Chapter 5

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

In Chapters 2 and 4, your trainees learned to identify and diagnose plant pest and disease symptoms. Chapters 5 and 6 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 6 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).

5.1 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 we learned in Chapter 3, 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 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.

5.2 What is IPDM?

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

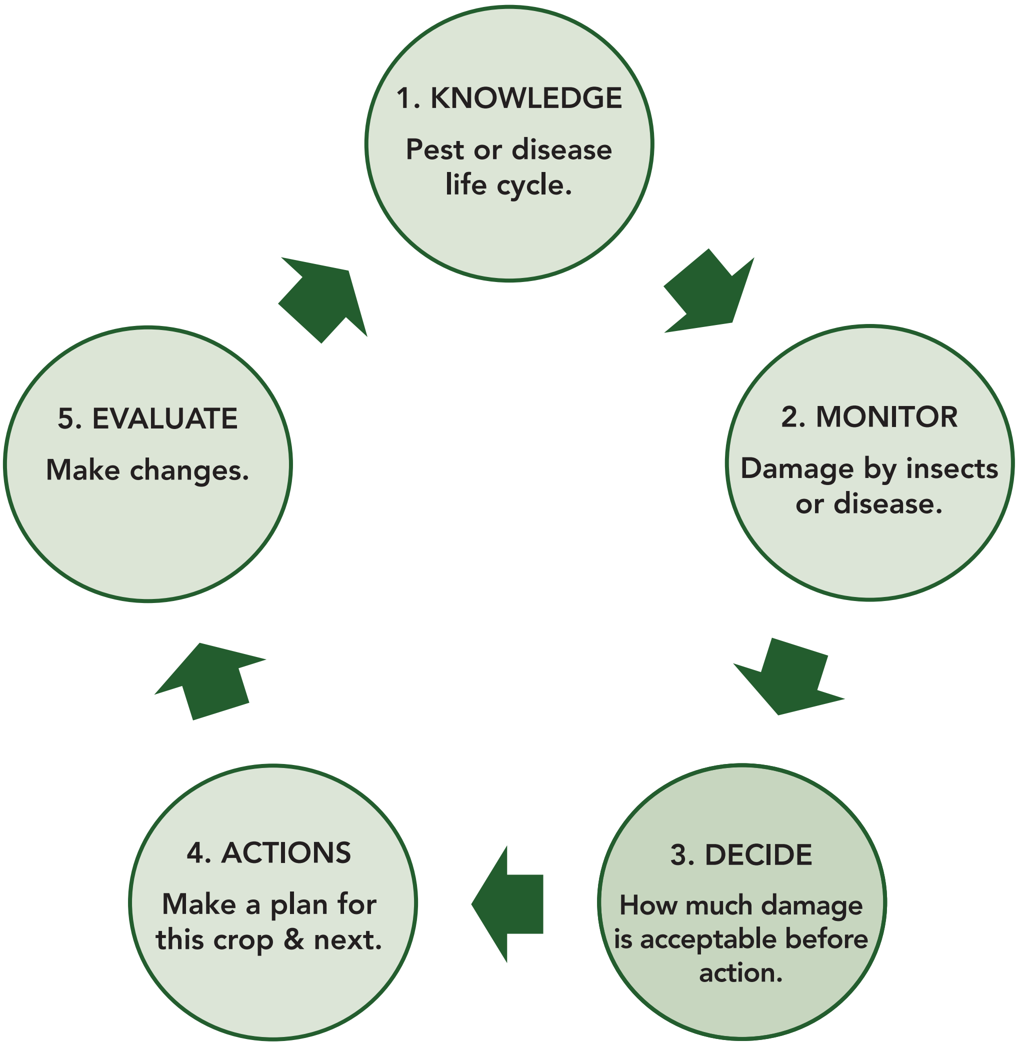
- **IPDM** uses different control measures or options to reduce pest and disease levels in an economical and environmentally sustainable way
- **IPDM** is based on knowledge of pests and life cycles, checking the crop, making plans for action, and evaluating the results
- **IPDM** is a way of encouraging natural enemies: using natural enemies can not be done if you are using broad-spectrum insecticides. IPDM does not preclude the use of insecticides but uses them 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. 5.1 shows that the IPDM process is a cycle.

Fig. 5.1 The IPDM cycle, indicating the information needed and the actions required for IPDM to be success. *Source: authors.*



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

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EXERCISE 5.1: What do you already know about IPDM cultural control methods for specific pests and diseases?

1. In groups, trainees should **fill in the table below**, for two pests and two diseases from their region
2. 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	How it works	For small scale	How it works
Insect/mite pest					
Example: Diamondback moth (DBM)	Brassicas	Remove weeds in the Brassica family	Reduce DBM populations that maintain populations between crops	Hand picking caterpillars	Remove pests
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					

5.3 Working through an example of using IPDM

Here is an example of the IPDM process when applied to the green vegetable bug *(Nezara)* on tomato (Fig. 5.2).

Knowledge: what do we know?

- **identify it:** use your knowledge and the identification processes from Chapter 2 and 4
- **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 5.2), 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?

[1] 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.

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.

Fig. 5.2 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.
Source: Rob Ransom. BuGuide (top left & right).
Wikimedia Commons (bottom right). Extension. University of Georgia (bottom left).

Action: what can you do now & what you can do in the future?

Before planting:

- **soil:** make sure you are planting in healthy soil (see Fact Sheet 486)
- **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 or preferably biopesticides.

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 they biological sprays?
- were the costs worth it?

EXERCISE 5.2: 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** below.

- in pairs or small groups, place the steps in the correct order
- discuss your answers with the class.

STEPS IN THE 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.

STEPS IN THE CORRECT ORDER

A.

B.

C.

D.

E.

5.4 Cultural control options for IPDM

The example of the green vegetable bug on tomato in Section 5.3 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

Chapter 3 covered the importance of soil health in detail, and stated that healthy plants are less likely to suffer from pests and diseases than weakened ones. 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 (Fig. 5.3). There are some exceptions, e.g. paddy rice varieties can grow under irrigated (water-logged) conditions where the roots form specialised gas spaces allowing oxygen to be transported from leaves to the roots; taro does the same.

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.

Fig. 5.3 Plots of Chinese cabbage in Vanuatu, with and without the addition of chicken manure showing the effect of nutrition on the crop. *Source: authors.*

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. See Chapter 3 for more details.

Table 5.1 shows the different crops that farmers can use to help them draw up options to carry out effective crop rotation. 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,

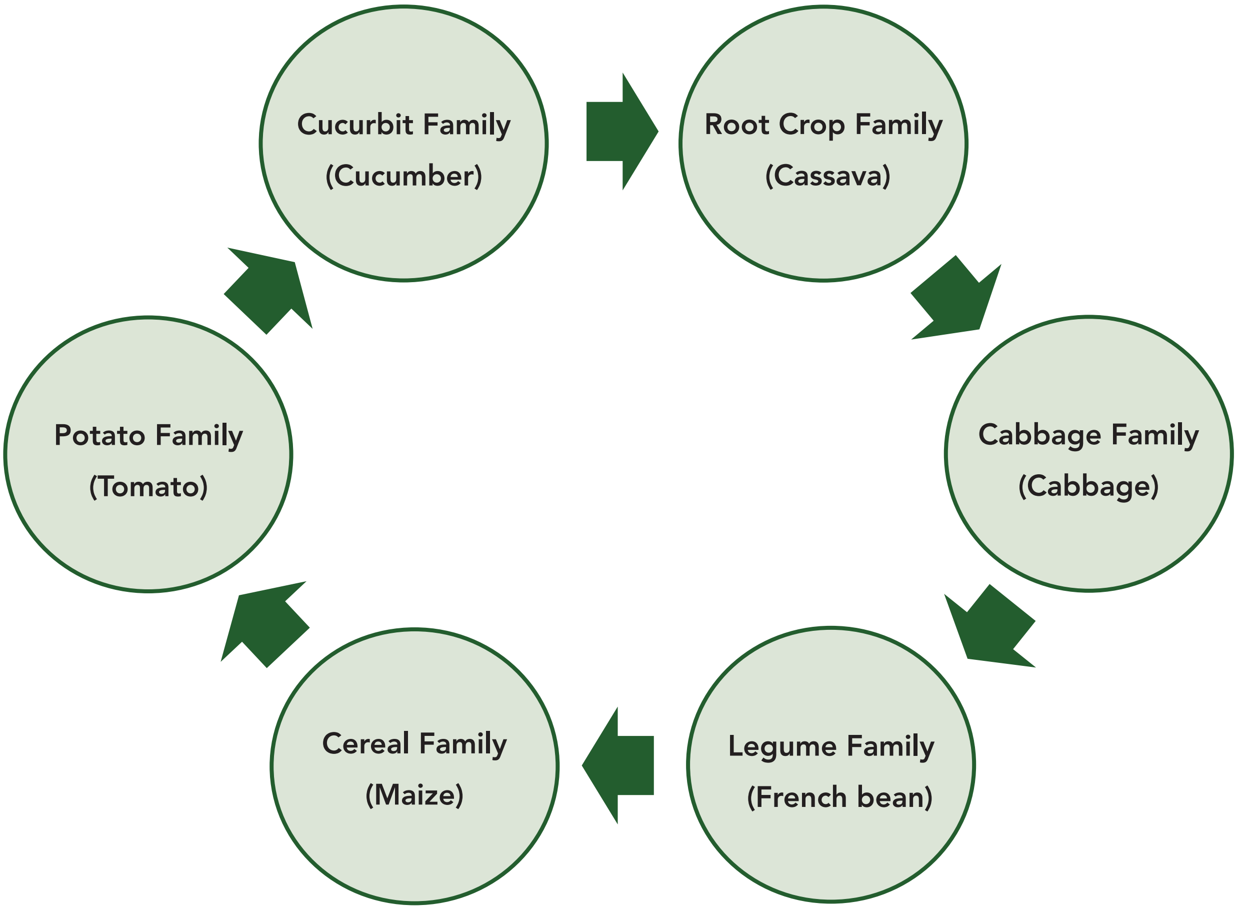
Table 5.1 Common vegetables that belong to the same plant families or groups.

Cucurbit family (Cucurbitaceae)	Cabbage family (Brassicaceae)	Potato family (Solanaceae)	Root crops (not all in the same family)	Cereal family (Poaceae)	Legume family (Fabaceae)	Leafy crops (not all in the same family)
Cucumber	English cabbage	Eggplant	Carrot	Maize	Long bean	Lettuce
Watermelon	Cauliflower	Potato	Taro	Rice	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				

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. Marigolds need to be planted as part of a rotation for nematode control.

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. 5.4).

Fig. 5.4 An example of a crop rotation cycle. *Source: authors.*



EXERCISE 5.3: 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. 5.5).

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 (Fig. 5.6). 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.

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

Source: authors.

Fig. 5.6 Bad practice: diseased cabbages left in the field will infect the next crop to be planted nearby. *Source: authors.*

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 5.2:

- 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'.

Trap cropping is a variation of companion planting. *Bixa* (the lipstick tree)

Table 5.2 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 *Apiaceae* (e.g. carrots) and *Asteraceae* (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

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 FAW. 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 part 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 *(Colletotrichum gloeosporioides).*

5.5 Genetic control

5.5.1 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 result in the preferential selection for rare individuals that carry genetic resistance and they become dominant in the population. A level of tolerance is better. A level of tolerance is better. There is some infection, but not enough to be of concern, but sufficient that there is no pressure on the pathogen population to select new strains. An example is the Samoan and Papua New Guinea lines bred for tolerance (not resistance) 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.

5.6 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 2.3.1 'What is a pest?').

Predators that eat pest species are spiders, scorpions, ladybird beetles, lacewings and hoverfly larvae, predatory thrips and predatory mites (Fig. 5.7). 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[2] 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. Common parasitoids are species of wasps (Fig. 5.8). Parasitoid activities often go on without farmers noticing them, although sometimes the 'mummies' of aphids can be seen on

Fig. 5.7 Syrphids (pale green, slug-like) larvae of hoverflies, and larvae of ladybirds (purple) eating aphids on maize. *Source: authors.*

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

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.

5.7 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.

5.7.1 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 maximise biocontrol in vegetables (see Fact Sheet no. 472 in the Pacific Pests, Pathogens & Weeds app). A summary of the common ones follows:

5.7.1.1 Bt – Bacillus thuringienisis

Bacillus thuringienisis or Bt, is the best example of a commercialised bio-insecticide. Bt produces very specific protein toxins that kills caterpillar pests. Bt is useful for the control of hornworms, some armyworms,

Fig. 5.8 Adult Diadegma wasp, laying eggs in a larva of diamondback moth.

Source: Mike Furlong. University of Queensland.

diamondback moth, and many other caterpillar pests. Usually, it is more effective against young caterpillars than against those near maturity. The common caterpillar strain is *Bt kurtaki*.

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

5.7.1.2 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. Another product, spinetoram, is also from the same bacterium, and closely related to spinosad. It is active against Lepidoptera larvae (caterpillars), thrips, and certain flies, beetles and psyllids.

5.7.1.3 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 neither cases was it particularity effective. In other parts of the world, it is used against swarms of locusts. 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

5.7.1.4 *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 parasitising them. There is also evidence that it produces chemicals that increase the resistance of the host plant to root pathogens.

5.7.1.5 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 of the virus being used in the Pacific region is the use of *Oryctes rhinoceros nudivirus* for the control of *Oryctes*, the rhinoceros beetle — Pacific strain. Unfortunately, there have been reports that the virus is not effective in all places to which *Oryctes* has spread in recent years.

5.7.1.6 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. 5.9 provides a summary of all methods that can be used for management of pest and disease problems.

Fig. 5.9 A summary of all control options for pests, diseases and abiotic factors. *Source: authors.*

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, bats
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 6)

1. home-made
2. commercial.

EXERCISE 5.4: Concept mapping of IPDM

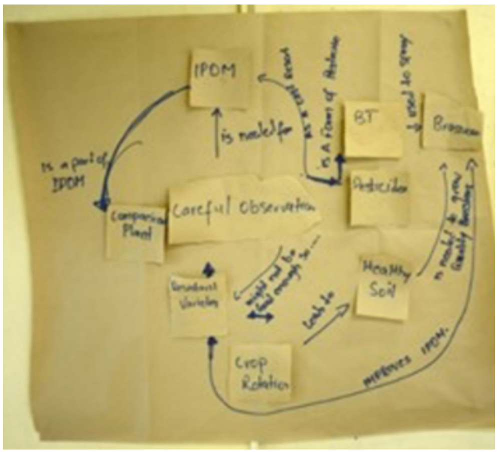
After working through the information on IPDM, your trainees should have a good overview of the concepts. This exercise helps them make the connections between them.

- **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 butchers 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.

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
- brassica plants
- crop rotation
- careful observation.



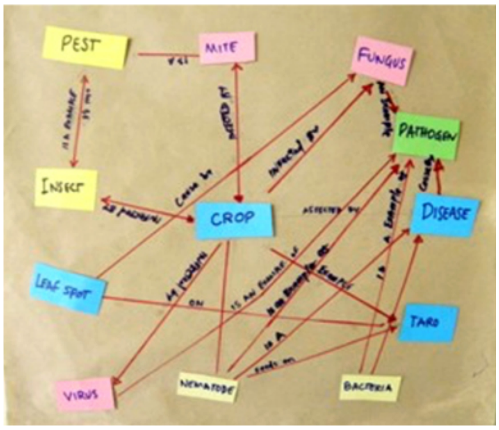


Fig. 5.10 Examples of concept maps from Tonga and Solomon Islands.
Source: authors.

EXERCISE 5.5: 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 (✗)** if they think it will not work. When finished, trainees should discuss their ideas with the rest of the class.

Cause	Example	Crop & part affected	CR	GH	F	GD	CP	V	HPM	HP	TC	BC
Pests (insects & mites)	Tomato fruit borer	Tomato fruit	✓	✓	✗	✗	✗	✗	✗	✓	✓	✓
Pathogen (nematodes)												
Pathogens (fungi, bacteria & 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

CHAPTER 5 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, decide amount of damage acceptable, 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.