listed below.

The qualities of a good trainer

Know your subject

- Be well-educated about the topics.
- Have a high level of confidence

Planning

- Plan well
- Prepare well

Communication

- Be a good listener
- Understand the audience
- Speak the audience's language
- Communicate well with the audience
- Ensure training materials match the audience's level of understanding

Personal qualities

- Have empathy
- Have a positive attitude
- Be approachable
- Be friendly and patient
- Show commitment
- Be a good role model
- Be able to build good relationships
- Be active

Fig. 7.2 What plant health clinic trainers say about the qualities of a good trainer.

7.5 Teaching strategies for effective learning

Research has given us a lot of knowledge about how people learn that can help us develop effective learning across the different cultures in our regional PHC network. Teaching something new so that people understand it well is complex, and no single way of teaching works for all people. We know that learning for deep understanding involves making new nerve pathways in the brain, and this requires effort and practice. Learning is not a spectator sport! We also know that people make sense of the world by integrating new knowledge with what they already know. Sometimes this may lead to misconceptions, such as thinking lightning causes dieback, or that a variegated plant has a viral disease. Trainers should be on the lookout for misconceptions about pests and diseases.

Because people learn in different ways, we need to use a range of teaching approaches. Here are some useful teaching strategies that are used throughout the manual.

- Small group discussion
- Brainstorming in small or large groups
- Drawing and writing
- Lecture with PowerPoint
- Creating a concept map
- Drawing a diagram or a cartoon
- Filling in a table
- Looking at pictures/photos

- Giving instructions to follow
- Practical work, e.g.
    - farm, garden and market observations
    - collecting and examining samples from the garden or farm
    - making up home-made pesticides
    - preparing samples to send away for diagnosis
- Role play and simulation
    - interviewing farmers and others
    - simulation of a PHC
    - role playing a process, e.g., the life cycle of a pest
- Cause and effects diagram
- Reflection, planning and retesting
- Creating reports and photosheets about a pest or disease
- Quizzes

Small group discussion

In general, discussion with a partner or in a small group is a very good way to help your trainees to develop new understanding. In a small group, people feel free to ask questions that they might not want to ask in front of a large class, and are more likely to share ideas with others. Having an expert and resources available to answer questions further helps their learning, so make sure you visit each group to check how they are going and whether they need any help.

Brainstorming

Brainstorming is a good method for finding out what your trainees understand before you teach a topic. It is also useful for starting to think about the topic. Begin by asking for ideas on a topic, and write down every idea without saying whether they are right or wrong, then discuss the ideas with the class. This allows the trainees to realise they already have some knowledge, and this will help build their confidence.

Drawing and writing

Drawing and writing are useful methods that assist people to learn, as well as helping you as the trainer to assess your trainees' understanding. For example, you might ask your trainees to draw their ideas of a life cycle, write down a definition of pests and diseases, or list methods of control.

Concept/mind mapping

Concept mapping is a powerful tool for both learning about and assessing your trainees' understanding of relationships between important concepts. This is best done in pairs or a small group, and requires real effort, as the trainees have to discuss in depth how they understand these relationships. The concepts are written on small pieces of paper, card or post-it notes and stuck on a large piece of brown paper with blu-tak or sticky tape. The pieces of paper can be moved around till the group is satisfied with the arrangement. Then words describing the relationships between the concepts are written on lines or described orally (Figs 7.3 and 7.4).

You can give your trainees the concepts to explore or ask them to come up with their own. Around 8 to 10 concepts is a good number, but you can add more or use fewer, depending on the group. It is best to start with a simple map, using everyday examples, e.g., house, mother, garden, chicken, taro, child, so that people understand the process.

Always give your trainees plenty of time to develop their maps, as the time spent in discussion is when the learning takes place.

Fig. 7.3 A concept map linking insect, pest, pesticides, food crops, food supply, resistance varieties, good plant hygiene, monocropping, beneficial insects, oil price (created in Solomon Islands).

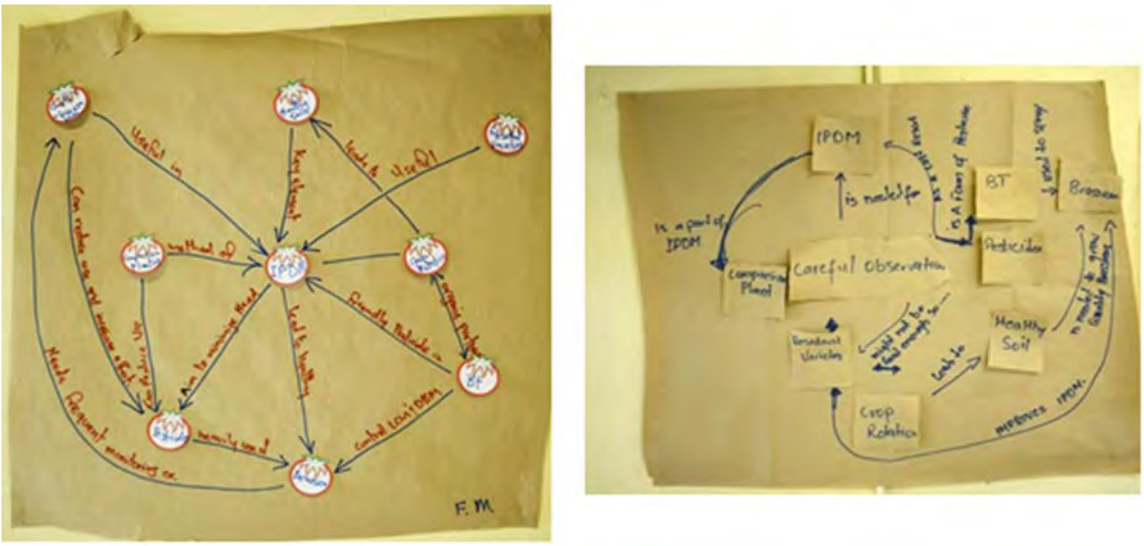


Fig. 7.4 Concept maps linking IPDM, companion plants, pesticides, Bt, resistant varieties, healthy soil, brassicas, crop rotation and careful observation (created in Tonga).

Filling in a table

Your plant health doctor trainees can deepen their understanding of any topic by filling in missing words in a table after discussion in pairs or small groups. This method is used widely in the training manual.

Practical work

Hands-on practical experience is extremely important for becoming a good plant health doctor. Your trainees cannot learn just from pictures in training manuals, videos or online apps. Practical work includes observing and examining samples from the field using a hand lens (and a binocular microscope if available), and discussing in depth what they might be observing using the ABC and possible/probable diagnostic process. They also need practical experience in preparing samples to send away for identification, making up sprays, using sprayers.

Role-play and simulation

Role-play is a very useful method of learning, where your trainees can work together to explore and develop their understanding of a concept or process through acting. A good role-play tries to put in as much detail as possible. People can even dress up! For example, you can role-play the life cycle of an insect.

Role-play can also be used to try out or simulate something you want to do in ‘real life’, e.g. working with farmers. Exercises in Chapters 5 and 6 ask your trainees to set up and run a clinic, and play the roles of plant health doctors and farmers. This allows them to experience and reflect on the process of preparing and running a clinic, and to make any changes they need before running a real one.

Cause and effects diagram

By thinking about cause and effect, this method is designed to help trainees to explore the immediate and long-term effects of a concept or problem over time, in order to trace out its overall importance. They need to think about the effect of each item in the diagram, so they can see the overall impact of the concept or problem (i.e. the ‘big picture’).

Ask your trainees to draw a template with concentric circles as shown in Figure 7.5. The concept or problem to be explored is written in the centre of the diagram, and the effects of this are explored and written down in the next circle going outwards. These then become the causes for the next circle and so on. More circles can be added if needed.

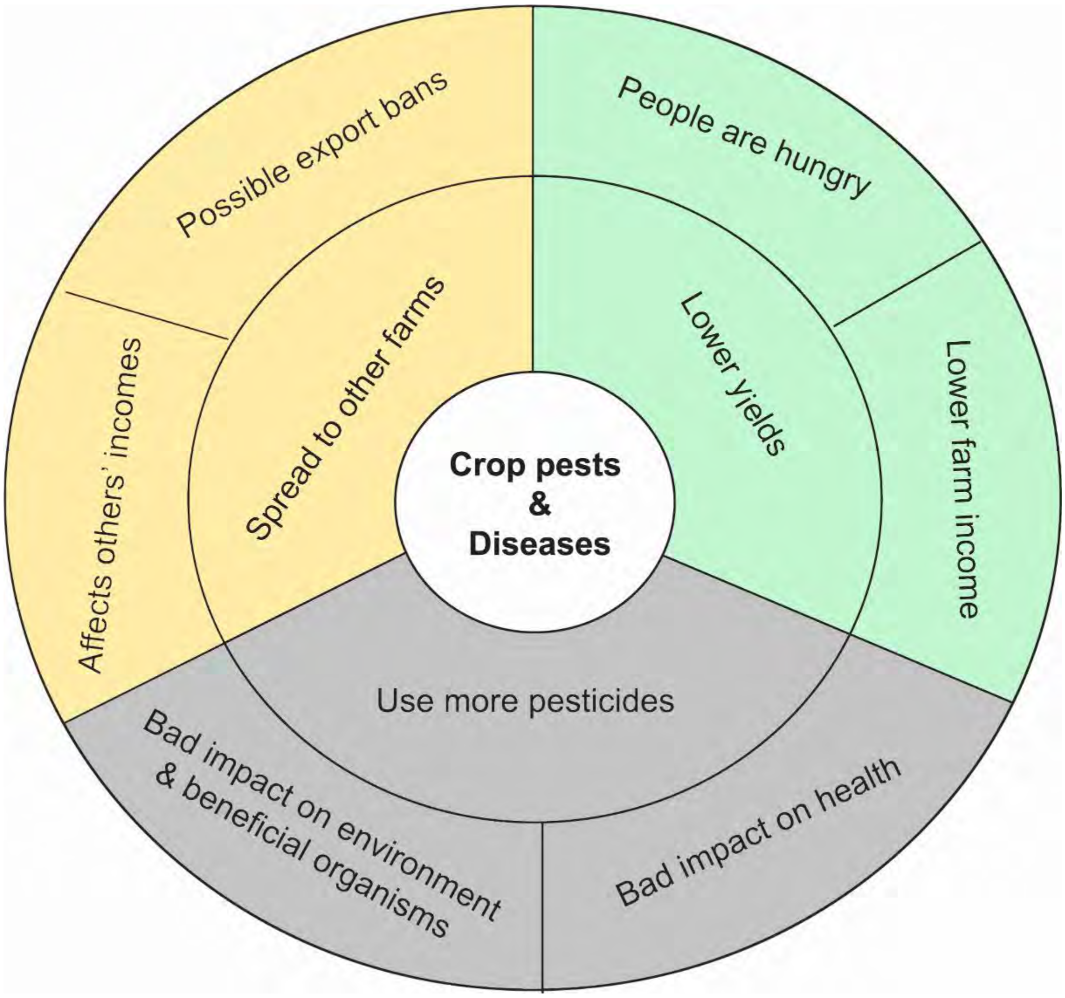


Fig. 7.5 Cause and effects diagram showing the possible effects of crop pests and disease.

CHAPTER 8

Guide to Exercises and Answers to Quizzes

8.1 Guide to exercises

This chapter provides a guide to the exercises and answers to exercises and quizzes in the manual. For each exercise in Chapters 2-6 of the manual, you will find information on the purpose of the exercise and some guidance on how to teach it. You will see that exercises are often done in pairs or small groups, then the class is brought together for discussion. When checking the answers, make sure you not only KNOW the answers but UNDERSTAND and can EXPLAIN the answers to your trainees.

Note: You will need to ask your trainees to draw up tables on butcher's or brown paper to fill in their answers for some exercises if you are unable to photocopy the templates for them

If you think some of your trainees prefer to work alone, allow them to do so from time to time. Remember, your job is to facilitate learning in ways that work best for your trainees to build their knowledge and confidence in a non-threatening, supportive learning environment. Also, remember that in your class there are likely to be some very experienced people as well as beginners. It is important that everyone has an opportunity to learn, so don't be afraid to call on those with more experience to help others. This will also help their ability to be trainers. You will also be building your own knowledge at the same time – we never stop learning!

REMEMBER

Some of the exercises have definite answers, others do not. This is because:

- some answers depend on the examples you as the trainer decide to use
- some answers depend on the samples you or the trainees bring to the class
- some exercises have more than one correct answer

8.2 PHC trainer planning and preparation checklist

IMPORTANT!!

Thoroughly plan and prepare before conducting your training workshop.

Before you begin, complete this checklist:

- ✓ Read through the manual carefully to become familiar and confident with the contents
- ✓ Work through the exercises and know how to facilitate them with your trainees. This will build your confidence as a trainer
- ✓ You do NOT need your trainees to work through EVERY exercise. It will depend on how much time is available and your judgment of how much they know already
- ✓ Do not be afraid to give your trainees reading to do for homework if you need to have something finished or to be prepared for the next session
- ✓ Make sure you have all the resources you need. A list is provided at the beginning of each chapter.
- ✓ Arrange to run one or two plant health clinics during the training - a simulated one so that your trainees know the process and how to fill in the Prescription and Farmer Feedback forms, then a full clinic with local farmers

8.3 Answers: Chapter 2

Chapters 2, 4 and 5 are the most difficult and important in the manual. Without good knowledge of identification, diagnosis and management, it is very difficult to be an effective plant health doctor.

In Chapter 2, you are helping your trainees to develop their identification skills by carefully observing and describing symptoms before they move to a diagnosis. It is worth taking time to go through these chapters very carefully before you teach them, checking your own understanding by completing the exercises yourself.

Exercise 1

ABC: Banana

1 **BIOTIC:** Banana black cross, *Phyllochora musicola,* fungus.

2 **BIOTIC:** Banana diamond leaf spot, *Cordana musae,* fungus.

3 **ABIOTIC:** Natural variation of an ornamental variety.

4 **BIOTIC:** Cucumber mosaic virus.

5 **BIOTIC:** Banana burrowing nematode, *Radopholus similis.*

6 **BIOTIC:** Scab moth, *Nacoleia octasema.*

7 **ABIOTIC:** Natural colour variation.

8 **BIOTIC:** Banana bunchy top virus.

ABC: Bele (Abelmochus)

1. **CONFUSED**: Could be i) feeding of a jassid (leafhopper), ii) hibiscus chlorotic ringspot virus, or the iii) plants are lacking an essential nutrient**.**

2. **BIOTIC:** Hibiscus chlorotic ringspot virus.

3. **BIOTIC:** Shoot borer, *Erias vitella,* moth.

4. **BIOTIC:** Leafminer, *Acrocercops* species, moth.

5. **BIOTIC:** Flea beetle, *Nisotra basselae.*

6. **BIOTIC:** White peach scale, *Pseudaulacaspis pentagona.*

7. **BIOTIC:** Cotton leaf roller, *Haritalodes derogate,* moth.

8. **CONFUSED:** Same as 1

ABC: CABBAGE

1. **BIOTIC:** Turnip mosaic virus.

2. **BIOTIC:** Damping-off, fungi.

3. **BIOTIC:** Chinese cabbage stalk rot, *Erwinia* species, bacteria.

4. **BIOTIC:** Cabbage centre grub, *Helula undalis,* moth.

5. **CONFUSED:** Possibly stalk rot (see 3) or Black cutworm, *Agrotis ipsilon,* moth.

6. **BIOTIC:** Cabbage black rot, *Xanthomonas campestris* pv. *campestris,* bacterium.

7. **ABIOTIC:** Boron deficiency.

8. **CONFUSED:** Possible snail damage.

ABC: CASSAVA

1. **BIOTIC:** Cassava green mottle virus.
2. **ABIOTIC:** Natural variation of an ornamental variety.
3. **BIOTIC:** Cassava *Amblypelta* dieback, bug.
4. **BIOTIC:** Spiralling whitefly, *Aleurodicus disperses.*
5. **BIOTIC:** White peach scale, *Psedaulacaspis pentagona*
6. **BIOTIC:** Spider mite, *Teranychus* species.
7. **BIOTIC:** Bacterial blight, *Xanthromonas axonopodis* pv. *Manihotis.*
8. **CONFUSED:** Possible mineral deficiency.

ABC: CITRUS

1. **CONFUSED:** Caused by scale insects on the underside of the leaf.
2. **BIOTIC:** Citrus sooty blotch, *Meliola citricola,* fungus.
3. **BIOTIC:** Greening or Huanglongbing disease of citrus, *Candidatus liberibacter asiaticus*, bacterium.
4. **BIOTIC:** Citrus tristeza virus.
5. **BIOTIC:** Greening or Huanglongbing disease of citrus, *Candidatus liberibacter asiaticus,* bacterium.
6. **BIOTIC:** Citrus scab, *Elsinoe fawcettii,* fungus.
7. **ABIOTIC:** Zinc deficiency.
8. **BIOTIC:** Fruit piercing moth, *Eudocrima fullonia.*

ABC: COCONUT

1. **BIOTIC:** Foliar decay virus.

2. **ABIOTIC:** Potassium deficiency on fan palm.

3. **BIOTIC:** Coconut thread blight, *Corticium penicillatum,* fungus.

4. **CONFUSED:** Coconut Bogia disease or lightning strike.

5. **BIOTIC:** Coconut termite, *Neotermes rainbowi.*

6. **BIOTIC:** Coconut leafminer, *Promecotheca* species.

7. **CONFUSED:** Sooty mould, fungi - but this is not the main cause of the problem.

8. **CONFUSED:** Feeding lines created by *Promecotheca* species - *Brontispa longissimi,* the coconut hispine beetle causes similar symptoms.

ABC: TOMATO

1. **BIOTIC:** Tomato black leaf mould, *Pseudocercospora fuligena,* fungus.

2. **ABITOIC:** Calcium deficiency, blossom end rot.

3. **CONFUSED:** One of the many tomato fungal leaf spots.

4. **ABIOTIC:** Catface. Cause unknown, possibly irregular growth during flowering

5. **CONFUSED:** Purple patches on leaves can be caused by phosphorus deficiency, one of a number of viruses, or old age.

6. **CONFUSED:** Spots on fruit can be caused by fungi or bacteria.

7. **BIOTIC:** Eriophyid mite, *Polyphagotarsonemus latus.*

8. **ABIOTIC:** Tomato fruit splitting caused by irregular temperatures and/or water.

9. **BIOTIC:** Bacterial wilt, *Ralstonia solanacearum.*

ABC: MIXED

1. **BIOTIC:** Maize mosaic virus.
2. **ABIOTIC: T**omato sunscald.
3. **CONFUSED:** Cocoa cherelle wilt or *Phytophthora palmivora,* oomycete.
4. **BIOTIC:** Maize boil smut, *Ustilago zeae,* fungus.
5. **CONFUSED:** Cocoa dieback caused by lack of shade, sunscald or nutrient deficiency.
6. **ABIOTIC:** Maize zinc deficiency.
7. **BIOTIC:** Coconut tinangaja viroid.
8. **CONFUSED:** One of several tomato viruses or herbicide damage.

Exercise 2: Speed dating

This exercise gives more practice on how to describe symptoms on plants carefully and accurately before making a diagnosis.

Ask the trainees to form two lines facing each other so they are standing opposite a partner. Give each trainee a sample of a plant pest or disease, or they could collect their own. One of the pair now carefully describes the symptoms to their partner (their 'date') opposite them, and then both try to decide whether it is caused by abiotic (A) or biotic (B) factors, or it is confused (C).

Give no more than two minutes! When you say 'stop' the other partner has to do the same with their sample. Next, everyone in one line moves to the left so that each has a new partner. Repeat the process of describing the symptoms one more time each (or more if you think trainees need more practice).

Now ask the trainees to place their sample on one of three tables marked A, B or C, depending on whether they think the cause is A, B or C. ***Do not give any answers at this stage!***

Preparing for Exercise 3

Now that you have gone through Exercises 1 and 2, you have set up your trainees' 'need to know' about pests and diseases. It is time to introduce your PowerPoint presentation on pest and diseases which you will need to prepare from the information in Sections 2.3 to 2.8 in Chapter 2.

Alternatively, if they have access to a manual, you can ask trainees to read these sections for their homework, emphasising how important this information is, and ask if there are any questions. These are long sections with a lot of information, so take your time and give trainees plenty of breaks and time for discussion and questions during the presentation, and check for understanding.

EXERCISE 3: SIMILAR SYMPTOMS, DIFFERENT GROUPS

Table 2.3 shows that pest symptoms can be confusing, as similar symptoms can be caused by many different types of pests and diseases. Exercises 3 and 4 will help your trainees to think about symptoms of pest damage and the range of possible causes.

This is a challenging exercise, but the purpose is for your trainees to recognise that similar symptoms can have many causes. It is not necessary for them to have to learn the names of every pest.

By thinking about and discussing the possible answers in their groups and then with the whole class, your trainees will have a deeper understanding of the complexity of pest diagnosis, so they do not immediately jump to one answer when they see symptoms.

The answers filled in the table below are examples; there will be many other possibilities. Check with Table 2.3 for details.

Symptom	Type of damage (chewing, sucking or piercing)	Two orders (or sub-orders) causing similar symptoms	Stage of pest life cycle	Confirmed by fact sheets #
Holes (stem/trunk)	Chewing	1. Beetle/weevil 2. Moth/butterfly	Adult, nymph Larva (caterpillar)	?
Mines (Leaf	Chewing	1. Fly 2. Moth/butterfly	Larva (maggot) Larva(caterpillar)	?
Galls (leaf)	Sucking	1. Psyllid" 2. Mite (eriophyid)	Nymph Adult, nymph	?
Holes (leaf)	Chewing	1. Grasshopper/Katydid 2. Bee	Adult, nymph Adult	?
Holes (seed)	Chewing	1. Beetle/weevil 2. Moth/butterfly	Adult, larva Larva (caterpillar)	?
Wilt (plant)	Sucking	1. True bug* 2. Scale insect*	Adult, nymph Adult, nymph	?
Distortions (leaf)	Sucking	1. Aphid* 2. Mealybugs*	Adult, nymph Adult, nymph	?
Scraping (Leaf)	Chewing	1. Beetle/weevil 2. Moth/butterfly	Adult, nymph Larva (caterpillar)	?
Speckling (leaf)	Sucking	1. Thrips 2. True bug*	Adult, nymph Adult, nymph	?
Rot (fruit)	Piercing	1. Moth/butterfly 2. Fly	Adult Larva	?
Egg-laying strike (fruit)	Piercing	1. Fly 2. Weevil	Adult Adult	?

***Sub-orders of Hemiptera.**

Exercise 4: Understanding chewing, sucking and piercing damage

For this exercise, try to find samples of leaves, fruit or roots that show symptoms of chewing, sucking or piercing, but with no visible pests. This often happens at a plant health clinic. Give each pair of trainees a different sample of pest damage (or a photograph if you cannot find field samples). Your trainees should examine their sample carefully with a hand lens, and answer the questions in the exercise. Then they should share their answers with the whole class and discuss the diagnosis process and any difficulties.

Refer to Tables 2.2 and 2.3 for answers.

Exercise 5: Using symptoms to make a diagnosis

Once your plant health doctor trainees have received more information about pests and diseases from your PowerPoint presentation and/or worked through the sections in the manual, they should collect their samples from tables A, B or C and have another look at them, using a hand lens.

Again, ask the trainees to look at the symptoms (signs) on the plant carefully, and try to make a diagnosis. They may want to change their minds or add information. This is good; it means they have learned something new. Being wrong or only partially correct is an important part of learning.

Once they have finished this, discuss what they have learned and ask your trainees to complete Table 2.4 and fill in the last column.

The answers to this exercise will depend on the samples you or the trainees have collected. You will need to make sure you are able to identify as many of them as you can before discussing the answers.

Exercise 6: What have you learned about pests and diseases?

Your trainees should now be able to summarise their learning about pathogens. They should complete the table in pairs or threes. In the manual, some cells have been filled in as an example (green text). Here is the table completed with some answers, but there are many other possible answers.

Table 2.5: Test your knowledge of pests and diseases

	Fungi	Bacteria	Viruses	Nematodes	Insects
Size – can they be seen with the naked eye?	Spores – No. Fruiting bodies and cottony growth (mycelium) – Yes	*No*	No	No, with a very few exceptions.	Yes, with very few exceptions.
How do they reproduce?	*Spores*	Cells split in half (binary fission).	Use chemicals from host cells to make more virus particles.	There are males and females reproducing via eggs.	Incomplete or complete life cycles. Males and females reproducing via eggs; some give birth to living young without need for males.
How do they spread?	Produce masses of spores, spread in wind and rain; hyphae and mobile spores in soil, on or in planting materials; also via plants and soil associated with horticultural trade. More rarely carried by boring insects.	In wind, rain, movement of water in soil, on or in planting materials; also via plants and soil associated with horticultural trade.	In insects as they chew and suck sap, on tools, on or in planting materials; also via plants associated with horticultural trade. More rarely in fungi and nematodes.	Move though soil, transported in soil water, on or in planting materials; also via plants and soil associated with horticultural trade.	Mostly by flying (adults) that lay eggs on plants; also via plants and soil associated with horticultural trade.
How do they survive?	In soil, remains of plants after harvest, on leaf litter, on weeds. Many fungi have special survival spores.	In soil, in plants after harvest, on weeds. Some form resistant spores.	*In living cells,* either in plants or in insects.	In soil, feeding on weeds, as eggs. Some form cysts.	Many survive as eggs between crops, or on alternative hosts, especially weeds, and volunteer plants. In the tropics, survival occurs by moving from harvested to new planted crops.
What are some typical symptoms/signs on plants?	Spots, blights, rusts, wilts, mildews, rots, root decay.	*Wilts*, spots, rots, blights.	Mosaics (light and dark green patterns on the leaves), yellowing, stunting, distortions.	Wilts, yellowing of leaves, stunting, root galls	Holes, mines, chewed leaves, wilts due to root damage, silvering of leaves, distortions, rots, galls. Frass sometimes present.

EXERCISE 7: COMPLETE THIS TABLE FOR YOUR OWN COUNTRY

This is an important exercise to prepare your trainees by helping them become familiar with plant pests or diseases they are likely to see at the plant health clinic. Extension staff should already be aware of the major pests and diseases in their area, although sometimes new problems can spring up quickly, especially when weather conditions change.

As a trainer, it is important that you have a good knowledge of local pests and diseases. The tables list the most common pests and diseases in Samoa and Tonga. Trainers in Fiji and Solomon Islands need to ensure they also have country-based or region-based information.

Exercise 8 is an extension of Exercise 7 and optional. It helps your trainees consolidate their learning so far, so they are familiar with the major pests and diseases found in their region before the plant health clinic, and can confidently identify them.

EXERCISE 8: COMPLETING A 'STEM' TABLE (OPTIONAL ACTIVITY)

This exercise helps your trainees summarise their learning so far about pests and diseases. They should do this on their own or in pairs. It is like completing a sentence where the 'stem' is the beginning, starting with the first column (insect pests) and then filling in their ideas down the first column. Then they move down to the second column and so on until they have completed the table.
The example in red reads: insect pests are …. a biotic factor

Again, there will be more than one correct answer; the prefilled table below provides some possible answers. Ask trainees which ones they had difficulty with and discuss.

	Insect Pests	**Nematodes**	**N Deficiency**	**Viruses**	**Fungi**	**Bacteria**	**Drought**
Are	A biotic factor	A small worm-like animal	A lack of an essential element needed by plants	*Very small*	A biotic factor.	A single celled organism	Lack of water
Are not:	A mite.	*an insect*	A biotic factor	Visible to the naked eye	An insect	A virus	A biotic factor
Can:	Reproduce quickly	Live in soil	Cause plants to turn yellow	Be spread by insects	Form fruiting bodies called a mushroom	Spread very quickly	Kill crops
Cannot:	*Produce spores*	Fly	Be treated by applying a pesticide	Live outside a host cell	Photosynthesise	Reproduce sexually	Help plants to grow well
May cause:	Holes in leaves	Wilting	Low yields	Mosaics	Leaf spots	*Wilting*	Loss of income for farmer
Does not cause:	Mildew	Rust	Holes in a leaf	Nutrient deficiency	*Chewing of leaves*	Rust symptoms	Floods
Can be controlled by:	Beneficial insects	Marigolds	Adding well-decomposed manure to the soil	Rogueing	Fungicide	Copper	Irrigation
Cannot be controlled by:	Herbicide	White oil	*Fungicide*	Companion planting	Insecticide	Parasitoids	*Fertiliser*

EXERCISE 9: WHAT AM I?

This guessing game exercise is fun and can be carried out at any point during the training. It is also a useful icebreaker to do at the beginning of a training session. It can be as easy or difficult as you decide to make it, and you can make up any words you like that relate to what you are teaching. It makes sure your trainees really focus on the characteristics of what they are trying to guess.

Write a word or group of cards, on a piece of card and stick one card to each trainee's back with masking tape. Do not allow the trainees to see their card!

When you are giving out the cards, try to match the words to the trainees. For example, give the more knowledgeable trainees something more challenging, while you give a simpler word to those who are not as experienced or confident. Everyone needs to be able to guess their word, as this builds confidence.

The trainees pair up or move around the class, asking questions of each other. The idea is to find out what the word is, but the questions can ONLY be answered with '**yes**', '**no**' or **'sometimes/maybe'**. You may need to demonstrate this with a trainee first.

You should check in with the trainees while the exercise is in progress, as they may have been given wrong information! Ask: "What do you already know so far about your word?" Correct them where necessary. If a trainee is stuck, you may give a clue.

Ask trainees to sit down when they have correctly guessed their word.

Discuss the exercise afterwards. Was it easy? Difficult? Why?

Exercise 10,11,12: Using the possible and probable approach

By this stage in Chapter 2, your trainees have covered a lot about symptoms and have started to think about diagnosis. In Exercises 10, 11 and 12, they apply their A,B,C learning to use the **possible** and **probable** step approach to making a diagnosis. This is something they need to be able to do at the plant health clinic.

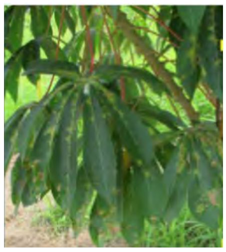
First of all, carefully go through the example of eggplant with the class to demonstrate the steps.
Your trainees should then use the same steps to work through the examples in Exercises 10,11 and 12, working in pairs or threes, or alone if they prefer.

Once they have finished, it is important to ask them why they have decided on a diagnosis, as you may be able to pick up any misconceptions.

Only when they have carried out the steps should they check their answers with the Pacific Plant Pests, Pathogens & Weeds App. They also need to think about what extra information they might need for a diagnosis, and what further questions they would ask if a farmer brought in this problem. If you think that your trainees need more practice, you can make up your own examples.

EXERCISE 10: USING THE POSSIBLE AND PROBABLE APPROACH

EXAMPLE: Large blotches on cassava leaves
Symptoms:
1. Yellow spots and blotches
2. Many spots and blotches alongside the midrib of the leaves
3. Lower leaves affected
4. No sign of wilt, rot, fungal/bacterial spots or blights



Possible Causes	Possible? ✓✗	Probable? ✓✗	Why did you decide this?
BIOTIC			
Insects	✓	✓	But first need to see the back of the leaf.
Mites	✓	✓	But first need to see the back of the leaf.
Fungi	✗	✗	Unlikely; would have expected some darker spots if fungus
Bacteria	✗	✗	Unlikely; would have expected some darker spots if bacteria
Viruses	✓	✗	Possible; but not a known symptom of a virus disease of cassava in Pacific Islands
Phytoplasmas	✓	✗	Unlikely; not a known symptom of a phytoplasma disease of cassava in Pacific Islands
Nematodes	✗	✗	NA for these symptoms
Weeds	✗	✗	NA for these symptoms
Parasitic plants	✗	✗	NA for these symptoms
Slugs & Snails	✗	✗	NA for these symptoms
Mammals	✗	✗	NA for these symptoms
Birds	✗	✗	NA for these symptoms
ABIOTIC			
Nutrient deficiencies	✓	✗	Unlikely; yellow blotches not typical of any cassava nutrient deficiency symptom in Pacific islands
Sun scald	✗	✗	NA for these symptoms
Water (too much or too little)	✗	✗	NA for these symptoms
Lightning	✗	✗	NA for these symptoms

Herbicide	✓	✗	Unlikely; no growth distortions and farmer says no herbicide used.
It's natural	✗	✗	NA for these symptoms

NOTES: Once the leaf is turned over, the answer is made clear – it is spiralling whitefly.

EXERCISE 11: USING THE POSSIBLE AND PROBABLE APPROACH

EXAMPLE: YELLOWING OF VEINS AND PATCHES ON SWEET POTATO LEAVES

Symptoms:

1. Yellow spots on the leaves (mosaics)
2. Yellowing along the veins
3. Symptoms on the young leaves
4. Leaves are normal size

Possible Causes	Possible? ✓✗	Probability? ✓✗	Why did you decide this?
BIOTIC			
Insects	✗	✗	Not a symptom of insects; no sign of presence or frass
Mites	✗	✗	Unlikely, but turn leaf over to look for mites and webbing to make sure
Fungi	✗	✗	Not a symptom of fungi
Bacteria	✗	✗	Not a symptom of bacteria
Viruses	✓	✓	Irregular yellow patches, and especially yellowing along veins are typical of known viruses of sweet potato.
Phytoplasmas	✓	✗	Little leaf of sweet potato exists, but leaves are not "little"
Nematodes	✗	✗	NA for these symptoms
Weeds	✗	✗	NA for these symptoms
Parasitic plants	✗	✗	NA for these symptoms
Slugs & Snails	✗	✗	NA for these symptoms
Mammals	✗	✗	NA for these symptoms
Birds	✗	✗	NA for these symptoms

ABIOTIC			
Nutrient deficiencies	✘	✘	NA for these symptoms
Sun scald	✘	✘	NA for these symptoms
Water (too much or too little)	✘	✘	NA for these symptoms
Lightning	✘	✘	NA for these symptoms
Herbicide	✓	✘	Yellowing of veins not typical; and no growth distortions
It's natural	✘	✘	NA for these symptoms

EXERCISE 12: USING THE POSSIBLE AND PROBABLE APPROACH

EXAMPLE: WILTING OF *XANTHOSOMA*

Symptoms:
1. Only four leaves
2. Leaves 'cup-shaped'
3. Leaves wilting
4. Root decay

Possible Causes	Possible? ✓✗	Probable? ✓✗	Why did you decide this?
BIOTIC			
Insects	✗	✗	No signs of insects and no frass
Mites	✗	✗	No sign of mites
Fungi	✓	✓	Edges of leaves are decayed, but damage likely to be result of leaves dying early. Root damage likely to be causing wilt. Fungal wilt diseases of *Xanthosoma* known.
Bacteria	✓	✗	Edges of leaves are decayed, but damage likely to be result of leaves dying early. Bacterial wilt diseases of *Xanthosoma* not known.
Viruses	✗	✗	NA for these symptoms
Phytoplasmas	✗	✗	NA for these symptoms
Nematodes	✗	✗	NA for these symptoms
Weeds	✗	✗	NA for these symptoms
Parasitic plants	✗	✗	NA for these symptoms
Slugs & Snails	✗	✗	NA for these symptoms
Mammals	✗	✗	NA for these symptoms
Birds	✗	✗	NA for these symptoms

ABIOTIC			
Nutrient deficiencies	✘	✘	NA for these symptoms
Sun scald	✘	✘	NA for these symptoms
Water (too much or too little)	✘	✘	NA for these symptoms
Lightning	✘	✘	NA for these symptoms
Herbicide	✓	✘	Not a symptom of herbicide damage
It's natural	✓	✘	Loss of leaves not due to plant maturity; other plants have many more leaves

END OF CHAPTER 2 QUIZ: Test your knowledge

Your plant health doctor trainees can do this on their own or in pairs. Ask them which they prefer.

The answers are given in **bold underline**. When they have all finished, go through the answers. You do not need to ask what marks the trainees got; they will have learned the correct answers by going through the test as a class.

Make sure you always discuss with the class any answers they are not sure about.

Explain that if there is anything they are still not sure about, trainees should read the manual again and/or ask for help.

You can change or add your own questions.

1. In ORDER, abiotic and biotic factors that cause damage on plants are:

A. a fungus and a mite
B. a bird and drought
C. <u>potassium deficiency and a virus</u>
D. phytoplasma and poor soil.

2. **Symptoms on tomatoes and cabbages caused by bacteria are:**
A. leaf spots and evenly spread leaf yellowing
B. <u>wilt and V-shaped yellowing at the edges of leaves</u>
C. rust spots and mosaics
D. dieback and with leaves going purple

3. A common disease of tomatoes in the Pacific is:
A. witches' broom
B. tobacco mosaic
C. <u>Late blight</u>
D. ring spot

4. The smallest of these pathogens is:
A. <u>virus</u>
B. phytoplasma
C. bacteria
D. fungus spore

5. A plant doctor finds a plant with symptoms of wilt. The most <u>unlikely</u> cause would be:

A. bacteria in the soil

B. <u>powdery mildew</u>

C. nematodes

D. stalk borer

6. Pests with eight legs:

A. <u>mites</u>

B. insects

C. nematodes

D. millipedes

7. Which of these diseases is caused by a fungus?

A. bunchy top on banana

B. blossom end rot on tomato

C. citrus canker

D. <u>damping-off on cabbage seedlings</u>

8. A plant doctor finds a cabbage with a lot of holes in the leaves. Which <u>are not</u> possible causes?

A. Diamondback moth

B. large cabbage moth

C. <u>leaf chewing nematodes</u>

D. snails

9. A virus cannot be spread between plants by:

A. bacteria

B. tools

C. <u>rhinoceros beetles</u>

D. aphids

10. Two insects with complete life cycles are:

A. aphids and beetles
B. <u>butterflies and bugs</u>
C. grasshoppers and ants
D. bees and moths

11. Where do you find the eggs of this spiraling whitefly?

A. inserted into the leaf
B. whiteflies don't lay eggs; they give birth to living young
C. <u>in the waxy spirals</u>
D. underneath the female whiteflies

12. What is the most likely cause for this hibiscus wilt?

A. mites or thrips have attacked the young leaves, and they have wilted
B. it was planted on a slope, and there has been a long drought
C. old age
D. <u>a fungus or an insect is destroying the roots</u>

8.4 Answers: Chapter 3

There are no exercises for Chapter 3. Just work through the chapter to ensure your trainees have joined their country WhatsApp group and know how to use CommCare (if available), the Pacific Pests, Pathogens & Weeds app, and are familiar with PestNet.

8.5 Answers: Chapter 4

In Chapter 2, your plant health doctor trainees learned to identify and diagnose pest and disease symptoms on plants, and Chapter 3 introduced digital resources to help diagnose unknowns. Chapters 4 and 5 help your trainees to understand ways of managing pests and diseases. Chapter 4 covers IPDM options using cultural and biological control methods, which should always be the first option. Chapter 5 covers pesticides.

Exercise 13: What do you already know about IPDM cultural control methods for specific pests and diseases?

Your trainees will already have a lot of knowledge about cultural methods of control. In groups, they should write down and discuss any IPDM pest and disease control methods they know about for two pests and two diseases from their region, for both large- and small-scale cropping, and how the methods work. They should fill in the table below, then share and discuss their answers with the rest of the class. Answers will depend on the examples chosen.

	Crop	What IPDM cultural control methods are possible?			
		For large scale	How it works	For small scale	How it works
Insect/mite pest					
Example: Diamondback moth (DBM)	*Brassicas*	*Remove weeds in the Brassica family*	*Reduces DBM populations that maintain populations between crops*	*Hand picking caterpillars*	*Removes pest*
1.					
2.					
Diseases					
1. (Example) Citrus scab (Elsinoe fawsetti)	*Citrus*	*Isolate nurseries from orchards.*	*Prevents spread of fungus.* *Prune to keep canopy open.*	*Isolate nurseries from orchards.* *Prune to keep canopy open*	*Prevents spread of fungus.*
2.					

Exercise 14: Using IPDM - Working out the steps

For IPDM to work properly, several steps need to be taken. This is what your trainees will need to tell the farmers at the plant health clinic. This exercise helps your trainees work through the correct steps for applying IPDM. When they have had time to think about their answers, ask each group to share their ideas with the class. If they have anything in the wrong order, discuss this.

The correct order:

E. Knowledge - Identify the pest or disease and know its life cycle.

A. Go to the garden regularly. Look for damage.

D. Decide how much damage the crop can tolerate before yields are affected.

C. Make a plan of action for the present crop and the next crop: A) before planting (next crop); B) during growth of present crop; and C) after harvest of present crop. If it is a pest, count the pests (can you see natural enemies?). Is the problem getting worse or not? KEEP NOTES.

B. Was your plan successful or not? Are any changes needed? Is it a problem likely to be caused by a pest or a disease? Use the possible/probable approach in Chapter 2.

Exercise 15: Applying crop rotation

It is important that your trainees are familiar with the principles of crop rotation and are able to explain it.

The example shows possible crops to plant in a rotation based on Fig. 4.4. Each column represents a separate plot and has four cycles.

Note that as long as the crops are in the correct families and follow the current sequence, the actual crop that the trainees suggest does not matter. There is more than one correct answer, but there are also incorrect answers.

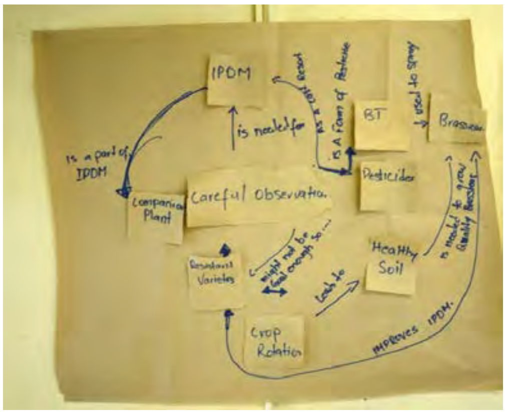
Cycle	Plot 1	Plot 2	Plot 3	Plot 4
1	Leafy crop e.g. bele	Legume crop e.g. Mucuna	Root crop e.g. taro	Legume crop e.g. Mucuna
Reason why you chose this crop rotation:				
2	Solanaceae crop e.g. capsicum	Curcubit crop e.g. cucumber	Brassica crop e.g. bok choy	Leafy crop e.g. lettuce
Reason why you chose this crop rotation:				
3	Root crop e.g. cassava	Root crop e.g. carrot	Legume crop e.g. bean	Solanaceae crop e.g. chilli
Reason why you chose this crop rotation:				
4	Legume crop e.g. peanut	Brassica crop e.g. cabbage	Cereal crop e.g. maize	Cucurbit crop e.g. watermelon
Reason why you chose this crop rotation:				

Exercise 16: Concept mapping of IPDM

Creating a concept map is a very useful exercise to help your trainees make connections between concepts in any topic. It is best done in pairs or small groups. The concepts are written on a sticky note or piece of paper with blu-tak or sellotape on the back, then moved around on brown paper or butcher's paper until the group agrees where they fit. The process of discussing and making decisions is an important part of the learning process.

You might want to start with a simple map of concepts that all trainees are familiar with, e.g. **house, mother, garden, chicken, taro, child**, so that they understand the process. They should write on the connecting lines how the concepts are linked.

You can decide to leave out or add other terms or change them if you think others might be better. About eight terms work well, but you can add more if your trainees need more challenges. Alternatively, you can ask the trainees to give you the terms to work with.



There is no one correct answer, but some answers could be incorrect. Some trainees will decide to create a flow diagram - 'this' leads to 'that' - while others will link the concepts. It does not matter how people relate the concepts, but trainees **must write how they are related** on the linking lines, as in the example here. See Fig.7.3 in section 7.3 for other examples.

When they have finished, ask the trainees to put their map on the wall, and explain it to the rest of the class.

You can use concept mapping at any time during the training to help your trainees deepen their learning and make connections between content.

Exercise 17: Summary of cultural control for IPDM control of some common pests and diseases

Exercise 17 is designed to help your plant health doctor trainees bring all their knowledge about cultural control for IPDM together. They should discuss the answers in their small groups, using their own knowledge as well as the resources and information you have covered in this chapter, to complete the table. Or you could set it as a homework exercise. When they have finished, discuss the answers with the whole class. Not everyone will be aware of all these cultural controls, so spend some time on the discussion.

The answers will depend on the examples the trainees use. You can provide them with examples, or they can come up with their own. Some examples are provided here.

Cause	Example	Crop and part affected	CR*	GH*	F*	GD*	CP*	V*	HPM*	HP*	TC*	BC*
Pests (Insects and mites)	Tomato fruit borer	Tomato fruit	✓	✓	×	×	×	×	×	✓	✓	✓
Nematodes	Dry rot *(Pratylenchus)* nematode	Yam, roots	✓	✓	✓	×	×	×	✓	×	×	×
Pathogens (fungi, bacteria and viruses)	Bacterial wilt	Tomato, whole plant	✓	✓	✓	✓	✓	✓	✓	×	×	×

***KEY**

- CR: Crop rotation
- GH: Good hygiene
- F: Fertiliser/compost/organic matter
- GD: Good drainage
- CP: Companion planting
- V: Resistant variety
- HPM: Healthy planting material
- HP: Hand picking
- TC: Trap crop
- BC: Biological control

END CHAPTER 4 QUIZ: TEST YOUR KNOWLEDGE

Your trainees can do this on their own or in pairs. Ask them which they prefer.

The answers are given **<u>in bold underline</u>**. When they have all finished, go through the answers. You do not need to ask what marks the trainees got, they will have learned the correct answers by going through the test as a class.

Make sure you always discuss with the class any answers they are not sure about. Then explain that if there is anything they are still not sure about they should read the manual again and/or ask for help.

1. In IPDM, pesticides should be used:

A. always
B. never
C. <u>as a last resort</u>
D. only if the farmer can afford them

2. The adult in the picture shown below is most likely to be:

A. a beetle
B. <u>a wasp</u>
C. a lacewing
D. a fly

3. In order, a companion plant, a biological insecticide and a beneficial organism are:

A. taro, DBM, *Trichoderma*
B. Chinese cabbage, kocide, ladybird
C. coconut, pyrethrum, *Trichogramma*
D. <u>marigold, Metarhizium, spider</u>

4. **An example of a good crop rotation would be:**

A. lettuce, cabbage, broccoli, bean.
B. cucumber, squash, potato, cassava.
C. potato, tomato, eggplant, capsicum.
D. <u>bean, cabbage, cassava, cucumber.</u>

5. Rogueing means:

A. using bio-insecticides
<u>B. destroying infected plants</u>
C. using companion plants
D. planting resistant varieties

6. In IPDM, monitoring involves:

A. deciding whether the problem is caused by a pest or a disease
B. using the best pesticide for the pest
C. <u>checking the level of damage and looking for bugs and eggs</u>
D. identifying the pest or disease

7. The correct sequence for applying IPDM is:

A. monitoring, evaluation, making a plan, identification of pest or disease
B. evaluation, monitoring, identification of pest or disease, making a plan
C. making a plan, identification of pest or disease, monitoring, evaluation
D. <u>identification of pest or disease, monitoring, evaluation, making a plan</u>

8. Which plants are all in the same plant family?

A. cabbage, bok choy, broccoli, chilli
B. potato, cassava, taro, sweet potato
C. <u>bitter gourd, pumpkin, cucumber, squash</u>
D. capsicum, chilli, eggplant, bean

9. The best way to control a soil borne bacterial infection is:

A. <u>use a resistant variety if it can be obtained</u>
B. spray with a pesticide
C. find a virus that attacks the bacteria
D. add compost to the soil

10. Which of the following is NOT thought to be a characteristic associated with companion planting?

A. companion plants can provide food for parasitoids
B. companion plants may have a smell that repels pests
C. <u>companion plants put copper into the soil</u>
D. companion plants may repel root knot nematodes

8.6 Answers: Chapter 5

In Chapter 4, your plant health doctor trainees learned about some of the cultural controls that can be applied to IPDM. Chapter 5 introduces them to pesticides. Remember to stress that these should be used only as a last resort, given the damage they cause to humans, natural enemies and the environment, as well as the problem of build-up of resistance in pest populations.

Chapter 5 reviews many aspects of pesticides and their uses, and Exercises 18-25 will test your trainees' knowledge on this topic. The following pages provide the answers for these exercises, as well as some tips on how to administer the exercises during your training sessions.

EXERCISE 18: WHAT DO YOU ALREADY KNOW ABOUT BOUGHT PESTICIDES?

Exercise 18 helps you find out what your trainees already know about some commonly used (commercial) pesticides. They can check their own answers in Table 5.2. If any answers are incorrect, discuss. Add any others not on the list. Exercise 18 also draws your trainees' attention to the fact that some pesticides may contain the same active ingredients but are sold under different trade names. It is important that they know this to be able to advise farmers properly. Trainees should carry out this exercise in pairs or small groups. Discuss with the class and add any they do not know. Pesticides with different trade names, but the same active ingredients, are grouped and highlighted below.

Pesticide name	Purpose	Type of pesticide	Active ingredient
Attack	Caterpillar, aphids.	I	Pirimiphos-methyl/permethrin
Sundomil	Broad-spectrum.	F	Mancozeb
Glyphosate	Perennial, woody weeds.	H	Glyphosate
Kocide	Broad-spectrum.	F (and a bacteriocide)	Copper hydroxide
Confidor	Sucking insects - aphids, leafhoppers, thrips, whitefly, mealybugs, scale insects and taro beetle.	I	Imidacloprid
Orthene	Chewing and sucking insects - caterpillars, aphids, thrips, leafminers, leafhoppers, cutworm on vegetables and fruits.	I	Acephate
Agazone	Annual and grass weeds.	H	Paraquat
Suncloprid	Sucking insects - aphids, leafhoppers, thrips, whitefly, mealybugs, scale insects and taro beetle.	I	Imidacloprid
Talendo	Broad-spectrum.	F	Chlorothalonil/ Thiophanate
Blitzem	Snails and slugs.	M	Metaldehyde
Steward	Caterpillars, pod borer, armyworm, centre grubs, cutworm, leafroller, leafminers.	I	Indoxacarb
Prevathon	Caterpillars, pod borer, armyworm, centre grubs, cutworm, leafroller, leafminers.	I	Rynaxypyr or chlorantraniliprole
Others:			
Farmers' imidacloprid	Sucking insects - aphids, leafhoppers, thrips, whitefly, mealybugs, scale insects and taro beetle.	I	Imidacloprid
Manzate	Broad-spectrum.	F	Mancozeb
Kotek	Broad-spectrum.	F	Mancozeb

Exercise 19: Understanding the pesticide label

Understanding a pesticide label is critically important for the correct and safe use of pesticides. Exercise 19 focuses your trainees on the information on the labels. Make sure each group has a different label to work with. They should write their answers on brown paper or butcher's paper. When finished, each group should hold their paper up and read out their answers to the class and discuss.

What kind of pesticide is it? (i.e. fungicide, insecticide, etc.)	Depends on label allocated to trainees
What is the pesticide used for?	Depends on label allocated
What is the common name of the pesticide?	Depends on label allocated
What is the trade name of the pesticide?	Depends on label allocated
Is the label divided into separate panels? If so, what information does each of these panels give you? Centre panel? Left panel? Right panel?	Depends on label allocated
What is an emulsifiable concentrate (EC)?	This will form a milky liquid when mixed with water
What is a sticker?	A substance that is put into a pesticide to make it stick to crop plants
What is a spreader?	A substance that helps spread the pesticide across the leaf surface
What is meant by compatibility?	Pesticides that can be used together

What should you avoid doing when spraying, but do immediately after spraying?	Avoid contact with undiluted pesticide during preparation Avoid getting spray on people, animals or into waterways Clean the tank immediately after spraying so that the chemical does not dry on the inside: To do this, open the tank, remove the strainer, fill the tank with 1.5 L of water, replace the cap and shake Pour the water out onto area that has been sprayed, or the ground nearby Add another 1.5 L of water and spray to clean the hose, lance and nozzle
What clothing is recommended when preparing the spray and spraying?	Masks (including respirators) and goggles to protect the mouth and eyes, gloves, boots, hat and overalls. *As a minimum, wear a long-sleeved shirt, long trousers, rubber boots and a hat*
What is the recommended way to store the pesticide?	Store the product in its original container, tightly closed, and away from heat and food, and out of reach of children, preferably in a locked cupboard
What does run-off mean?	Pesticide that has left the crop and run off into the soil, drains, waterways, etc.
Is there a hazard number on the label? What is it and what does it mean?	1a - extremely hazardous 1b - highly hazardous II - moderately hazardous III - slightly hazardous U - unlikely to present acute hazard
What should you do after spraying and before eating, drinking or smoking?	Remove your clothes and shower. Wash the clothes separately from other clothing Do not eat or drink after spraying until you have washed
Can you wash the sprayer or empty container in the river? If not, why not?	No. It may contaminate the water to make it undrinkable, as well as kill fish and other aquatic creatures that live there
Where are the best places to put the container when it is empty?	Bury it or send it to a landfill. Do not re-use the container or leave it in the field

Is it recommended that you induce vomiting if a person has drunk the pesticide?	Depending on the pesticide, the label will tell you whether vomiting should be induced or not
If you spill the pesticide, what should you do?	Wear protective clothing Cordon off the area Prevent the chemical from entering drains Absorb it with inert material (soil, sand or sawdust) Place it in bins for disposal in a landfill Wash the contaminated area with water
Can you give livestock feed that has been sprayed with the pesticide?	Depends on the pesticide. There may be a withholding period till the animals can be slaughtered when they have grazed on sprayed crops. The pesticide label should tell you this
What is meant by the pre-harvest interval (also known as the withholding period)?	How long before the crop can be marketed after spraying to be considered safe to eat
What do these pictograms mean, if they are present on the label? a) b) c) d) 	a) Wear protective clothing b) Always wash after applying pesticide c) Wear gloves d) Wear a mask or face guard

Exercise 20: Making up a pesticide for spraying

Exercise 20 asks your trainees to calculate the quantities needed to make up pesticide concentrations correctly for spraying. It is very important that they are confident with this sort of calculation. Go through it step by step if anyone is having difficulties.

Use the following information to determine how much pesticide is needed.

- The pesticide label (*Eko*) tells you that you should apply *Eko* in **400 L of water per ha**.
- *Eko* is made up at **34 ml per 20 L sprayer** (see Fig 5.6).
- The farmer has a **5 square chain tomato field**.
- Area: 5 square chains is equivalent to 0.2 ha (**25 sq chains = 1 ha, 5/25**)
- Spacing**: 0.5 m x 1 m.**
- The farmer has a **15 L** knapsack.

By yourself, calculate:

1. **How many knapsack sprayers are needed to spray 1 ha of tomato?**

Answer: 26.7 knapsacks if using a 15 L sprayer (40 if a 10 L sprayer; 20 if a 20 L sprayer).

2. **How much (*Eko*) chemical will you need to spray 1 ha of tomato?**

Answer: 680 ml of *Eko* chemical.

3. **What advice would you give the farmers on the amount of chemical (*Eko*) that he/she will use?**

Answer: 136 ml of *Eko* chemical.

Trainees should check their answers with a partner and then share with the whole class.

Exercise 21: Important factors in spraying

This exercise is also critically important to help trainees understand spraying safety. Some answers are given here, and trainees should check the manual for more information. Discuss all answers with the class. Here are some answers; trainees may be able to add others.

Before spraying	• Do not spray on windy days. • Have another person with you. • Check that your knapsack is not leaking and was cleaned properly after its last use. • Check you have the correct nozzle for the pesticide you are using. • Check you have the correct concentration of pesticide (consult label). • Wear proper protective clothing.
During spraying	• Spray either early in the morning or late in the afternoon, when wind is less strong. • Spray down wind. • Use a spray shield to prevent chemical drift. • If accidents happen, refer to the label. • In case of a spill, cover with sand, sawdust or soil, and bury away from the house at the edge of the garden or field, or take to land fill.
After spraying	• Clean the tank immediately after use so that the chemical does not dry on the inside. • Open the tank, remove the strainer, fill the tank with 1.5 L water, replace the cap and shake. • Pour the water out onto the area that has been sprayed, or the ground nearby. • Add another 1.5 L water and spray to clean the hose, lance and nozzle. • After spraying, remove your clothes and shower. • Wash these clothes separately from other clothing. • Do not eat or drink after spraying until you have washed.

Exercise 22: Advantages and disadvantages of using pesticides

Your trainees have now covered Chapters 4 and 5 on IPDM methods of management of pests and diseases. They should now be able to discuss what they have learned about the advantages and disadvantages of using pesticides compared with other methods included in IPDM. Some possible answers are given here.

Advantages of using pesticides	Disadvantages of using pesticides	Safer alternatives
• They are cheap. • Farmers see their effects immediately. • They can be applied quickly over large areas.	• They are toxic to human beings and the environment. • They destroy beneficial insects. • Pests become resistant to them. • For many people, they are difficult to choose and use at the correct rate.	• Cultural control strategies For example: ▪ Crop rotation ▪ Destruction of crop debris at harvest • Resistant varieties

Exercise 23: Using trainees' knowledge to identify and develop a management strategy for a farmer

Your trainees have now studied identification, diagnosis and management of pests and diseases. The next step is to put their knowledge into practice by working through the kinds of issues and problems they may encounter at a plant health clinic. Practice and experience are essential, as by now your trainees would have realised that being a good plant health doctor is complicated and takes effort.

This exercise is **very important,** as it prepares your trainees for the clinics, and is a good introduction to Chapter 6, where they will actually run a real plant health clinic. It also gives them practice in filling out the prescription forms that are used at clinics, and asks them to reflect on their advice and to think about what they could do better.

The exercise is in five parts:

(1) identification and diagnosing the problem
(2) what questions to ask the farmer about the problem
(3) how to manage the problem now and into the future: making a plan
(4) completing the Prescription Form
(5) discussion and reflection on the process

Allow your trainees plenty of time to work through each part carefully.

Part 1 – Identifying and diagnosing the problem

Using the photos, trainees should now work through the process of identification and diagnosis of the problems. They should use all the information from the manual, fact sheets and Pacific Pests, Pathogens & Weeds app, as well as their own knowledge and experience.

Now is the time to remind trainees to use the identification and diagnosing process in Chapter 2:

1. Is it A, B, or C? (Abiotic, Biotic or Confused)
2. Possible and probable
3. Check with the app *only after they have done steps 1 and 2.*

Part 2 – Asking the farmer questions about the problem

As well as examining the sample at a clinic, trainees will need to ask the farmer questions to provide more detail and information to help diagnose and understand the seriousness of the pest or disease.

Trainees should make a list of questions they would ask the farmer. These questions could include:

1. How widespread is the problem? (e.g. a whole field, a few plants only)
2. Have other farmers in the area got the same problem?
3. Has the farmer seen the problem before?
4. Is it a new problem or does it occur every year?
5. How serious is the problem? (e.g. only a few leaves affected, the whole plant is affected)
6. How has the farmer tried to manage the problem? Was he or she successful?
7. What has the weather been like? (e.g. rain, drought, cyclone, frost, etc.)
8. Other questions?

Each pair should show the class their photos, discuss their diagnosis and read out their questions.

For unknowns, refer your trainees to the online tools in Chapter 3.

Part 3 – Managing the problem - making a plan

Once you are satisfied that the trainees have the correct diagnosis, next ask them to discuss and write down all the different ways the problem could be managed, both now and into the future.

- Biological control
    - Are there any natural enemies that are important to preserve, and which might be killed with pesticides?
- Cultural control
    - What to do before planting
    - During growth
    - After harvest e.g. crop rotation, hygiene

- Resistant varieties?
    - These can only be recommended if they are known to be available in the country
- Chemical control
    - Homemade pesticides
    - Commercial pesticides

Part 4 – Completing the Prescription Form

Once they think the problem has been diagnosed and they have thought about a management plan, trainees should now practise completing the plant health clinic Prescription Form. This is the form they will use at the clinics, so it is **very important they are familiar with it.** Stress that they should fill in **ALL** parts, **using clear handwriting**. (They can make up the farmer's details.)

Stress to your trainees that plant doctors should NEVER give advice if they are uncertain.

If using a language other than English, an English copy will be needed as well for record-keeping, or use the CommCare on a smartphone or a tablet.

Make it very clear that the Pacific Pests, Pathogens & Weeds app should be used to check a diagnosis and to guide management strategies **ONLY** after this process is complete. Suggest to your trainees that they use the mini fact sheets in preference to full fact sheets as they present a summary of problems.

Part 5. Discussion and reflection

Reflection is also a very important part of the process. Discuss the exercise as a whole class, encouraging your trainees to discuss not only what they were able to diagnose easily, but also the unknowns and other difficulties. Ask them what they need to do to give a farmer better advice? What further study do they need to do?

If time, this exercise should be repeated using a sample from a garden or field. Your trainees can never have enough practice!

Answers: End of Chapter 5 quiz:

The plant health doctor trainees can do this on their own or in pairs. Ask them which they prefer.

The answers are given in **bold underline**. When they have all finished, go through the answers. You do not need to ask what marks the trainees got; they will have learned the correct answers by going through the test as a class.

Make sure you always discuss with the class any answers they are not sure about.

Then explain to the trainees that if there is anything they are still not sure about they should read the manual again and/or ask for help.

You can add your own questions.

Multiple choice. Pick only one answer

1. Which of the following are all fungicides?

A. Manzate, milk, baking soda, malathion
B. Sundomil, Kotek, Kocide, Talendo
C. Glyphosate, neem, Blitzem, pyrethrum
D. Confidor, Orthene, Bt, Manzate

2. A sprayer nozzle suitable for fungicides should:

A. be an anvil type and the spray should form a light rain
B. be a flat type and the spray should form a mist
C. be a hollow cone type and the spray should form a mist
D. be a flat type and the spray should form a cloud

3. A pesticide label says that it should be made up at a concentration of 10 ml pesticide to 10 L water. The concentration of the pesticide is:

A. 10%
B. 1%
C. 0.1%
D. 0.01%

4. A farmer has 10 ha of a crop to be sprayed. The pesticide label tells her that the spray should be 30 ml pesticide per 20 L of water and the crop should receive 400 L per ha. How many ml of the *pesticide* should she use to make up the spray to cover the whole crop properly?

A. 4000 ml
B. 600 ml
C. 6000 ml
D. 2400 ml

5. **Build-up of insecticide resistance in a pest can be prevented by:**
   - A. alternating the spraying between an insecticide and a fungicide
   - B. spraying early in the morning
   - C. using the correct type of nozzle for spraying
   - **D. making sure the same type of insecticide is not used all the time**

6. **Which of these pesticides are not allowed in organic farming?**
   - A. copper fungicides
   - B. tobacco
   - C. castor oil
   - **D. glyphosate**

7. **Which action should you NOT do if you accidently spill some pesticide?**
   - A. cover the area with sand
   - B. make sure you wash yourself and your clothes thoroughly
   - **C. get the dog to lick it up**
   - D. keep children away from the spill

8. **Pesticide resistance in insects is caused by:**
   - **A. a genetic mutation that is passed on to new generations of the insect**
   - B. a fungicide being used by mistake
   - C. a virus getting into the insect
   - D. using the wrong crop rotation

9. **Which of the following information is NOT usually found on a pesticide label?**
   - A. the type of product
   - **B. which pests are resistant to it**
   - C. what it contains
   - D. what crops it may be used on

10. **An emulsifiable concentrate:**
    - A. is the same as a wettable powder
    - B. is incompatible with all other pesticides
    - C. cannot be mixed with water
    - **D. forms a milky liquid when mixed with water**

11. **A pesticide withholding period means:**
    - A. how long before it is safe to enter a field after spraying
    - B. the period during which animals are not allowed to graze on the crop at any time
    - **C. the number of days between the last application of a pesticide and crop harvest**
    - D. how long before a pesticide is allowed into a country

12. Copper can be used to control:

A. phytoplasmas and viruses
B. nematodes and mites
C. snails and insects
D. <u>bacteria and fungi</u>

13. Pests in a small farm or garden are best controlled by:

A. ignoring them
B. using pesticides as soon as they are seen
C. <u>encouraging beneficial insects and spiders</u>
D. using insecticides and fungicides weekly

14. Pesticides allowed in organic farming:

A. come only from plants
B. are the same as bought pesticides only weaker
C. <u>are controlled under organic standards</u>
D. are always safe

8.7 Answers: Chapter 6

Chapter 6 brings together everything your trainees have learned in the previous chapters to plan, run and reflect on a PHC, first as a simulation and then a real one for farmers.

Exercise 24: What do we need to run a successful plant health clinic?

This exercise helps your trainees to think about everything they will need for a successful clinic.

When asking them to report back, start with ‘before’ and let each group give their ideas. After the first group has spoken, the other groups should just add anything that has been left out (see section 6.2). Otherwise it will take too long, be repetitive and people might get bored. An example is given here, but check the manual for the full list.

What do we need?		
Before the PHC	**During the PHC**	**After the PHC**
• Good location for farmers • Awareness of the clinic before it is held • Tables/chairs • Banner • Join country WhatsApp group	• Pacific Pests, Pathogens & Weeds app • CommCare app • Prescription forms • Pen or pencil • Knives • Hand lens • Camera	• Samples brought by farmers • Farmers’ Feedback Forms • Prescription Forms (copies) • Photosheet summary template

Exercise 25: WhatsApp - How to use it

The country WhatsApp groups were discussed in Chapter 3. Here, your trainees learn to send pictures of unknowns or confusing samples to the WhatsApp group as part of running a clinic. Trainees should send their phone numbers to the person in charge of the WhatsApp groups before the clinic.

You should ask members of the country and other WhatsApp groups if they can be available when you run this exercise.

Exercise 26: Role play - filling out the prescription form

This exercise builds on Exercise 23 in Chapter 5. Ask the trainees to go outside and collect a sample of each of:

- a pest
- a disease
- an unknown problem

If this is not possible, you need to provide the samples yourself, or use one of the photos in the manual or from the Pacific Pests, Pathogens & Weeds app.

You should carefully model the process of the clinic first, acting as the plant doctor while one of your trainees plays the role of the farmer. Go through the farmer interview process step by step, explaining clearly what you are doing at each step while the trainees observe.

After you have done this and discussed any issues or questions, ask trainees to form pairs. Provide each pair with a **Prescription Form** to fill in.

Remind the trainees to go through the A,B,C and possible/probable identification and diagnosis steps carefully (see Chapter 2). **They should not** go straight to the Pacific Pests, Pathogens & Weeds app. When doctors do this at clinics, they often make the wrong diagnosis, something similar to humans self-diagnosing a disease using Google!

The 'doctor' should interview the 'farmer' and fill in the Prescription Form carefully and clearly. The data can also be added to the CommCare app to practise using it.

Sometimes doctors give a farmer incorrect information because they do not want the farmer to think they do not know something. Stress to your trainees that they should not fill in answers if they do not know what the problem is. It is much better to tell a farmer they do not know and they will find out, than give incorrect advice. In this case, they should write on the Prescription Form 'unknown'.

When they have finished, discuss the exercise with the class. It is really important that proper reflection is done at this stage to uncover problems the trainees may have encountered.

Exercise 27: Using the CommCare Prescription Form

Demonstrate to the class how the CommCare form works. Have the trainees download the CommCare app to their smartphone or tablet and open the plant health clinic Prescription Form. Now take any pest or disease sample and fill in the form (offline), as has been done for the hard copy.

Even if we find a way to print out the form, there may still be a need to have the completed form translated into local languages first. There is also the difficulty of deciding how to treat Solomon Islands Pijin where it is not used commonly as a written language.

These issues need to be discussed and resolved by the plant health team in each country.

Exercise 28: Filling in the Farmer Feedback Form

The farmer feedback form is an important document to be used after the farmer has seen the plant health doctor at the clinic. The clinic manager or another designated person (especially someone who speaks the farmer's language) interviews each farmer about his/her experience of the clinic and completes the feedback form. The team in each country should ensure translations into their language (Fijian, Samoan, Solomon Islands Pijin or Tongan) are made available, as well as English.

The manager collects and collates all the feedback forms to present and discuss during the reflection after the clinic. This is an important part of reflection, as well as monitoring and evaluation.

After each interview, the person who played the role of the farmer should use the form to give feedback to the plant health doctor on the diagnosis process and suggested recommendations. Discuss the answers with the whole class and reflect on what improvements could be made.

Exercise 29: What to do if large number of farmers attend the clinic with the same problem

Often, a number of farmers bring the same problems to the clinic if there is an outbreak of an insect pest or disease in the area. If the clinic manager notices this, and if there is time after they have received their prescription from the doctor, it would be very useful to gather the farmers together and ask one of the doctors to give them a short talk about the problem. This will give the farmers the opportunity to talk to each other about the problem and what they are trying to do about it.

Note that it is important that all farmers see the doctor first.

It is very important that you prepare your trainees for the possibility that many farmers will bring the same problem; you can do this by helping them become familiar with plant pests or diseases that they are likely to see at the clinic. Extension staff should already be aware of the major pests and diseases in their area, though sometimes new problems spring up quickly, especially when weather conditions change.

As the trainer, it is important that you have some knowledge about what these pests and diseases are likely to be. Tables 2.6 and 2.7 in Chapter 2 have a list of the most common pests and diseases in Samoa and Tonga. Trainers in Fiji and Solomon Islands need to ensure they also have country-based or regional-based information.

For this exercise, give your trainees an example of a pest or disease which is likely to be a problem in the area where the clinic is to be held. If you cannot find a live sample, use a picture or an example from the Pacific Pests, Pathogens & Weeds app. The trainees should prepare a short presentation about the problem for the class covering:

- the symptoms
- the diagnosis
- recommendations for control now and in the future

Ensure each group presents on a different pest or disease.

Exercise 30: Reflection on the clinic process

Exercise 31: Looking at the farmer feedback forms

Exercise 32: Reflection on diagnosis and recommendations

These three exercises are critically important for learning and improving the clinics, and should be gone through carefully. Emphasise that being wrong is nothing to be ashamed of, rather it is a vital part of the learning process, and that everyone gains from it, however experienced we may be. It is something we can all share in.

Exercise 33: Sending ‘unknown’ samples for identification

This is an exercise in sending a sample to an expert for examination, locally or overseas, so that an identification can be made. Make sure that you have the equipment needed before starting this exercise.

Set up three tables, with examples of either: (1) a fungal or bacterial disease; (2) a pest; or (3) a virus.

Write the instructions for sending away each type of problem and place on the table.

To start, each group should write a label to put inside the parcel containing:

- Crop/plant name
- Code given at the clinic
- Location of the clinic
- Farmers’ name
- Farmer’s village
- Short description of the problem

Trainees should follow the instructions for their pest or disease, and when they have finished, they should unwrap or dismantle the sample for the next group and move to the next table.

Exercise 34: Plant health doctor self-evaluation form

Now it is time to ask your trainees to evaluate themselves as a plant health doctor using the self-evaluation form. Emphasise that this is anonymous. Self-evaluation is important. It helps the trainees think about their progress and helps the extension service to monitor how well the program is running, and what further training may be needed.

Collate and report the overall results from the class. Discuss what this says about your trainees' confidence and ability to conduct a clinic. Ask:

- What do they think needs to be done to improve?
- How should this take place?

Exercise 35: Making a plant health clinic photosheet summary

It is very important to make a summary for the clinic to record the main points and to send it to senior officers, the media and others who are interested in the clinic program. This should be done on the day of the clinic if possible, usually by the clinic manager. The template for this is in Appendix 3.

END OF CHAPTER 6 QUIZ: Test your knowledge

The answers are given **in bold underline**. When they have all finished, go through the answers. You do not need to ask what marks the trainees got; they will have learned the correct answers by going through the test as a class. Make sure you discuss any answers they are not sure about. Then explain that if there is anything they are still not sure about, they should read the manual again and/or ask for help.

1. Plant health clinics are important parts of:

A. a country's food security
B. a country's plant health system
C. the agricultural extension system
D. all of the above

2. The best place to hold a clinic is:

A. where many farmers gather, e.g. a market
B. at the research station
C. on a farm
D. at the university

3. Important advice for farmers when raising awareness about a forthcoming clinic is:

A. to bring the whole plant, including roots
B. to bring a few leaves
C. to bring a soil sample
D. to bring your phone

4. If you do not know what the problem is, you should:

A. leave that part of the prescription form blank
B. tell the farmer something, even if you are not sure
C. ask if anyone else knows what the problem is
D. send the farmer away

5. Look at the steps below for identifying a disease sample.

1. Make a parcel for the specimens with newspaper
2. Write a label and put the specimen in a plastic bag with a water and seal the bag
3. Collect samples showing a full range of symptoms

The correct order to do these steps in is:

A. 1, 2, 3
B. 3, 2, 1
C. 2, 1, 3
D. 1, 3, 2

6. Insect samples to be sent away for identification are best preserved in:

A. methanol
B. isopropyl alcohol
C. 70% alcohol
D. beer

7. A plant doctor suspects a farmer's sample has a bacterial wilt. She can test this by:

A. smelling it to see if it smells rotten
B. cutting the stem and dipping the end of it in water and looking for milky streams
C. finding the bacteria under a microscope
D. looking for spots on the leaves

8. The most important items to take to a clinic are:

A. chairs
B. kava
C. uniforms
D. prescription forms

9. After a clinic, a plant health doctor must always:

A. follow up with a farmer if the farmer has been told that will happen
B. reflect on and review the clinic data and plan to improve for next time
C. collect all the samples for looking at later with the other plant health doctors
D. do all of the above

10. A farmer brings yams that have died and gone black. The farmer tells the plant health doctor they have been damaged by lightning. The doctor thinks the problem is anthracnose. The doctor should help the farmer straight away by:

A. agreeing that lightning might be the cause but also offering other ideas of the cause, and suggesting what the farmer could do
B. offering to visit the farm
C. telling the farmer he or she cannot be helped at the clinic
D. asking the farmer to bring in more samples

The Big Quiz - Answers

This should be done at the end of the training as a revision exercise, and afterwards, celebrate the end of the training!

The answers are given **<u>in bold underline</u>**.

1. A plant health system should include:

- **A. <u>plant health clinics, extension staff, research staff, ministries of agriculture staff</u>**
- B. biosecurity staff, research staff, hospital staff, quarantine staff
- C. plant health doctors, vets, extension staff, research staff
- D. media, tourism, agriculture, horticulture

2. Which of the following are all insecticides?

- A. Manzate, milk, baking soda, Taratek
- B. Sundomil, Attack, Multiguard, Confidor
- C. Glyphosate, neem, Blitzem, pyrethrum
- **D. <u>Confidor, Orthene, Bt, Taratek</u>**

3. A sprayer nozzle suitable for fungicide should:

- A. be an anvil type and the spray should form a light rain
- B. be a flat type and the spray should form a light rain
- **C. <u>be a hollow cone type and the spray should form a mist</u>**
- D. be a flat type and the spray should form a cloud

4. A pesticide label says that it should be made up at a concentration of 1 ml pesticide to 10L water. The concentration of the pesticide is:

- A. 10%
- B. 1%
- C. 0.1%
- **D. <u>0.01%</u>**

5. A farmer has 10 ha of a crop to be sprayed. The pesticide label tells her that the spray should be 30 ml pesticide per 20 L water and the crop should receive 500L per ha. How many ml of the pesticide should she use to make up the spray to cover the whole crop properly?

- A. 3000 ml
- B. 4000 ml
- C. 6000 ml
- **D. <u>7500 ml</u>**

6. Build-up of pesticide resistance in a pest can be prevented by:

A. alternating the spraying between an insecticide and a fungicide
B. spraying early in the morning
C. using the correct type of nozzle for spraying
D. <u>making sure the same type of pesticide is not used all the time</u>

7. Which action should you NOT do if you accidently spill some pesticide?

A. cover the area with sand
B. make sure you wash yourself and your clothes thoroughly
C. keep children away from the spill
D. <u>leave it to evaporate away</u>

8. Pesticide resistance in insects is caused by:

A. <u>a genetic mutation that is passed on to new generations of the insect</u>
B. using the wrong crop rotation
C. a herbicide being used by mistake
D. a virus getting into the insect

9. Which of the following information is NOT usually found on a pesticide label?

A. the type of product
B. <u>which pests are resistant to it</u>
C. what it contains
D. what crops it may be used on

10. A wettable powder:

A. is the same as an emulsifiable concentrate
B. is incompatible with all other pesticides
C. <u>can be mixed with water</u>
D. forms a milky liquid when mixed with water

11. A pesticide withholding period:

A. is the period before it is safe to enter the crop after spraying.
B. is the period when animals are not allowed to graze on the crop at any time.
C. <u>is the number of days between the last application of a pesticide and crop harvest</u>
D. is the period before a pesticide is allowed into a country from overseas

12. **In IPDM, pesticides should be used:**
   A. always, as a prevention
   B. never
   C. <u>as a last resort</u>
   D. only if the farmer can afford them

13. **The adult insect in the picture below is most likely to be:**
   A. a beetle
   B. a wasp
   C. <u>a lacewing</u>
   D. a fly

14. **In order, a companion plant, a biological insecticide and a beneficial organism are:**
   A. taro, DBM, *Trichoderma*
   B. Chinese cabbage, kocide, ladybird
   C. coconut, pyrethrum, *Trichogramma*
   D. <u>marigold, *Metarhizium*, spider</u>

15. **An example of a good crop rotation would be:**
   A. lettuce, cabbage, broccoli, bean
   B. cucumber, squash, potato, cassava
   C. potato, tomato, eggplant, capsicum
   D. <u>bean, cabbage, cassava, cucumber</u>

16. **A plant health doctor is faced with an unknown pest or disease at the clinic. What should s/he do first?**
   A. send a picture to WhatsApp
   B. make up something; it's better than the farmer thinking they don't know
   C. <u>see if anyone else in the clinic knows</u>
   D. tell the farmer to go away

17. In IPDM, monitoring involves:

A. deciding whether the problem is caused by a pest or a disease
B. using the best pesticide for the pest
C. checking the level of damage and looking for bugs and eggs
D. identifying the pest or disease

18. The correct sequence for applying IPDM is:

A. monitoring, evaluation, making a plan, identification of pest or disease
B. evaluation, monitoring, identification of pest or disease, making a plan
C. making a plan, identification of pest or disease, monitoring, evaluation
D. identification of pest or disease, monitoring, evaluation, making a plan

19. Which plants are all in the same plant family?

A. cabbage, bok choy, broccoli, chilli
B. potato, cassava, taro, sweet potato
C. bitter gourd, pumpkin, cucumber, pineapple
D. capsicum, chilli, eggplant, potato

20. The best way to control a soil-borne bacterial infection is:

A. use a resistant variety if it can be obtained
B. spray with a pesticide
C. use a virus that attacks the bacteria
D. add compost to the soil

21. Which of the following is NOT thought to be associated with companion planting:

A. companion plants can provide food for parasitoids
B. companion plants may have a smell that repels pests
C. always add large amounts of potassium to the soil
D. companion plants may repel root knot nematodes

22. In order, abiotic and biotic factors that cause damage on plants are:

A. a fungus and a mite
B. a bird and drought
C. potassium deficiency and a virus
D. phytoplasma and poor soil

23. Typical symptoms on plants caused by bacteria are:

A. leaf spots, angular or round, with or without haloes

B. wilt and yellowing at the edges of leaves

C. rusty spots and mosaics

D. dieback and the leaves go purple

24. A common disease of tomatoes in the Pacific region is:

A. witches' broom

B. tobacco mosaic

C. Early blight

D. ring spot

25. The smallest of these pathogens is:

A. a virus

B. a phytoplasma

C. a bacterium

D. a fungal spore

26. A plant doctor finds a plant with symptoms of wilt. The most unlikely cause would be:

A. bacteria in the soil

B. rust fungus

C. nematodes

D. stalk borers

27. Pests with eight legs are not:

A. mites

B. insects

C. scorpions

D. spiders

28. Which of these diseases is caused by a fungus?

A. bunchy top on banana

B. blossom end rot on tomato

C. scale on sweet potato

D. damping off on cabbage seedlings

29. A plant doctor finds a cabbage with a lot of holes in the leaves. Which is not a likely cause?

A. Diamondback moth
B. large cabbage moth
C. <u>leaf spot</u>
D. snails

30. A virus can be spread by:

A. bacteria
B. fertiliser
C. rhinoceros beetles
D. **<u>aphids</u>**

31. Two insects with simple life cycles are:

A. <u>aphids and katydids</u>
B. butterflies and bugs
C. grasshoppers and ants
D. bees and moths

32. Plant health clinics are important parts of:

A. a country's food security
B. a country's plant health system
C. the agricultural extension system
D. <u>all of the above</u>

33. The best place to hold a clinic is:

A. <u>where many farmers gather, e.g. a market</u>
B. at the research station
C. on a farm
D. at the university

34. Important advice for farmers when you are raising awareness about a forthcoming clinic is:

A. <u>to bring a whole sample if possible</u>
B. to bring a few leaves
C. to bring a soil sample
D. to bring their phone

35. If you do not know what the problem is, it is best to:

A. leave that part of the Prescription Form blank

B. tell the farmer something, even if you are not sure.

C. send the farmer away.

D. ask if anyone else knows what the problem is

36. Look at the steps below for identifying a disease sample.

1. make a parcel for the specimens with newspaper
2. write a label and put the specimen in a plastic bag with a few drops of water and seal the bag.
3. collect samples showing a full range of symptoms.

The correct order to do these steps is:

A. 1, 2, 3

B. 3, 2, 1

C. 2, 1, 3

D. 1, 3, 2

37. Insect samples to be sent away for identification are best preserved in:

A. beer

B. methanol

C. isopropyl alcohol

D. 70% alcohol

38. A plant doctor suspects a farmer's sample has a bacterial wilt. She can test this by:

A. smelling it to see if it smells rotten
B. looking for spots on the leaves
C. dipping the end of the root in water and looking for milky streams
D. finding the bacteria under a microscope

39. The most important items to take to a clinic are:

A. chairs
B. kava
C. uniforms
D. prescription forms

40. After a clinic, a plant health doctor must always:

A. follow up with a farmer if the farmer has been told that will happen
B. reflect on and review the clinic data and plan to improve for the next clinic
C. collect all the samples for looking at later with the other plant health doctors
D. do all of the above

41. A farmer tells the plant health doctor he thinks his crops have been damaged by an evil spirit. The doctor should help the farmer by:

A. agreeing this might be the case and offering other ideas of what the farmer could do
B. sending the farmer to a priest
C. telling the farmer he cannot be helped at a plant health clinic
D. asking the farmer to bring in more samples

42. Which Pacific countries now have the Guam strain of the rhinoceros beetle?

A. Samoa
B. Tonga
C. Fiji
D. Guam, Palau, Papua New Guinea, Solomon Islands

43. Good soil is likely to have a pH of around:

A. 1
B. 3
C. 9
D. 7

44. Which of these home-made pesticides is particularly harmful to fish?

A. chilli
B. *Gliricidia*
C. neem
D. <u>derris</u>

45. What are the pests in this photo?

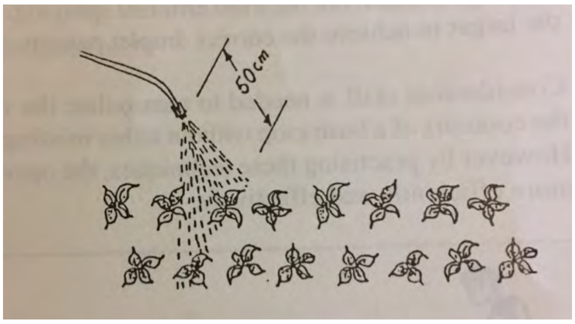
A. rhinoceros beetles on mango
B. <u>green vegetable bugs on tomato</u>
C. black ticks on pumpkin
D. aphids on guava

46. What is the difference between a parasite and a parasitoid?

A. there isn't one: they are the same
B. <u>a parasite does not kill its hosts; a parasitoid does</u>
C. a parasitoid can't be seen with the naked eye; parasites can
D. parasites have complex life cycles whereas those of parasitoids are simple

47. The picture below shows you how:

A. <u>to spray low-growing crops</u>
B. far apart crops should be
C. to use a mist sprayer
D. to water your plants in a drought



48. A farmer brings a plant with large irregular spots on the leaves. It is most likely to be:

A. a wilt
B. a deficiency disease
C. <u>a fungal disease</u>
D. something I know nothing about

49. You want to teach your trainees to think about how plant diseases relate to people going hungry. The best teaching strategy is probably:

A. <u>a cause and effects diagram</u>
B. a picture of a hungry child
C. a role-play
D. a concept map

50. Which symptoms are often confused?

A. a powdery mildew and a leaf spot
B. <u>a virus and a deficiency disease</u>
C. a bacterial leaf spot and a bacterial wilt
D. overwatering and copper deficiency

APPENDIX

The appendix contains the following resources:

1. The plant health clinic Prescription Form
2. Farmer Feedback Form
3. Template for making a photosheet
4. Plant health doctor self-evaluation form
5. Procedure check list for running plant health clinics
6. Refresher training for continued capacity building of Regional and National core group of plant health clinic trainers

Appendix 1 The Plant Health Clinic Prescription Form

CLINIC

Date: ☐ Fiji ☐ Samoa ☐ Solomon Islands ☐ Tonga Code:

FARMER

Family Name: Given names: Sex: M☐ F☐

Village/Settlement: Province: Mobile:

Clinic visit: 1st ☐ 2nd ☐ 3rd ☐ other: Age: < 29 ☐ 30-55 ☐ > 56 ☐ Sample: Yes☐ No☐

CROP

Crop: Estimate planted area (m^2):

Variety: Estimate no. of plants:

Seed source: Estimate no. of plants damaged: Few ☐ Many ☐ All ☐

Previous crop: Plant problem: Common ☐ New ☐

Crop stage: Weather: Normal ☐ Wet ☐ Dry ☐ Unusual ☐

DESCRIBE WHAT YOU SEE (if no sample, write what the farmer tells you)

WHAT CONTROL MEASURES HAS THE FARMER TRIED?

WHAT DO YOU THINK THE PROBLEM IS?

YOUR RECOMMENDATIONS

What can the farmer do now?

Cultural control Chemical control

What can the farmer do in future (when growing the same crop)?

Cultural control Chemical control

Before planting: Any resistance varieties?

During growth

After harvest:

Photo(s) taken: Yes ☐ No ☐ Sample sent to lab? Yes ☐No ☐

Plant doctor: Signature: Mobile no.:

Appendix 2
Farmer Feedback Form

1. Did the plant health doctor diagnose your problem?

Yes No Not sure

Why?

____

____

2. Do you think you can carry out what the doctor said you should do?

Yes No Not sure

If not, why not?

____

____

3. Was the clinic useful?

Yes No

Why?____

____

4. Do you have any suggestions on how to improve the plant health clinic?

____

____

5. Would you recommend the clinic to other farmers?

Yes No

Why?

____

____

6. If there is another clinic in your area would you come again?

Yes No Maybe

Appendix 3
Photosheet Template

COUNTRY

XX (major administrative area)

XX (PLACE ORGANISATION) PLANT CLINIC

XX (organisation) | DATE

INSERT PHOTO 1	INSERT PHOTO 2
INSERT PHOTO3	INSERT PHOTO 4
INSERT PHOTO 5	INSERT PHOTO 6

This plant clinic was held at XX and organised by XX. The XX (clinic) is located XX km N/S/E/W from XX town.

N (number) farmers participated at the clinic; there were N men and N women).

N samples were received.

Some of the key problems presented were XX.

The plant doctors were XX.

[Other information]: You could add if any specimens were sent for identification.

Prepared and reported by XX, Organisation. For more information contact XX (person, phone number, email etc.).

Photos by XX (if a different person).

Plant clinics are held as part of the ACIAR project: Responding to emerging pest and disease threats to horticulture in the Pacific islands.

Appendix 4
Plant Health Doctor Self-Evaluation Form

1. How confident are you in your abilities to make correct disease diagnoses?

1 2 3 4 5

2. How confident are you in your ability to correctly diagnose pest problems?

1 2 3 4 5

3. How confident are you in your ability to make correct recommendations?

1 2 3 4 5

4. Do you feel you need more training?

Yes No

5. If 'Yes' what training is needed? Please specify (e.g. IT, diagnosis, filling out the prescription forms, interviewing farmers etc.)

Appendix 5
Plant Health Clinic Procedure Check List

Before a clinic	Tick when done
1. Confirm the clinic date, time, and venue	
2. Farmer awareness (ongoing in different ways – farmer networks, social media etc.)	
3. Preparation and planning (select manager and working committee)	
4. Organize all materials for the clinic (refer to PHC checklist in Chapter 6)	
5. Conduct at least 1 day refresher training on areas of need e.g. P&D identification and diagnosis, management, filling in of forms etc.	
6. A recap of pest and diseases of the target clinic location	
7. Set up the clinic site and ensure the plant doctors and supporting team are ready	
During a clinic	
1. Clinic manager opens the clinic (maybe with a short welcoming speech) and then directs farmers to plant doctor stations	
2. Plant doctors work alone or in teams to serve farmers filling the Prescription Form (hard copy Prescription Form and soft copy – CommCare)	
3. Clinic manager collects samples (or delegates job) and directs farmers to fill Farmer Feedback Form	
4. Clinic manager provides or directs consultation support if necessary (if any consultant or senior officers/trainers available) to any doctor requiring a second opinion of diagnosis or management advice	
5. Clinic manager provides help in setting up any quick diagnosis tests to help plant doctors	
6. Ensure that farmers are served well and not waiting too long (keep farmers occupied)	
7. Engage online network(s) for external support in any unknown case to the clinic team on site	
After a clinic	
1. Manager thanks farmers (if any still around) and plant doctors	
2. Arrange field visit to farmers with urgent problems if time, transportation and farm location permit	
3. Clean up site and pack samples and clinic materials	
4. Quick audit of clinic materials to ensure all important tools and other items are accounted for (lenses, tables, etc)	
5. Reflection on clinic and samples (plant doctor group debrief) and then properly dispose of the samples (i.e., those not to be sent to the laboratory)	
6. Complete clinic summary photosheet and brief data/financial report to send to superiors and key partners	
7. Follow up on any field visits to farmers and send any specimens sent to laboratory if necessary; report updates	

Appendix 6
Refresher Training for Continued Capacity Building of Regional and National Core Group of Plant Health Clinic Trainers

This short course (3-4 days) aims to provide refresher training for capacity building in collecting, describing common pest and disease symptoms, giving diagnoses and providing recommendations for management to core groups of national trainers who are delivering plant health clinic training to extension staff in the Pacific islands. Any extra training on any gaps identified should be organised by SPC via video communication, e.g., Zoom.

Capacity-building in pest description, diagnosis and management

Equipment/Materials needed

The material collected will not only be used for you to understand the pests and diseases, their biology, lifecycles, etc., but also for teaching purposes. It will become **your** collection. Equipment needed (each person):

- Newspaper - plenty
- Cardboard to place over the samples, e.g. 40 cm x 40 cm
- Alcohol (propyl alcohol from the pharmacy)
- Tubes for collecting and preserving insects
- Plastic bags for collecting samples
- Labels (and Sellotape if the labels are not self-adhering)
- Pens and pencils
- Pins – for pinning out the moths
- Polystyrene blocks
- Camera or smartphone
- Notebook
- PHC Manual prescription form

2. Collect pests and diseases

In pairs (preferably) or on your own, go to research stations and/or farmers' fields and make a collection of common pests and diseases of important crops in the country. Each person should make their own collection. Do not collect too many samples at one time, otherwise you will not have time to process them. (You want to collect 10-15 samples maximum. Aim for 50:50 insects/mites and pathogens.)

Remember to collect a lot of material for each sample, so that you have enough to press to show the different stages of insect life cycles, and the variation of symptoms of each disease.

3. Preserve the samples

Each sample is to be described and diagnosed, and conserved:

- Use the prescription form from Chapter 5 to make a description and a diagnosis, AND do the same with the CommCare app
- Make a herbarium sample of the diseased specimens and preserve the pests in alcohol. If you want to pin out the moths, read the part on setting moths here:

  http://lepidoptera.butterflyhouse.com.au/faqs/setting.html

If you are not sure how to make a herbarium specimen of diseases or preserve an insect, use the following references:

- PestNet: https://www.pestnet.org/how-to-send-specimens/. Insects will be preserved in propyl alcohol.
- Exercise 33 in Chapter 6
- Contact SPC Plant Health, Land Resources Division, Suva.

4. Label the samples

Make sure you have enough diseased material collected, or enough insects or mites conserved. Make a label for each sample, with the following information:

- Name of crop
- Give each sample a unique number
- Common name of pest or disease (if known)
- Locality
- Date
- Collector's name

Take a photo of each of your samples; place the label by the sample and make sure it is included in the image. **Describe each sample on the prescription sheet and on the CommCare app**. Make sure the number on the label coincides with the number against each description. **Contact SPC for details how to access the CommCare app designed for PHCs.**

If you collect insects, make a herbarium sample of the damage caused, if practical. If not, just take photos of the damage, or draw it. Make sure that the numbers are carefully recorded.

Create a table in your notebook with details of each specimen, providing the information on the label, plus anything else that you think is relevant

5. Review: Summarise observations on Prescription Forms and the CommCare app

Each sample should be used to fill in a copy of the Prescription Form from the PHC Manual, and the CommCare app. This is important. It's as if you have been given the sample by a farmer. Obviously, there are some sections that you will have to make up, or record your own ideas (as a farmer), e.g., what you have done to control the problem, but most of it is straightforward.

Note, using the CommCare app you can take a photo. Send the CommCare list of sample descriptions to your email.

6. Make a summary of your work using the Word and Excel templates

Use some of the samples that you have collected to make a one-page summary. Make a heading, then enter the photos you have taken into the table, and add:

- date
- location
- number of farmers (estimate, divided by gender)
- number of samples
- crops and important pests and diseases
- list of plant doctors (yourself)
- further information, and support from the project
- Add your prescription data into an Excel spreadsheet. **Check with SPC for latest format.**
- If you are using the CommCare form, go over it carefully, checking that the data have been entered correctly

7. Carry out a reflection on collecting, diagnosis, management, preservation

In pairs, discuss these questions and then present your answers to the whole group:

- Has this exercise been of help to you? Have you improved in certain areas? If so which ones?

- What further training do you still need: i) technical and/or; ii) delivering the training to extension staff (based on your past experiences).
- Discuss your reflections.

8. Fitting in the course with your present duties

Remember you have to change the newspaper each day or the specimens will collect mould. Because you have other duties, you do not have to do the collecting, preserving, prescribing and other activities every day. You need to fit the exercise in with your other work. **BUT** if you can't go each day to change the newspaper, then take the samples back to your office so that it can be done there.

9. Participants

It is recommended that the course be done by national trainers, and staff selected from extension, research, biosecurity, and NGOs.

Identification of gaps in knowledge and training via Zoom

This will follow after the collections have been made, and photos of the samples have been sent, and analysed. The areas covered will be identified come from the reflections that you make (see 7 above).

When complete, refer to the relevant sections in the manual:

- Use the fact sheets app to review the most common pests you have collected
- Discuss management methods
- Discuss teaching methods for your next training session

Contact SPC to arrange this training.