Integrated pest management for apples & pears

Australian Apples & Pears

Apple & Pear Australia Ltd.
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Dedication
This manual is dedicated to my son Benjamin. Research and production were therapy during hard times…You taught me that tough guys sometimes wear nappies!

Dr Shane Hetherington
Industry Leader (Temperate Fruit)
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What is IPM?

Integrated pest management (IPM) is a philosophy of pest control founded on the principles of ecology. In practice, it involves using several control tactics based on a knowledge of the crop, pests and associated natural enemies to avoid crop loss and minimize harmful effects on the environment. Implementing IPM requires an understanding not only of insect and mite biology and ecology but also of the entire orchard system. This includes the plants and animals that comprise the orchard community, as well as consideration of contributions from the surrounding habitat. The orchard system also takes into account financial, physical and human aspects of orchard operations. More simply, IPM involves evaluating your pest problems and then applying the most appropriate solution.

IPM requires a more tolerant approach to pest control than traditional insecticide-based programs. Eliminating all insects and mites from the orchard is not the objective of IPM. Natural enemies are to be conserved as much as possible and some damage, especially to foliage, is tolerated. For example, pests that attack the foliage can usually be allowed to build to levels higher than those that attack the fruit.

There are both positive and negative impacts associated with the reduced insecticide use that usually accompanies the adoption of an IPM approach. Benefits of IPM include greater survival of natural enemies, slower development of resistance, less pest resurgence, fewer outbreaks of secondary pests, less negative impact on the environment, and greater worker safety. On the negative side, potential pests that are coincidentally controlled by insecticides used to control key pests may be released from all but natural controls. Natural controls will be effective for some. For others, however, the release from insecticidal control will result in population levels that are sometimes damaging. The transition to more intensive IPM programs in orchards will require knowledge and patience—knowledge of pest and natural enemy biology and patience to allow natural enemy build-up. Selective controls will have to be used for pests that are not maintained at acceptable levels by natural controls.

This information was taken from the Washington State University IPM online manual. I feel it encompasses the mind shift that needs to take place when entering into an IPM system. I feel it summarises quite well the feelings of where APAL see this manual taking growers. I am not sure whether this is too wordy for your liking, it is just a suggestion which I feel embraces the idea of IPM to me.

The complication is that, when choosing this option, you must consider its impact on the entire block.

All orchard blocks are home to a range of insects, mites and micro-organisms that attack and kill the pests that damage crops. These ‘beneficials’ attack pests and limit the amount of damage that they cause. Unfortunately, many beneficials are killed by common orchard pesticides. Broad-spectrum pesticides kill a wide range of organisms regardless of whether they are pests or beneficials. When too many beneficials are killed they can no longer reduce pest numbers, and unexpected outbreaks of pests or diseases occur on crops. Often these outbreaks do not involve the pest for which the spray was originally applied.

In the example (see page v), a broad spectrum pesticide applied for codling moth control reduces populations of this pest to low levels but results in an unexpected outbreak of two-spotted mites late in the season (see Option 1, page v). Because broad-spectrum insecticides kill a wide range of insects it is likely that predators of mites such as ladybird beetles, stethorus, hoverflies and lacewings will be killed in addition to the pest. IPM advocates management which reduces the likelihood of secondary problems such as this developing. An alternative management strategy more likely to fit within IPM would be to use mating disruption within the orchard (see Option 2, page v). Mating disruption specifically affects the pest species, leaving beneficial insect populations to develop normally. In this case, mating disruption will stop codling moth mating and reduce populations while leaving mite predators unaffected. As a consequence season-long control of both codling moth and two-spotted mite is more likely than under pesticide-only management.
Option 1
‘Hard’ pesticides e.g. Azinphos-methyl

Two-spotted mite

Option 2
IPM e.g. Mating disruption

Hover fly

Two-spotted mite

Ladybird beetle and larvae

Stethorus

Lacewing

Controlling Codling moth
Carbaryl is another orchard chemical that is often responsible for secondary outbreaks. In addition to being a broad-spectrum insecticide it is frequently used as a blossom thinner. Carbaryl is very toxic to bees, and carbaryl-contaminated pollen may remain toxic for up to 8 months when stored in the hive. Inappropriate use of carbaryl can severely reduce pollination and fruit set. Carbaryl is also toxic to the predatory mite *Typhlodromus occidentalis*, and its use early in the season for crop regulation and/or pest control can result in outbreaks of pest mites later in the season.

Often, fewer pesticides are used in a well-run IPM program. Although this isn't the overall objective of IPM, it is a natural consequence of considering the entire range of control options available. When an orchardist using IPM chooses a management option, it is because it is the most effective at controlling the pest without any bias toward or against chemical pesticides or other management options. IPM consists of several logical steps:

- **Prevention of pest infestation** is an important component of IPM. Many problems can be avoided by making your orchard an inhospitable place for pests and diseases. Some general strategies for doing this are outlined in this manual in the chapter entitled 'The plan' (see page 2). Specific prevention strategies for each pest are given throughout.
- **Monitoring pest presence and numbers.** Systematically inspecting your orchard to determine if pests are present and whether they are present in sufficient numbers to cause problems.
- **Appropriate action.** Where unacceptable damage is likely, early action is taken to reduce pest numbers, but consideration is given to the off-target impact of this management.
- **Monitoring and measurement of effectiveness.** Continue to monitor pest numbers and damage to your trees and crop after you've taken action. This is the only way that you'll know whether what you have done is effective.
- **Keeping good records.** The key to IPM success is to keep good records. Records should be sufficiently detailed to allow you to honestly evaluate whether you're choosing the best options.
- **Continual improvement.** Reject bad options, try new techniques, innovate and improve.

**Making the decision to use IPM: personal choices**

Australian pome fruit orchardists are understandably conservative. Bad and damaged fruit costs money, and margins are tight. Irrespective of economics, the level of damage that is considered acceptable varies between orchardists. Some want to produce ‘perfect’ fruit and are willing to pay to do this, whereas others will tolerate some damage. IPM involves making personal choices about what you think is acceptable and what level of risk you're willing to accept. There are no firm rules and regulations.

A well-run IPM program involves no reduction in pack-out. However, during the first few seasons inexperience means that mistakes will happen. The information in this manual provides a way of minimising that risk:
- **Start small.** Orchardists with limited experience should never convert an entire enterprise or a large, high-value block during the first seasons of transition. Start with a small, low-value block until you build up confidence.
- **Take it step by step.** Change one aspect of your pest management and evaluate the impact of the change over several seasons. At the end of each season modify the strategy until you're happy with the result. Gradually introduce changes to other management practices.
Some IPM terms defined

IPM comes with its own jargon. The terminology is quite simple and will help you to understand this manual. It’s important that you understand the following four terms and how they are related.

1. Monitoring
Monitoring is a structured system for quantifying the likelihood of pests becoming a problem in the orchard. It involves both:

• carefully monitoring certain trees in the orchard, paying particular attention to trees prone to problems (i.e. hotspots)
• carefully monitoring the weather for conditions likely to favour pests.

2. Sample unit
This is the precise item that is monitored. For example:

• If two-spotted mite is being monitored, the sample unit is a leaf.
• If Phytophthora is being monitored, the sample unit is the crown or lower trunk.
• If black spot is being monitored, the sample units are the air temperature and leaf wetness.

3. Action threshold
This is the point in time when monitoring indicates that damage to the crop will be unacceptable unless the pest is managed. The action threshold can be the time at which:

• a certain number of pests are seen while monitoring
• a certain amount of damage is seen while monitoring
• the weather is so favourable to a pest that it is almost certain that damage will follow.

4. Appropriate action
When the action threshold has been reached appropriate action must be taken. Appropriate action must:

• be effective over a long period
• not cause secondary problems, or at least minimise them.

About this manual

This manual outlines an Australian apple and pear integrated pest management (IPM) strategy. The development of this strategy has involved collaboration between Australian apple and pear growers, researchers and extension specialists. The objective was to create a strategy that gave practical pest management options instead of ‘warm fuzzy’ philosophy.

The information-gathering phase of the strategy involved interviews with apple and pear growers from eight production regions in six States. The objective was to identify the problems that were most important to industry. Orchardists were asked what their major pest and disease problems were. This series of interviews took place before the 2007–08 fruit season, at a time when many of Australia’s orchard regions were in the grip of a long-running drought. The interviewees were asked to take into account the possible reduction in pest problems due to the drought by recalling their problems from up to 10 years ago.

Australian pome fruit is grown in a range of climatic zones; naturally, the pest problems experienced by orchards in our regions are diverse. Writing a national manual was therefore challenging. The manual deals with this diversity by providing information on which regions have had problems with specific pests and diseases over the past 10 years. Where the information provided is region-specific, this is highlighted in the manual.
The manual provides a framework for setting up IPM in your orchard. Many orchardists will want to be personally responsible for monitoring and decision-making. Others may not have the confidence or time to do this. Consultants are available for this work in most regions. In any case, a successful IPM program will save money and improve your orchard and possibly even your personal health.

As we moved about the country asking questions, we realized that some of the issues being raised were quite different from what we expected. Bird damage was an issue that came up at almost all of the meetings. Initially, we wanted to limit the manual to insect pests and diseases, but birds were such an issue that we included a section on bird control.

Many orchardists were interested in the life cycles of their pests and wanted this information included in the manual. This was difficult, because life cycles vary from region to region and are also often complicated. Presenting a full life cycle at times creates confusion. The manual therefore presents simplified life cycles that contain enough information to help with pest control decisions but are not intended to cover all aspects of a pest's growth, development, and reproduction.
Six steps to controlling diseases of apples and pears
## The Plan

### Step 1: Prepare and prevent (page 3).
- Prepare the orchard
- Prepare and calibrate machinery
- Train and thin trees
- Consider netting
- Review your records and buy supplies
- Preparing the packing shed

### Step 2: Have a pest management plan for the season (page 14).
- Choose your blocks
- Know which pests are likely to cause problems
- Keep records

### Step 3: Monitor (page 16).
- Monitor your trees and the weather
- Know how much time it takes to monitor

### Step 4: Take action only if you need to (page 19).
- Know your thresholds
- Check your spray coverage

### Step 5: Evaluate the season (page 20).
- Find out which pests caused trouble
- Determine which types of management worked

### Step 6: Plan for next season (page 21).
- Work out what you have to do
- Make sure all your preventive management strategies are in place
- Plan for each pest and disease that has been a problem recently
- Consider alternatives
- Consider using IPM on more blocks
Step 1: Prepare and prevent

Before anything else, preparation is the key to success.
Alexander Graham Bell

An ounce of prevention is worth a pound of cure.
Benjamin Franklin

Prepare the orchard
Growers need to consider many things when establishing a new block or setting up a block for the upcoming season. Many of the decisions they make will contribute to how hard they have to work and how much money is spent on pest control.

Setting up new blocks

1. Plan ahead (before removing old trees). Start planning before the old orchard is removed. This gives you time to:
   • identify and correct any drainage problems
     and soil nutrition
   • order the correct variety and rootstock
     combinations from nurseries
   • order trellising and irrigation systems
   • plan labour requirements
   • plan cultural practices and equipment
     requirements such as ripping, discing, marking
     out, fertiliser incorporation and planting
   • consider protective netting and OH&S issues
   • consider future opportunities for orchard
     improvement.

The steps to take include:
   • Test soils for pH, soil nutrients, salinity and
     organic matter. These tests identify whether
     you need to add nutrients or improve the
     soil. Subsoils should be tested for acidity and
     sodicity in areas prone to such problems. It is
     essential that these are known before there is
     any soil disturbance, so that correct measures
     can be applied at the right time and in the
     most appropriate way.

   • Check the site for apple replant syndrome, other
     soil borne problems, and nematodes. Bioassay
     tests of soils show the extent of the effect the
     unamended soil will have on the growth of
     young trees. In some soils it may be necessary
     to test for specific soil-borne problems that will
     affect the soil treatments, for example, white
     root rot (*Rosellinia necatrix*) in Queensland,
     Phytophthora and Armillaria. Because
     nematodes can severely affect tree growth, a
     nematode test is highly recommended for light
     soils. Heavy metals (cadmium, arsenic, copper)
     may be an issue in some locations; obtain local
     advice and test if necessary.

   • Identify the lime, gypsum and/or dolomite
     requirements for the site. It is extremely
     important that soil amendments (and
     phosphorous fertilisers) are incorporated into
     the root zone before planting, as they are
     highly mobile in the soil. Surface applications
     take several years to reach the root zone and to
     have a beneficial effect. Do not use dolomite
     in soils with high magnesium levels. Use
     calcium carbonate lime if acidity is an issue.

   • Accurately map the old area (or use an aerial
     photograph). Using a map or photograph allows
     you to accurately determine where problems
     are (e.g. drainage, poor trees, different soil
     types, and prevailing winds). This allows
     time to plan for corrective measures such as
     installing drains or grassed waterways and
     planting windbreaks, or to make adjustments
     in irrigation systems. Accurately mapping old
     tree rows allows you to rearrange row positions
     and minimise the number of trees planted in
     an old tree row.

   • Select and order your varieties and rootstocks.
     Selecting the right variety determines how
     much money you can make. Selecting the
     right rootstock determines the extent to
     which you can minimise production costs and
     maximise packouts and yield – and therefore
     maximise profits. When ordering trees, specify
     the type of trees you want for the training
     system you plan to use, for example whip,
     well-feathered trees (10 to 12 feathers) or
     double leader for Tatura trellis. With effective
     nutritional/soil adjustments and cultural
     practices, dwarfing rootstocks can be used to
     replant old orchards. It is not always necessary
     (or practical) to use vigorous rootstocks.
     Efficient and productive trees are preferred for
     today’s orchard systems. Plan to plant what
     you want, not what you can get.
Budget accurately. Budgeting helps you to plan effectively and make sure that you have everything you need. It also ensures that you don’t get any unpleasant surprises.

Check local advice. All production areas vary in their soil type, microclimate, soil problems and nutritional status. Obtain advice about any local issues you may need to consider.

Consider site rotation and possible cover crops. Preparatory planning may show that it is inappropriate to replant the orchard. A change of crop or a longer-term approach to replanting may be necessary. Orchards are expensive to establish: don’t waste money on a problem site by taking shortcuts.

Obtain the necessary permits for vegetation removal, as well as planning permits and environmental impact statements, if you are removing native vegetation and constructing water storages or erecting protective structures.

2. Remove the old orchard or virgin bush and tree roots. The following steps need to be taken when removing old vegetation:

- **Remove trees when soil conditions enable easy removal of trees and roots.** It is important to remove as many roots as possible. Therefore, avoid dry periods or wet soils (erosion risks) when removing trees. The time and method of removal (bulldozing, front-end loader or stumping) will depend on the soil condition, the slope (safety and erosion), and the presence of permanent fixtures in the orchard.

- **Collect and dispose of as many roots as possible.** Old roots harbour harmful or dangerously high levels of soil organisms that can reduce new tree performance. Decaying roots can be toxic to young trees. Where practicable, remove all root pieces longer than 30 to 40 cm and/or larger than 4 to 5 cm in diameter. Use a disc to cut roots if they cannot be collected economically.

- **Wherever possible, do not burn old trees on the land to be replanted.** Heat generated by burning old trees affects the soil micro-organisms and nutrient availability under the heap. For orchard uniformity it is best to burn the trees away from the planting site. If trees have to be burned on site, several small heaps are better than one large one.

- **Take precautions to avoid erosion problems.** Tree removal can be one of the highest erosion-risk periods on steep slopes. Once the trees have been removed and heaped, use interceptor drains, add temporary contour grades, or roughly plough the block to minimise the speed with which water runs down the block. Establish a cover crop if land is to be left bare for any length of time, particularly in winter.

3. Prepare the site. Steps for preparing the site include:

- **Rip the site to improve soil aeration, drainage, and root removal and to reduce compaction problems.** Rip in late summer when the soil is dry and therefore shatters easily. Rip old orchards to break up hardpans and compacted areas, to improve aeration and root penetration, and to bring old roots to the surface. Remember to locate irrigation lines and controls and underground drainage On steep sites, minimise the erosion risk by leaving the soil in a rough condition until you are ready to further prepare the site. In some situations erosion can be minimised by ripping only the proposed new rows, not the whole area. If you use this technique the new rows need to be marked out early in the process.

- **Roughly cultivate the site and remove any visible roots.** Each preparatory activity unearths old roots. The more roots that are removed (especially large roots), the better.

- **Mark out new rows, minimising planting in old tree rows.** The replanted block will usually have new training systems and different planting densities. Using your orchard plan (see ‘Step 1: Prepare and prevent’ p. 3), accurately mark out the new block. Minimise the number of rows in old row positions.

- **Even-out the site if required (and practicable).** Even-out any rough or shallow areas (especially along the planting row) to develop a uniform block. This is a high erosion risk activity, so take suitable precautions.

- **Apply and incorporate (to a depth of 15 cm or more) any fertiliser, lime gypsum, dolomite or organic matter (identified in step 1).** If problems are identified with subsoil acidity or sodicity, incorporate gypsum into the rip lines. Before final soil preparation, broadcast any fertilisers and soil amendments (e.g. lime, gypsum) and incorporate by cultivation. If significant quantities of trace elements and/or phosphorous are to be added, it is preferable to apply the soil amendments first, cultivate, and then apply the fertiliser separately.
4. **Plant wisely.** Use the following steps to ensure that your planting is well planned:

- **Store nursery trees correctly before planting.** Nursery trees (and especially their root systems) should never be allowed to dry out. Trees should be planted on arrival from the nursery. If this is not practicable, store them by:
  - healing into moist sawdust, sand or well-prepared soil (good drainage is critical).
  - placing them in a draught-free shed, bundled together and covered with moist hessian or tarpaulin. Moisten the cover several times a day. This is suitable only for short-term storage.
  - putting them in cool storage. Place trees upright in a bin with the roots thoroughly covered with sawdust. Moisten tops daily and do not store with fruit. Only fully dormant trees are suitable for longer-term storage using this method.

- **Plant a cover crop.** When rows and mounds are defined, the inter-row area should be cultivated lightly and planted with a cover crop as soon as possible — preferably in autumn to stabilise the soil before winter and provide a firm surface during the winter/spring planting. When choosing a cover crop, pay attention to the pests that are likely to occur in the block, and plant appropriately. For example, Western flower thrips (p. 123) can build to large numbers in an inter-row containing white clover before they move into — and damage — the crop.

- **Plant early (June/July) where possible.** Weather conditions determine when soil can be prepared and therefore when trees can be planted. Early planting reduces stress on young trees and allows the roots to settle and recommence growth before shoot growth. Trees should be planted between June and mid-August.

- **Late planting (September/October) affects first year performance.** In some cases planting after mid-August increases stress on young trees because they have to produce roots and shoots at the same time. Shoot growth is retarded, desiccation may be a problem, and tree losses can increase. However, some orchardists report that late-planted trees can perform as well as those planted early provided that they are well maintained and planted before wet weather.

- **Don’t put fertiliser in the planting hole.** Mono-ammonium phosphate (MAP) is often used as a planting hole amendment in replanted orchards. If it is placed incorrectly, young root systems can be burned and tree performance affected; trees can even die. If fertiliser requirements are correctly determined and the fertiliser is applied as outlined previously, there should be no need to use any fertiliser in the planting holes. Fertiliser containing nitrogen would be better on top, after planting.

- **Plant quality, balanced trees with good root systems.** Ensure that the trees delivered are what you require for the training system. If there is considerable variation, discuss this with the nursery manager and consider regrading. Orchard uniformity is improved if similar-sized and -shaped trees are planted in the same row. If it is difficult to get uniform trees, grade for scion diameter and plant sequentially within the block and prune to the same structure. Good nursery trees should have a complete, evenly distributed root system with plenty of fibrous roots. Australian nursery trees are often large, with many fibrous roots removed. These trees must be looked after to ensure good establishment. A medium-sized tree with good fibrous roots should establish better in the first year than any tree that has had its roots severely pruned. Wherever possible, plant virus-tested trees.

- **Don’t plant diseased, damaged or desiccated trees.** Only healthy trees that are free of obvious diseases, including crown gall, should be planted. Damaged trees or roots should be graded out and treated/pruned. Avoid using desiccated trees. These trees can be rehydrated by placing in a running stream or bath of water for no more than 24 hours.
Planting depth and graft unions. Planting depth is influenced by soil type, budding height and rootstock. Shallow soils should be mounded to give a satisfactory soil depth. Some dwarfing apple rootstocks are prone to burr knotting (especially M26), so graft unions should be as close to the soil as possible but high enough to minimise scion rooting (5 to 10 cm). Ensure that, irrespective of rootstock, all graft unions are at a consistent height above the soil. Using a consistent height increases the uniformity of tree growth in the orchard. Hand planting provides more consistency in planting depth than machine planting. Up to 2 weeks after planting, trees planted too low should be carefully raised.

Ensure trees are adequately watered-in at planting (by hand, rain or irrigation). It is important to exclude air pockets from around the roots of newly planted trees. This improves soil–root contact, reducing moisture stress on the tree, and stimulates quicker growth. In dry conditions or soils, all trees should be watered-in at planting.

Minimise all stress to trees. Attention to detail and careful handling at all stages of planting improve the chances of successful tree establishment. During planting, ensure trees are well protected from direct sunlight and wind, as desiccation at this stage will damage the tree. Don’t plant into wet soils, as growth will be retarded.

Install an irrigation system. Once planted, it is important not to allow the rapidly growing new trees to experience any moisture stress. Dwarfing apple rootstocks (especially M9, Ottawa 3 and M26) have small, fine root systems and are susceptible to moisture stress during establishment. It is therefore critical to have an irrigation system installed and operational at planting.

Install support systems, especially for dwarfing rootstocks. Wind plays havoc with newly planted trees. Movement of tree tops will rock and break new roots. Provide support for trees soon after planting to minimise root damage.

5. Care for your trees. The following steps will help ensure that your trees remain healthy:

Use tender loving care. The old strategy of treating young trees hard is totally inappropriate for new high density orchards. To ensure yields and quick returns on capital invested, do everything to maximise growth and minimise problems. The first two years of a newly planted orchard are the most critical. Poor establishment or tree performance in these years can negate the benefits of high-density plantings and substantially reduce the net profit of the orchard for its entire life.

Don’t over fertilise – use little and often. Proper application of fertiliser pre-planting negates the need for large applications of fertiliser to young trees. Young trees primarily require nitrogen for growth. This should be applied (to soil or fertigated) in small frequent doses during the first two seasons. Large doses of nitrogen fertiliser will encourage excessive soft foliage growth and encourage aphids and other sap-feeding pests. Once trees begin cropping the soil/trees should be tested and fertiliser applications adjusted according to test results.

Avoid moisture stress – irrigate carefully (light and frequent). Problems with moisture stress cannot be overemphasised. Small trees have small root systems, so light frequent irrigations are required to avoid excessive soil wetting and drying. Investing in a moisture probe is advisable.

Keep young trees weed free. Weeds compete for moisture and nutrients and must be removed. Be careful with herbicide applications.

Use tree guards where appropriate. Tree guards reduce damage caused by rabbits, hares and wallabies, and they protect young green stems from herbicide. Don’t bury tree guards, as this traps moisture around the tree stem and induces problems with Phytophthora. Pay careful attention to the type of tree guard used with M26 rootstock to avoid burr knotting.

Protect from the wind – support adequately. See previous comments about tree support systems.

Keep trees pest and disease free. Pay particular attention to pests that damage shoot development, such as light brown apple moth. Careful management of apple or pear scab on young trees is also very important.
• **Mulches may be used for moisture regulation and weed control.** Avoid disease; don’t place mulch too close to tree trunks. Consider growing mulch in the inter-row and using a mower that throws it on to the tree line.

• **Grow the tree, then crop it** — avoid the temptation to overcrop early. The quickest way to slow down the growth of a tree (particularly on dwarfing rootstocks) is to crop it. A careful balance between crop load and yield is necessary to ensure adequate shoot growth in the first 2 or 3 years. Never overcrop a tree of any age.

• **Hand-remove flowers in the first season.** For most training systems it is highly advisable to hand-remove any fruit that sets in the first season after planting, as it can significantly affect tree canopy development. Avoid thinning chemicals as they suppress tree growth.

• **Don’t neglect young trees.** Attention to detail helps to quickly establish (or re-establish) an orchard. Neglect affects the viability of the business. Measure the growth of representative trees across the block to pinpoint necessary management actions.

### Preparing established blocks for a new season

**Pest carryover.** Pests need to survive through winter without fruit, leaves or succulent shoots for nutrition. Some migrate, but most pests never leave the orchard or its nearby surrounds. Knowing where these pests are, and destroying them, will reduce pest problems in the upcoming season.

Remove all fallen and hanging fruit and destroy it. Apply urea and/or mulch fallen leaves to hasten their breakdown.

Look for disease cankers and insect damage on limbs. This damage is easier to see and remove during dormancy.

**Training, pruning, thinning and fertilisers.** Training systems that provide open canopies result in greater air flow and shorter drying times. Consequently, disease incidence tends to be lower. Open canopies allow light penetration for strong spur development and increased colour development. Increased light discourages woolly aphid (p. 134), a particularly difficult pest to control.

Training systems that minimise pruning and, subsequently, pruning cuts (disease entry points) result in fewer problems from diseases such as silver leaf.

Although benefits can be gained from opening up the canopy through pruning and training, orchardists need to be aware of the problems that may arise from sunburn in warmer regions. Sunburn can result in bark cracking and splitting and predispose the tree to fungal infections.

**Pruning should:**

• remove water shoots

• remove diseased tissue

• open the canopy to allow air movement and better spray distribution and increase light penetration.

**General maintenance.** Service all tractors and sprayers well before they’re needed. For diseases such as black spot and powdery mildew you will need sufficient well-maintained equipment to spray the entire orchard within 3 or 4 days after rain. If your equipment is broken down and sitting in the shed you may be setting yourself up for a pest outbreak.

**Prepare and calibrate machinery**

Sprayers that are not properly prepared and calibrated are not likely to apply the correct volume of pesticides in the right location. If too little pesticide is applied, inadequate pest control is likely. If too much is applied, money is wasted and there is an increased likelihood of off-target damage (e.g. to beneficial insects) occurring.

The following extract from the I&I NSW Spray Sense information on pesticide issues (see ‘More information: Six steps to controlling diseases of apples and pears’ p. 200) will prove useful for preparing spray equipment for the coming season.

**Hand-operated sprayers**

Hand-operated sprayers, such as knapsack and mistblowers, which are designed to be carried and operated manually by one person, are widely used in agriculture. They are:

• suitable for treating small areas

• cheaper than tractor-mounted sprayers

• effective in restricted areas (e.g. slopes and close plantings).
Types of hand-operated sprayers. There are two main types of hand-operated sprayers:

- **Knapsack sprayers.** These sprayers have a tank capacity of up to 20 L capacity. They are usually carried on the operator’s back and have a pressurising system and a hand lance with a pressure gauge and one or more nozzles. The lance or wand usually has a simple on-off valve.

Three systems of pressurising the liquid are available:

1. **Lever-operated sprayers** use a regular pumping action to operate a piston or diaphragm pump within or near the spray tank to maintain operating pressure.

2. **Compression sprayers** are filled to two-thirds capacity and the remaining air space is pressurised by a piston action air pump or gas cylinder. This constant pressure forces the spray out of the tank by replacing it with air. Compression sprayers should be equipped with a pressure gauge and a relief valve.

3. **Motorised knapsack sprayers** use a small two-stroke engine instead of manual pumping to force the liquid to the nozzle. The pressure is adjustable by either changing the rpm of the engine (piston pump) or with a pressure regulating valve (diaphragm pump).

- **Mist blowers.** Mist blowers have a fan and a flexible discharge hose. The spray mixture is fed in to the air stream by gravity and fine droplets are formed by the shearing action of the high-velocity air stream (90 to 100 m/s). Mist blowers are ideal for applying pesticides in dense crops.

**Nozzles.** The nozzles used in knapsack sprayers are the same as those used on boomsprayers. Hollow-cone nozzles are used for insecticides and fungicides and flat-fan nozzles are used for herbicides.

Nozzles and nozzle tips are available in a wide range of materials. Ceramic nozzles are the most resistant to wear, followed by plastic and stainless steel. Brass nozzles wear quickly.

**Pressure.** Most hand-operated sprayers operate at low to moderate pressures (300 to 600 kPa). Droplet size and flow rates can be regulated by adjusting the pressure. The higher pressure, the smaller the droplets. The lower the pressure, the larger the droplets. Once the pressure and droplet size are determined it is important to maintain the same pressure. Pressure gauges on the hand lance make it easy to adjust and control the pressure.

With mist blowers, pressure is not important. However, air velocity and volume are critical because they decline markedly at low speeds, affecting droplet size and coverage. Spray at maximum rpm to maintain air velocity and air volume.

**Calibration.** All hand-operated sprayers need to be calibrated at the start of the season and kept in good operating condition. This will ensure that the correct rate of chemical is applied to the target plant.

Follow these steps to calibrate a knapsack sprayer:

1. Measure the spray width of the nozzle(s) on a dry surface (in metres).
2. Spray a test area at the intended pressure and walking pace. Record the distance (in metres) covered in 1 minute.
3. Measure the nozzle output in litres over 1 minute in a measuring jug (L/min).

The spray volume can be calculated by the following formula:

\[
\text{Application rate (L/ha)} = \frac{\text{Nozzle output (L/min) × 10 000}}{\text{Spray width (m) × walking speed (m/min)}}
\]
For example:

Nozzle output in 1 minute = 5 L
Spray width = 1 m
Walking speed = 100 m/min

Application rate (L/ha) = \( \frac{5 \times 10000}{1 \times 100} \)

= \( \frac{50000}{100} \) = 500 L/ha

Mist blowers can be calibrated by the following method:

1. Fill the tank with water up to the defined mark.
2. Spray over a measured distance of 100 m.
3. Measure the volume of water (in litres) required to top up the tank to its previous mark.
4. Multiply the measured water (L) from step 3 by 100 to obtain the application rate L/ha.

How much to put in a tank. The following formula can be used to determine the amount of product needed for each tank.

\[
\text{Product / tank (L or kg)} = \frac{\text{Recommended rate (L/ha)} \times \text{tank size (L)}}{\text{Application rate (L/ha)}}
\]

For example:

Recommended product dosage: 5 L / ha
Application rate: 500 L / ha
Tank size: 20 L

\[
\text{Product / tank (L or kg)} = \frac{5 \times 20}{500} = \frac{100}{500} = 0.2 \text{ L or 200 mL}
\]

In this example, 200 mL of the product is added to a 20-L knapsack sprayer to give the recommended rate of 5 L/ha.

**Airblast sprayers**

Airblast sprayers are designed to apply low to medium volumes of spray using small droplets between 30 and 350 \( \mu \text{m} \) in size. The droplets of the water and chemical are carried to the target plant in an air stream generated by the fan. The airblast sprayer displaces the air in the canopy of the target plant with the spray-laden air from the machine.

Most airblast sprayers have at least two fan speeds. Normally, the lower fan speed is used on smaller, less dense trees. As plant size and density increase, more air is needed, so the higher fan speed is used. Airblast sprayers can generate their own wind, so spraying can be undertaken under calm conditions. However, a slight breeze of 5 to 8 km/h may improve spray penetration.

The air stream that carries the droplets plays no part in their production. The size of the droplets is controlled by the nozzles used on the machine and the operating pressure.

Other types of sprayers are also being used more frequently in apple and pear orchards. Tower or directed sprayers can offer benefits in terms of cost effectiveness, resistance and environmental issues.

**Nozzles.** Nozzles are the most important component of any spray machine. The type of nozzle commonly used on airblast sprayers is a hollow cone that produces small droplets. The nozzles are usually arranged so that nozzles producing larger droplets are at the top and those producing smaller droplets are at the bottom. This setup is designed to apply two-thirds of the spray volume to the top third of the target plant.

In most cases nozzle size and placement are specified by the manufacturer.
Position the nozzles on your sprayer so that spray droplets cover the target plant from top to bottom. Nozzles directed into the air and on to the ground waste spray. Turn off nozzles that are not needed. Nozzles wear out quickly, so check them at the beginning of the season and continue to check them regularly. Usually they need replacing at least once a year.

Calibration. The aim of calibration is to ensure that a specified rate of chemical is applied to the target plant. To do this you need to measure the total spray output of the machine and the travel speed, and then calculate the application rate.

- Calculating total sprayer output ($L/min$). The aim here is to measure the total liquid sprayed from your machine in one minute. First, disengage the gearbox and set the pressure at the correct level for spraying and the PTO at $540$ rpm. Leave on all the nozzles used for spraying, but turn the fan off.

1. Fill the spray tank with clean water.
2. Place a measuring jug under one nozzle. If you do not want to get wet, attach a piece of plastic hose to the nozzle and place the other end in the jug.
3. Run the sprayer for 1 minute at the correct pressure with all the nozzles operating.
4. Measure how much water is in the jug. Compare this with the output specified by the manufacturer, using the correct pressure. Nozzle output should not vary by more than $10\%$. If it does, the nozzle is worn and needs to be replaced.
5. Repeat steps 2 to 4 for all nozzles.
6. Add all the jug measurements to find the total sprayer output in litres per minute.

Nozzle set up commonly recommended by manufacturers to most efficiently deliver pesticides. The figures in yellow circles are the percentage of volume delivered by that particular nozzle. Nozzles wear, and maintaining sprayer efficiency requires orchardists to check nozzle output each season and replace nozzles that don't deliver the required volume. © I&I NSW
**Six steps to controlling diseases of apples and pears**

**Calculating travel speed (km/h).** The normal speed for spraying is between 4 and 8 km/h. The slower you travel, the higher the application rate. A change in ground speed of 10% results in a 10% change in application rate. Adjust your travel speed so that the target plant is covered with spray but the spray is not running off the leaves. If you have large, dense trees you can reduce tractor speed to improve spray coverage and penetration.

1. Measure out a distance of 100 m on the ground and mark the start and finish positions with pegs.
2. Select the correct gear for spraying and increase the engine rpm to give 540 rpm at the PTO.
3. Measure how many seconds it takes to travel 100 m with the sprayer attached and half full.
4. Calculate your travel speed by inserting the time in seconds into the following formula:

   \[
   \text{Travel speed (km/h)} = \frac{100 \text{ (m)} \times 3.6}{\text{Time (seconds)}}
   \]

**Calculating spray application rate (L/ha).** First, measure your row width. If you are spraying both sides when travelling down every row, the row width is the distance between the two rows of trees. If you are spraying only one side when travelling down every row, the row width is the distance from the centre of the row to the tree line.

Calculate the application rate by using the following formula:

\[
\text{Application rate (L/ha)} = \frac{600 \times \text{total sprayer output (L/min)}}{\text{Row width (m)} \times \text{travel speed (km/h)}}
\]

Example: If your total sprayer output is 40 L/min, your speed is 5 km/h, and the row spacing is 5 m:

\[
\text{Application rate (L/ha)} = \frac{600 \times 40}{5 \times 5} = \frac{24000}{25} = 960 \text{ L/ha}
\]

**Benefits of calibration.** By calibrating your machine you find out your spray application rate. This information is necessary whenever you use chemicals that have application rates specified in amounts per hectare. It will also allow you to work out how many spray tanks are needed for a particular job.

The spray application rate varies for different crops and different plant spacings, and with the age, height and density of crops. Therefore, you need to calibrate for each crop or block. In the long term it will save you time and money and result in a more effective and efficient spraying job.

**Train and thin trees**

One of the objectives of tree training should be to create an open canopy. More and more Australian orchards are being grown at high density. One of the few disadvantages of these growing systems is that they reduce air flow in the orchard and make it more difficult to achieve good spray penetration. Both of these factors make pest control more difficult, and good tree training has become even more critical. Many pests become established in the tops of trees because inadequate pruning and poor calibration of spray equipment have led to poor spray penetration high in the tree. It is important to check spray coverage regularly (see ‘Check your spray coverage’ p. 19).

Good advice on tree training can be found in a number of manuals or from your local commercial supplier, consultant or State government agronomist. In the context of pest and disease control it is important to keep the following in mind:

- Always make clean cuts with sharp, well-maintained pruning equipment.
- Consider painting large wounds to stop pests entering.
- Always prune trees with pests last.
- Carefully remove pest-infested prunings from the orchard and burn them.
- Consider the time of the year and the weather and what influence pruning will have on pest spread. For example, pruning in the middle of winter is not advisable in orchards with silver leaf infections.

Thorough fruit thinning will also help to reduce pest problems. Clusters of fruit are prone to pest infestation because:

- they provide sheltered feeding and nesting sites for insect pests
- humidity between fruit is higher, making clusters more prone to disease infection
- pesticides don’t reach the space between fruit
- fruit-to-fruit contact leads to skin damage, making it easier for pests to infest and spread between fruit. Damage starts on one fruit and soon the entire cluster is worthless.
Netting has a number of implications for pest management:

- Higher humidity under nets may increase the likelihood of disease problems.
- When using airblast spraying equipment a light breeze helps pesticide penetration. The still air under netting will influence spray coverage.

In practice, neither of these factors seems to cause significant problems, and disease control under nets is usually no more difficult than in adjacent uncovered blocks. However, care must be taken when spraying pesticides under nets before flowering. Dormant sprays of copper sometimes drift on to nets and dehydrate to form a residue. If the next rain is during blossom, or if blossom sprays wet the net, the copper can go back into solution, drip down, and damage the flowers. Similarly, care needs to be taken in the weeks leading up to harvest. Sprays applied to comply with withholding periods can dry on overhead netting, fall later and cause residue problems.

Temporary netting can also provide protection against birds and is much less expensive.
Nets draped over T-trellises are compatible with the trellising systems being promoted by Future Orchards 2012; these new systems are essential for support of dwarfing varieties. Because they involve establishment of some infrastructure they can be expanded as finances allow and developed into more conventional netting systems. Experience has shown that the systems allow good colour development and spray penetration and there is good air movement in the canopy of the trees.

Other temporary netting systems fully enclose the trees. Users of these systems say that spray penetration is adequate, as is colour development. Tree growth can be affected. If the tree has low vigour it will develop rounded, misshapen branches in the shape of the cover. Some growers believe that although this looks ugly it is actually beneficial in that the trees have even less vigour with the netting and therefore are easily and quickly pruned. Trees with high vigour are hardly affected and will maintain shape.

Both systems allow some protection from hail damage. Less hail damage occurs on the T-trellis system. With the enclosed netting system there will be hail damage to those fruit directly exposed to the outside of the netting. This would equate to less than 5% of fruit.

The main disadvantage of both systems is the labour required to lay out and retract netting. Growers using these systems consider this extra labour expenditure to be worthwhile.

**Review your records and buy supplies**

Reviewing your records from previous seasons will allow you to anticipate and prepare for the arrival of pests. Using records, you should be able to approximately judge the time at which pests will arrive. As seasons pass, this accumulated knowledge can be used to refine monitoring and pest management. Monitoring can be intensified when pests are likely to arrive and be less intensive when they are unlikely to be present. This will save time and money.

Well kept records will also tell you which management options have worked in the past allowing you to prepare early. For example, if the management option is pesticide application you will be able to make sure that the most appropriate pesticide is available at your local supplier when it’s likely to be needed.

**Prepare the packing shed**

Good packing shed hygiene is essential. Poor hygiene can lead to serious problems with postharvest diseases such as *Penicillium* and *Mucor*. Before the start of the season:

- *Clean and sanitize bins using a high pressure water cleaner using either hot (70°C+) or an approved sanitizer (e.g. quaternary ammonium or hypochlorite). Alternatively exposing bins to intense sunlight can be used to sanitise bins provided bins are turned to expose all surfaces.*

*Fully enclosed temporary netting* Michael Cunial, © I&I NSW
• **Check bins for damage.** Repair any loose boards or rough surfaces to make sure that they don’t lead to cuts and other damage to the crop, that may provide entry for postharvest diseases.

• **Clean grading equipment and cold rooms.** Non-corrosive food grade sanitizers, steam or pressurised hot water can be used to clean grading lines. Coldstores should also be thoroughly cleaned before use.

At the start of each season, drenching systems for DPA, fungicide and calcium application should be fully tested. If using DPA for scald control, prepare a chart showing the amounts of DPA and fungicide required for each variety. Put in a place an easy system to measure top-up volumes to make sure that the DPA concentration is correct. Further information on DPA application can be found in ‘Guidelines for postharvest drenching of apples and pears’ at www.apal.org.au/information-fact-sheets.cfm?id=3213&t=/post-harvest-drenching-of-apples-and-pears/

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### Step 2: Have a pest management plan for the season

*When a man does not know what harbor he is making for, no wind is the right wind.*

Lucius Annaeus Seneca, Roman statesman

A pest management plan should be started at the beginning of each season. The plan is not set in stone. As the season progresses unexpected problems will occur and the pest management plan will need to be modified.

The plan is underpinned by a comprehensive and well-kept set of records from the current and previous seasons.

#### Choose your blocks

Start small! No-one likes to take risks. IPM usually involves a reduction in the number of pesticide sprays applied. A well-run IPM system will not result in more pests, but until you have gained some experience there is a risk. By reducing the number of pesticide sprays you run the risk of more pests and greater financial loss. Therefore, it is a good idea to introduce IPM gradually.

In the first season, use IPM on a low-value block. It would be best if this block is relatively large, but if a large block isn’t available a small block will do.

Most IPM strategies work best on larger blocks or even across whole orchards and even regions. Using a small block to start means that you don’t get the full benefit of IPM. As you gain confidence and IPM spreads across the whole orchard, pest and disease control become easier.

#### Know which pests are likely to cause problems

The most effective way to control pests is to anticipate which ones are likely to cause a problem and be ready to control them. Make a list of the pests that have been in your orchard over the last four seasons. As a general rule, if a pest hasn’t been seen for four seasons it shouldn’t be necessary to monitor for it. Pests that have caused financial losses should be given priority. If pests have been present but haven’t caused losses, then include them on the list, but it may not be necessary to do anything about them in the coming season.

Pest lists will vary from orchard to orchard and probably from block to block; in some cases they will be linked to climatic conditions.

Find out all you can about the pests and diseases that attack your orchard:

- When can you expect them to occur?
- What do they look like (particularly early, before they’ve had a chance to do serious damage)?
- When is the most effective time to control them?

The pest fact sheets in the following chapters provide this information for most common pests of the Australian apple and pear industries.

You should also become familiar with the beneficial organisms that are likely to become more common in your orchard as you convert more and more blocks to IPM.
**Keep records**

*Write it down. Written goals have a way of transforming wishes into wants; can’ts into cans; dreams into plans; and plans into reality. Don’t just think it — ink it!*

Source Unknown

**Compulsory records**

All Australian States have legislation that requires anyone using pesticides for commercial or occupational purposes – such as on your produce or farm or in your business – to keep a record of each pesticide application. Many quality assurance schemes also specify pest management information that must be recorded.

Typically, these pesticide records need to made within 24 hours of application, must be written in English, and must be kept for 3 years. A record must be made when:

- spraying crops, plants or produce
- spraying fallow land
- dipping produce
- baiting for pests.

The information recorded for each application includes:

- *details of who applied the pesticide*: their name, address and contact phone number. If a contractor or employee applied the pesticide, they need to also record the contact details of the employer.
- *the owner of the land sprayed*. This may be the owner, manager or lessee. Record their name, address and contact phone number.
- *date and time of application*. Record the date and both the start and finishing time of the application.
- *product details*. You need to record the full product name of the pesticide used.
- *crop or area treated*. Record the crop type or situation where the pesticide was used.
- *application equipment*. Specify the type of equipment used (e.g. backpack, mister or airblast sprayer).
- *the amount of product used*. You need to record how much pesticide was used (rate) and what area was covered. You can do this by specifying the total concentrate or the total spray mix and the area covered (in m² or ha).
- *where the pesticide was applied*. You need to record the property address and the name or number of the block sprayed.
- *the order of blocks sprayed*. If more than one block was treated at the same time you need to record the order in which the blocks were sprayed.

- *weather information*. You need to record wind speed and directions as well as any significant weather changes during applications. You can estimate the wind speed by using the Beaufort Wind Strength Scale. A portable weather meter (which can measure wind speed, temperature and humidity) will give more accurate readings.

An example of one type of pesticide record sheet is provided in Appendix 1: Pesticide application record sheet (p. 168). It includes all categories that you must record when applying agricultural pesticides.

These compulsory records are *not* adequate to manage pests using IPM. Recording and updating the following information will give you much more information for use in developing management strategies for pests and diseases.

**Block plans**

Numbering tree rows is time consuming to start with, but it’s helpful over a number of years in terms of time saved in big blocks looking for particular trees (especially in trellised orchards). Block plans should be written in sufficient detail that individual trees, service points (e.g. tank filling points, chemical stores and dams) and other points of interest can be found quickly by someone who has no prior knowledge of the property.

Block plans are extremely useful for many things, but in the context of pest management they enable outbreaks to be recorded and monitored over time much more easily. For example, it is easier to find a small infestation of mites knowing the exact location of the tree rather than having only a rough idea of where it is in a block.

The indexing system (block and row names, numbers or letters) is at the discretion of individual growers, but it must be documented as a written record and kept in the shed or office.

Hand-held global positioning systems (GPS) can be used to determine orchard dimensions very accurately and are extremely useful in calculating pesticide application rates.

**Monitoring records**

Most growers keep a record of the pests that have affected their orchards during a season. Often this is kept in conjunction with compulsory spray records. A separate book should be devoted to the information, which will be collected as a result of systematic monitoring (see ‘Step 3: Monitor’ p. 16).
The information in this book should include:

- **Pest name.** For most orchard pests the common name (e.g. black spot, codling moth) will suffice. For other, less familiar, pests, accurate identification will be needed. Keep in mind that in some cases pests that appear similar are controlled in very different ways. Most State departments of agriculture provide pest identification services (see ‘Appendix 2: Useful contacts’ p. 169). Fees for this service usually apply.

- **Date and location first noticed.** This can be compared with records from previous and future seasons to determine whether pests are arriving earlier or later. In some cases pests that arrive very late may not have time to build their numbers to damaging levels and won’t require management.

- **Location.** Record where the pest was first seen by using a reference from the block plan. Nothing is more frustrating than searching for a pest outbreak in a poorly mapped block. This information can also be used in your end-of-season review to decide whether monitoring trees should be changed. If pest outbreaks persistently occur in one area of the block, perhaps something can be done to improve management there.

- **Damage.** A record should be kept of the type and severity of damage. By combining this information with the record of when the pest arrived, growers should get an indication of how serious the damage is likely to be. This estimation can be even more accurate if you have a knowledge of the pest’s life cycle and a weather forecast.

- **Beneficials.** A record of beneficial organisms will also help to decide whether management is needed in the current season. If numbers of beneficial organisms are high it may not be necessary to apply management, even if pests are present.

**Management records**

Fruit growing is a business. When making decisions on pest management it’s important to have a complete set of financial records from previous seasons. Balance the financial inputs associated with pest management against the economic benefits. For example, were the costs of a particular pesticide (and the machinery running costs and labour needed to apply it) justified by the increase in money received for that crop?

**Weather records**

Many pests respond to the weather in a predictable way. It’s particularly useful to record rainfall, temperature and humidity. Over a series of seasons an accurate picture of what pests are likely to become problems following a certain type of weather will become clear. This allows earlier, preventive management to be done before problems become serious.

**Rejected-fruit records**

Often problems – particularly diseases – don’t become apparent until after harvest. Infections that occur in the orchard may not show up until fruit is harvested. Keep a record of the quantities of fruit rejected or downgraded in the shed, in storage or on the grading/packing line, together with the reasons for rejection.

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**Step 3: Monitor**

**Monitor your trees and the weather**

The type of monitoring done will be determined by the types of pests that are likely to cause problems. For some pests, careful observation and detection can allow early, effective action to be taken. Systematic visual monitoring of the orchard block can save money and time later in the season.

In other cases even detection of the very earliest stages of the pest are too late to prevent significant damage. However, monitoring the weather that allows the pest to develop may give forewarning of its arrival.
**Visual monitoring**

In IPM a ‘block’ is a group of trees that are fairly uniform in terms of physical characteristics, variety and age. It is an area that is managed as a unit. This includes pest and disease management (e.g. spraying).

Most orchardists don’t have the time to monitor every block in the entire orchard. Instead, indicator blocks can be used. Choose indicator blocks with care. The blocks chosen for monitoring should be those with a history of pest problems.

Within the indicator blocks, monitor the same trees during the entire season. Mark these trees with flagging tape or by painting their butts. Because trees within blocks are numbered according to the block plan you will be able to keep an accurate record of where in the block problems are occurring.

Choose trees:
- that have been pest ‘hotspots’ in past seasons
- in a pattern that makes you visit all parts of the block during monitoring. Even though the trees between the monitored trees aren’t formally part of the IPM system, watch out for unusual pest activity as you walk through each time.

**Step 1.** Select trees to be monitored in the orchard block. Concentrate on trees which have had pest or disease problems in the past.

**Step 2.** Mark the trees clearly with flagging tape or bright acrylic paint. Randomly select and mark flowers, shoots or fruits to monitor on each of the chosen trees.

**Step 3.** Every 7–14 days during the fruit development season, carefully monitor the marked flowers, shoots and fruit for early signs of pests. Record any pests seen.

Surprisingly little equipment is needed visually inspect the indicator trees. Close examination of pests can generally be done with a hand lens. Professional consultants will need more equipment, including a binocular microscope for counting and identification of mites and thrips.

The table below gives an indication of the number of trees to monitor in orchard blocks of various sizes.

**Determining how many trees to monitor in your orchard blocks**

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Number of trees sampled</th>
<th>Time taken (minutes) to check block*</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>10</td>
<td>20–30</td>
</tr>
<tr>
<td>1–3</td>
<td>15</td>
<td>30–45</td>
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<td>3–4</td>
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<td>4–6</td>
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<tr>
<td>&gt;6</td>
<td>30</td>
<td>60–90</td>
</tr>
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</table>

* Time taken for an experienced operator; allow more time when you first start.
Monitoring the weather

Some pests quickly become damaging after weather that favours their development. Often, by the time these pests are seen, serious damage has been done to the crop. Fortunately these pests tend to respond to weather in a predictable way.

By carefully monitoring the weather, it is possible to apply management before these pests become a problem. Temperatures can be monitored by using a simple thermometer, but more information can be gained by using a maximum–minimum thermometer (these are available at most rural suppliers). It is important that thermometers are mounted in the orchard but not in direct sunlight.

Using a data-logger will give you better weather information. Small, relatively inexpensive units are available from a number of Australian suppliers. It is useful to buy loggers that measure temperature, humidity, rainfall and leaf wetness.

The ways in which a number of pests respond to weather have been studied and developed into mathematical models. These models have been programmed into predictive forecasting units that can be placed in the orchard and downloaded regularly to help with pest-management decisions.

Know how much time it takes to monitor

Monitoring takes time. Allow sufficient time to do the job properly. Monitoring should never be deferred because of other commitments. When IPM fails it is almost always because monitoring loses priority at peak times. Be realistic – if you don't have time to do the job properly, hire a consultant or scout.

For a beginner, as a rough guide, the time needed will be:

- 15 to 20 minutes per hectare every 7 to 14 days at peak times

It will take several months for an inexperienced person to monitor confidently and accurately.

For an experienced person, the time needed will be:

- 10 to 15 minutes per hectare every 7 to 14 days at peak times.

If you are using a consultant to monitor your orchard and you don't think IPM is working, make sure they are spending at least this recommended length of time in your orchard.
**Step 4: Take action only if you need to**

*You must take action now that will move you towards your goals. Develop a sense of urgency in your life.*

Les Brown

**Know your thresholds**

An action threshold is the point in time at which monitoring indicates that the financial loss caused by a pest is unacceptable. At this point something must be done to control the pest. If a pest isn’t costing you money or causing other problems, why waste time, money and effort controlling it?

But how do orchardists know when pest damage has reached this point?

- Very little research has been done on the relationship between damage and economic loss.
- The level of acceptable damage will vary from orchardist to orchardist and from market to market.
- The level of acceptable damage will vary from year to year, depending on the market.
- For some pests it’s too late by the time you see the problem.

In some cases threshold damage levels have been published, and they have been included in this manual in each pest section. They should be regarded as a guide only. Orchardists are encouraged to try them and then modify them to suit their enterprises. Review whether they worked after two or three seasons and then revise them up or down.

Thresholds are important tools for avoiding either pest damage or unnecessary sprays, but in most cases orchardists will need to decide upon reasonable thresholds themselves. The key to deciding on a reasonable action threshold is to keep good records:

- What pests have been problems in the block over the last 2 to 5 years?
- How much damage have they done?
- What control measures were used and how much did they cost?
- Did the control measures work?

**Check your spray coverage**

There are many reasons why a pesticide application can fail to control a pest. Although it’s tempting to look for complex reasons, often the solution is simply that the rig wasn’t set up to provide good coverage. This is particularly the case when the trees are dense or tall, or when pests tend to shelter in rough bark or other cryptic parts of the tree. It’s good practice to check coverage immediately after a pesticide has failed, so as to eliminate this possibility.

**Spray cards**

A spray card is a strip of water- or oil-sensitive paper. The cards are produced in a range of sizes. They were developed for use in the field for quick evaluation of spray coverage and droplet size.

- **Water-sensitive paper.** These strips are made of specially coated yellow paper that turns blue when exposed to water droplets. The paper will also change colour when exposed to high humidity or even sweat from your fingers and hands. When not in use, the paper strips must always be stored in the foil packet and kept dry.
- **Oil-sensitive paper.** These strips are made of a black card coated in a white oil-soluble wax. The waxy surface is dissolved when contacted by oil-based droplets, leaving permanent black marks on a white background. This paper is not sensitive to all oils.

**Using spray cards.** Spray cards are among several tools you can use to assess spray coverage. They allow you to see where the spray is going in your crop and what sort of spray coverage you are getting with your spray equipment.

The spray cards can be placed in the crop by using staples, pegs, or paper clips before any spray operation. Be sure to use brightly coloured pegs, as the water-sensitive cards turn blue when wet and can be difficult to see in green foliage. The cards should be collected as soon as they are dry.

The cards can also be used to give you an indication of droplet size and density. However, once the liquid hits the paper, the droplets expand and may appear slightly larger. For assessing droplet size and density, the cards were originally designed to be viewed under a microscope or hand lens; the droplets were counted and compared to pictures showing different densities per square centimetre.
Spray cards are good tools for evaluating both your spray equipment and your spraying operation. They can be used to check where your spray is going in the crop and whether it is getting inside the canopy and to the top and bottom of trees. This information is useful when calibrating your spray equipment, especially with regard to nozzle size, placement, direction and travel speed.

Limitations of spray cards. Spray cards have certain limitations:

- The cards don’t work under very humid conditions, as the water-sensitive paper turns blue at about 80% relative humidity.
- Droplets smaller than 100 µm are not visible on the cards. Remember that there is often a large percentage of spray droplets smaller than 100 µm (100 µm = 0.1 mm). This is especially the case with spray equipment such as airblast sprayers and misters designed to produce droplets smaller than 100 µm.
- You need to wait until the plant’s foliage is dry before placing cards in the crop. Wait until fog has lifted or dew has evaporated.

- Once the cards have been used, don’t collect them from the crop until they are dry.
- Wear gloves when handling the cards so that they don’t become stained from your perspiration.

Other spray assessment tools

The other main method of visually assessing spray coverage is by using ultra violet (UV) fluorescent dyes. The liquid dye is placed in the tank of your sprayer and a normal spray operation is undertaken. To see the UV droplets you need to use a UV light at night to view the area sprayed.

This method of assessment is far superior to using spray cards but is a lot more difficult to organise.

Where to buy spray cards

Spraying Systems Co. Pty Ltd is the only company in Australia supplying spray cards (phone 03 9318 0511). Contact your local agricultural supplier for more information.

Step 5: Evaluate the season

Find out which pests caused trouble

Keep accurate records of pest incidence in your orchard during the season. Keep your records for up to 10 years. The more historical information that you have, the better the decisions you’re likely to make.

Losses caused by pests that generally affect leaves or branches (e.g. powdery mildew, two-spotted mite) are more difficult to assess then those affecting fruit. Keeping accurate records of the percentage of trees affected and comparing these with previous seasons’ is the only way that management action can be evaluated.

Examine rejected fruit regularly in the orchard, after picking, and in the shed. Determine the major reason why the fruit wasn’t packed. Some pests can be very obvious in the orchard but really don’t cause major problems. More effort than is needed is sometimes put into controlling these problems than other, less obvious – and perhaps more damaging – pests.

Determine which types of management worked

After reviewing losses due to specific pests, think about how you tried to control that problem during the season. For example, for pesticides, estimate the total volume of pesticide applied for each pest (spray records will provide this information); the price of the pesticide; and the total cost of control, including application time (labour) and running and maintenance of equipment.

More accurate records allow for better decision-making, and the overall objective of IPM is to find the best management options.
Step 6: Plan for next season

When defeat comes, accept it as a signal that your plans are not sound, rebuild those plans, and set sail once more toward your coveted goal.

Napoleon Hill

For all of the blocks you have in your IPM program it is important to do a pest and disease management review at the end of each season. The best way to improve your pest and disease management is to look at what you’ve done and then put more emphasis on the things that worked and find alternatives for those that didn’t.

Work out what you have to do

A plan for next season should include each pest you think you may have to control. Answer this question:

Has the pest or disease caused a problem in my orchard during the previous four seasons?

1. Yes. Formal monitoring will be needed. Control may be needed, depending on the results of monitoring.
2. No. Only casual monitoring will be needed. Specific control measures will probably not be needed next season.

Make sure all your preventive management strategies are in place

If the pest or disease was a problem last season, start by doing some preventive management. Often prevention reduces the number and severity of problems encountered during the season. This manual contains suggested preventive management strategies for the most serious pests of the Australian pome fruit industry.

Plan for each pest and disease that has been a problem recently

Planning on the run usually doesn’t work; plan well in advance.

The technique you use for monitoring should detect pests before they cause serious damage. Where serious damage did occur, why did monitoring fail? Was enough time allocated to it? Were the designated monitoring trees (see ‘Step 3: Monitor’ p. 16) the right ones? Are there more serious ‘hotspots’ in the block that would be better suited for monitoring?

Have you been happy with the management options for each pest and disease in the past? Look at your records and consider:

- Did it work?
- Was it cost-effective?

For pesticides:

- Did it cause secondary problems, such as mite outbreaks?
- Did it cause any other problems, such as health or disposal problems?
- What about residues?
- Have new, and potentially better, products come on to the market?
- Is there a danger of pesticide resistance developing?

Consider alternatives

Even if something is working well, there may be an even better alternative. If for any reason you’re not happy with some aspect of pest management, change it. Be conservative to reduce risk: trial major changes to your pest management on small, low-value blocks before using them more generally.

This manual provides a number of pest and disease management options for each of the major pests of Australian pome fruit.

Consider using IPM on more blocks

Consider switching more blocks to IPM if:

- pest and disease losses in IPM blocks are no higher than those in other blocks, and/or
- pest and disease losses in IPM blocks are no higher than they were before conversion to IPM.
Mating disruption
Mating disruption

Introduction

Many moths use chemical signalling systems to enable males and females to find one another, mate and produce a new generation. The chemicals used in this signalling are called pheromones. In Australian orchards, pest moths that produce pheromones include:

- codling moth
- lightbrown apple moth
- oriental fruit moth.

Commercially available products using artificially produced pheromones can be used to manage these pests in a number of ways. Pheromones are emitted by the female moths, and these powerful scents are able to draw males from great distances. The presence of male moths (even at low numbers, early in the season) can be monitored by placing point sources (lures) in orchards and using sticky traps to monitor the numbers of moths attracted. The techniques for monitoring using this method is outlined in this manual in the sections specific to the moths listed above.

Some orchardists will be able to make even better use of pheromones by using mating disruption to control their pest moths.

What is mating disruption?

Under normal circumstances a male moth is able to follow a single scent trail to locate a specific female moth. Mating disruption uses a grid of powerful dispensers to release massive quantities of pheromone into an orchard. In an orchard using mating disruption to manage pest moths there are so many strong scent trails that the male moth becomes confused and is unable to find a female. Imagine being in a room with a group of friends. You should be able to find a specific friend when they call you, even if other people are talking at a normal level. But now imagine what happens if everyone begins to shout your name … you become overwhelmed, confused and have no idea who to go to.

These confused male moths have trouble finding a female moth with which to mate so that some females will go unpaired or mating will be delayed so that the number of fertile eggs laid will be very much reduced.

Advantages of mating disruption

- **Specificity.** Each of the pest moths produces a specific type of chemical signal or pheromone. This means that the mating disruption products that use these pheromones are effective only against the pest that they target (although note that products using more than one pheromone in a single package are likely to be available in future). For example, Isomate CTT® pheromone affects only codling moth, not lightbrown apple moth, oriental fruit moth or any other insect in the orchard. Mating disruption agents have no effect on biological control agents (e.g. predacious mites, hoverflies, Trichogramma) or bees.
• **Reduced pesticide use.** Conventional insecticidal control of these moths usually requires frequent applications to be made throughout the season. This is particularly the case for codling moth, where entire insect pest management programs are based on how codling moth is controlled. Mating disruption should allow for the number of insecticide applications to be reduced (see ‘Emergence of secondary pests’ p. 27) and provide savings not just in the cost of insecticides but also in the cost of application (diesel, spray rig maintenance and labour). Because biological control agents such as hoverflies are likely to become more active, fewer sprays should be required for other pests.

• **Fewer pesticides on fruit.** Mating disruption agents should allow you to use fewer sprays; this will lower the possibility of fruit being contaminated with insecticide residues.

**Can mating disruption be used on my block?**

Before deciding to use mating disruption to manage pest moths it is important to assess the suitability of your blocks. There are a number of factors to consider.

• **Pest numbers.** Mating disruption works best when pests are present in low numbers. If pests are present in very high numbers it is probably best to use insecticides and other measures to reduce the populations over a number of seasons before switching to mating disruption. It is also possible to augment mating disruption by applying insecticides, but at a reduced frequency.

• **Block shape and size.** Mating disruption should not be used in blocks or contiguous areas of trees that are under 2 ha. Mating disruption does not work well on long thin blocks; square blocks are preferable.

• **Likelihood of migration.** Mating disruption will not stop mated female moths from flying into a block and laying eggs. Blocks adjacent to areas in which moths are not controlled are not suitable for mating disruption. Encouraging neighbours to clean up and (preferably) implement mating disruption will improve outcomes.

• **Slope.** Mating disruption will work best in flat blocks. Pheromones drain away with air movement down slopes.

• **Wind and shelter.** The pheromone concentration is diluted on windy or exposed blocks. Hill sites are often windy and can be a particular problem.

• **Trees.** A uniform block with large trees is better than one with many small or missing trees.

**Optimising the effectiveness of mating disruption**

Where an orchard block is suitable for mating disruption (see section on this page) the key to optimising pest moth management is to know which products are available and how to get the most out of them (see table below).

A grid of mating disruption dispensers must be set up well before the emergence of the first moths in spring. Records of monitoring from previous seasons should be used to calculate this date, but be careful not to rely on information from an abnormally hot or cold year. Preferably, predict the emergence date by averaging emergence dates from a number of years and

### Numbers of mating disruption dispensers for various pests

<table>
<thead>
<tr>
<th>Pest</th>
<th>Product</th>
<th>Registered crop</th>
<th>No./ha</th>
</tr>
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<tbody>
<tr>
<td>Codling moth</td>
<td>Isomate C® pheromone</td>
<td>Apples and pears</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Isomate CTT® pheromone</td>
<td></td>
<td>500</td>
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<tr>
<td></td>
<td>Disrupt CM®</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Oriental fruit moth</td>
<td>Disrupt OFM®</td>
<td></td>
<td>270</td>
</tr>
<tr>
<td>Lightbrown apple moth</td>
<td>Isomate LBAM Plus® pheromone</td>
<td>Apples</td>
<td>500 – 600</td>
</tr>
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</table>
then ensure that mating disruption is applied 1 month before this predicted date. The timing of application will vary between regions, and application times from other districts should not be used. If you are uncertain, contact your local horticultural consultant.

Dispensers will release effectively high concentrations of pheromones into the orchard for a period of 200 days under Australian conditions. Late season moth problems should not occur if good control has been observed throughout the season. However, where monitoring (see p. 27) has indicated that moth populations are not under control, a late-season insecticide application may be necessary.

When applying mating disruption dispensers the objective is to create a 'pheromone fog', which should be as uniform as possible across the block. Where there is a high risk of moth infestation the 'fog' should be thicker.

Examples of mating disruption dispensers. Isomate C (left), Isomate CTT (centre) and Disrupt CM (right) © I&I NSW

**Tips for optimising dispenser use**

- Draw up a good block plan. Before starting the job, sit down with the plan and decide on the placement of dispensers. In general, placement should be in grids, but remember to map out areas that are at increased risk of moth infestation and allow for extra dispensers in these areas. Ad-hoc placement without planning is likely to not achieve uniform pheromone saturation and will waste dispensers (and therefore money).

- For twist-tie-type dispensers, bend the dispenser around the tree and use one twist to loosely attach it. Tying the dispenser too tightly will lead to tree training and structural problems and also takes too long. At the end of the season – when the dispensers are exhausted – it is important to go back to the orchard and remove the dispensers before tree damage occurs. Winter is a good time for this job, because they are easier to see.

- Dispensers should be placed toward the top of a tree because the pheromone from a dispenser flows down a tree. In many cases moth courting and mating also predominantly takes place here. Place dispensers in the top 10% of a tree's height. Do not place a dispenser on a branch or twig that is likely to bend over and take the dispenser below the height required for adequate protection. You will probably need a ladder or cherry picker to place the dispensers; allow 2 to 4 hours per hectare.
Double-tube dispensers can be applied from the ground using poles.

Dispensers should be placed on the shady (southern) side of the tree, as this will reduce the rate of evaporation of the pheromone and prolong the dispenser’s life.

Most trees in the mating disruption grid will need only one dispenser. Where there is an increased likelihood of infestation, it may be necessary to place two dispensers in one tree. In these cases, place the dispensers individually on opposite sides of the tree.

In high-density plantings it will not be necessary to place a dispenser in each tree. The number of dispensers required, and their grid pattern distribution, can be calculated from the number of dispensers required per hectare.

Extra dispensers are likely to be needed on boundary trees, at the top of slopes, on the side of the orchard from which the prevailing wind blows, and along fence lines.

Is mating disruption working?

Monitoring in mating disruption blocks

As with any form of pest management, it is important to monitor and determine whether what you have done has been successful. In conventional orchards that rely on insecticide applications, monitoring is done by using pheromone caps and sticky traps. This technique will not work where mating disruption is being used. The ‘pheromone fog’ associated with mating disruption masks the pheromone from standard monitoring dispensers. Standard monitoring traps used in a mating disruption orchard will therefore underestimate the number of moths present. The solution is to use a modified pheromone-based monitoring system and other non-pheromone-based methods of monitoring.

Use of 10x concentrate pheromone caps

When using 10x concentrated caps in traps, placement is important. Traps should be placed in the very tops of trees at a density of 1 trap every 2 ha, with a bias towards areas more prone to infestation.

Traps containing DA (pear ester) lures will also be useful for monitoring moth numbers in blocks using mating disruption. These lures use substances associated with ripe fruit (rather than sex pheromones) to attract moths and are therefore not confounded by the presence of a grid of mating disruption lures. They are used similarly to other monitoring lures and full instructions can be found on their packaging. Growers should be aware that the variety of the trees in the block in which they are placed may impact on their effectiveness.

It should be possible to place these traps containing these lures using a long piece of PVC pipe with a wire hook at one end. Check and clear the traps weekly and record the number and type of moths caught. Change the bases and caps as often as needed. If monitoring indicates a rise in the numbers of pest moths, an insecticidal spray may be needed.

Crop monitoring

The structured monitoring procedure outlined in this manual becomes even more important in orchards using mating disruption, and orchardists should be prepared to devote sufficient time to monitoring to discover any outbreaks as quickly as possible. This monitoring should look for the physical signs of infestation (damaged fruit or foliage, curled leaves and silken feeding nests) as well as the insects themselves.

Emergence of secondary pests

Where an orchard’s size, condition and topography make it possible to use mating disruption to control pest moths, there is only one serious disadvantage. As with all pest management strategies that minimise the use of broad-spectrum insecticides, insect pests previously considered occasional or secondary become more serious. If mating disruption is used, other moth pests such as helicoverpa and loopers often become serious enough to warrant spraying. However, the damage caused by these secondary pests is seldom serious enough to consider a return to conventional management of codling moth, lightbrown apple moth and/or oriental fruit moth.