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GENERIC IPM GUIDELINE

FOR VEGETABLE CROPS

Walker M, Davidson M, Wright P

This generic guideline for vegetable crops has been developed by Plant & Food Research for the Vegetable Research and Innovation Board. The contents of the original report published by PFR for the VR&I Board has been formatted as this IPM guide for Vegetable Crops.

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CONTENTS

Tip: Click on the text below to jump to a section.

SECTION 1
INTRODUCTION

SECTION 1
INTRODUCTION

While an integrated pest management (IPM) approach to pest and disease management is generally crop-specific, the components and principles of an IPM programme are more generic.

This guideline provides information on these generic aspects of IPM. Much of the information has been sourced from the IPM in Vegetable Brassicas manual (updated by Plant & Food Research in 2015 for Vegetables New Zealand Incorporated) with modifications to provide generic information for all vegetable crops (1). The New Zealand Good Agricultural Practice (NZGAP) "Integrated Pest Management Principles Code of Practice, 2017" (2) also provides a quick reference guide that can be used alongside this current guideline.

Pest and disease management in vegetable crop production can be improved by increasing the use of non-pesticidal controls and integrating any remaining pesticide use with non-pesticidal management tools. Most pests and diseases can be controlled in vegetable crops without applying pesticides on a calendar-based routine. IPM procedures help to minimise the development of pest populations, identify problems, and determine the best control decisions based on information gained through crop monitoring. By applying pesticides only to meet an identified need, the use of pesticides and risk to the sustainability of cropping and to the environment can be substantially reduced.

IPM aims to use a compatible combination of control strategies (biological and cultural controls) to minimise infestations. Regular crop monitoring detects if and when further controls are needed and are, therefore, most effective. Finally, where possible, selective pesticides are used to preserve natural enemies and therefore to minimise the resurgence of pests.

The aim of this guideline is to provide vegetable growers, crop scouts, crop consultants and crop managers with an understanding of the key components and strategies for growing vegetable crops using IPM.

1.1 HOW TO USE THIS GUIDELINE

1. Firstly, read the Grower IPM Checklist (Section 1.2) and answer the questions posed to consider all the key aspects of an IPM approach.
2. Secondly, after answering the questions, determine which aspects of an IPM approach you are already practicing in your crop, and the areas you are not practising and would like to learn more about.
3. Thirdly, refer to Sections 2 to 8 of the guideline for detailed information on all the key components of an IPM approach for vegetable crops.
4. Lastly, refer to Section 9 for useful extension resources.

1.2 GROWER IPM CHECKLIST

Question	Yes	No
Has your sector developed an IPM programme? If so, have you sought assistance from your sector product group to implement it through training and/or extension as part of an industry specific IPM programme or from qualified advisors?	○	○
Do you know what pests (and their natural enemies, including predators and parasitoids) and which diseases occur in your crops? It is essential to be able to accurately identify all the pests, natural enemies and disease organisms in your crop. Refer to Section 8 for more information.	○	○
Do you carry out regular monitoring for pests, their natural enemies, diseases, and weather conditions in your crop? Regular crop monitoring and good record keeping are the cornerstones of successful IPM programmes. Refer to Section 4 for more information.	○	○
Is there a crop growth stage or time of year when your crop is susceptible to pests and diseases? This will determine how regularly you will need to monitor. Refer to Section 5 for more information.	○	○
Are there known thresholds for key pests and diseases in your crop? Reliable thresholds have not been developed for all pests and diseases, but you can still use IPM by regularly recording presence of plant pathogens, and numbers of pests and their natural enemies. This will allow you to determine if natural pest suppression will be effective or if you need to use other control strategies. Refer to Section 4.1.3 for more information.	○	○
Have you considered strategies to conserve your natural enemies? For example, by providing favourable habitats. Refer to Section 5.2 for more information.	○	○
Are there any cultural control methods you can use to minimise pests or diseases in your crop? For example, tolerant or resistant cultivars, timing of planting, irrigation regime, and crop rotations. Refer to Section 5 for more information.	○	○

	Yes	No
If insect pest numbers are much higher than natural enemies and you decide to apply an insecticide, are there any selective insecticides available (to minimise impact on natural enemies) instead of a broad-spectrum insecticide? Selective insecticides will allow at least some, if not all, the natural enemies to survive in your crop, whereas broad-spectrum insecticides will kill all insects, including the natural enemies, and other beneficial insects. This information will also help you to comply with the recommendation that growers "… justify the chemical usage on crops …" for NZGAP certification. Refer to Section 6 for more information.	◯	◯
Do you rely heavily on one or two active ingredients to manage your pests and diseases? If so, pesticide resistance could become an issue, resulting in control failures. An IPM approach could help to avoid pesticide resistance from developing. Refer to Section 7 for more information.	◯	◯
Have you considered strategies to minimise the risk of herbicide resistance when controlling weeds in your crop? For example, using herbicides from different mode-of-action groups during the growing season. Refer to Section 7.5 for more information.	◯	◯
Have you considered crop management practices compatible with reducing pest populations, alongside NZGAP (2) requirements for sustainable production? Refer to Section 5.1 for more information.	◯	◯

If you answered NO to any of the questions on this checklist refer to the detailed information in Sections 2 to 8 for more information on these IPM approaches.

CLICK HERE TO SEE SECTION 1 SOURCES

SECTION 2
INTEGRATED PEST MANAGEMENT (IPM)

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INTEGRATED PEST MANAGEMENT (IPM)

Failures to control vegetable pests using pesticides alone have led to the worldwide development of techniques based on integrating a range of methods to achieve sustainable control. This approach is known as integrated pest management (IPM).

IPM programmes aim to use a combination of control strategies (biological and cultural controls) to minimise infestations. Regular crop monitoring detects if and when interventions (i.e. controls) are needed and are therefore most likely to be effective. Finally, IPM guidelines recommend the use of selective pesticides that will preserve natural enemies and minimise environmental impacts.

Sole reliance on pesticides as a quick fix for pest and disease problems is not a workable long-term solution for vegetable crops. This is because of the risks of pesticide resistance and the build-up of secondary pests that occurs when natural enemies are removed by pesticides. Such reliance on pesticides can become economically and environmentally unsustainable. The main principle of IPM is to bring together a range of pest management tactics to prevent pests from causing economic damage in crops, while reducing reliance on any single method.

Definition

IPM is the sustainable control of pests:

- Using a compatible combination of methods
- That recognises economic, ecological and toxicological factors
- While emphasising natural controls and economic thresholds.

Features of IPM programmes

- Use of techniques that emphasise monitoring (scout and record), scout = careful, regular observation
- Effective pest and disease control
- Use of selective pesticides in preference to broad-spectrum materials
- Reduction of pesticide risks
- Production of crops that meet market standards
- Minimal impacts on the environment

Crop Monitoring

The key to most IPM programmes is the use of crop monitoring techniques. Monitoring includes identifying the problem, and using regular standardised estimates of pest populations on plants.

This regular sampling is often called 'crop scouting'. The key to carrying out successful crop scouting is careful, regular observations to assess the population trends, fresh damage and risks (crop growth stage, weather, insect pest life stage), with the aim of providing a representative sample of the crop so that the resulting recommendations apply to the whole field. The precision of the estimate is determined by the number of samples and the degree of infestation or disease pressure – for example, it is easier to reach a decision on whether any controls should be applied if insect pest populations are high or low, but more difficult to decide with intermediate populations.

IPM programmes ensure controls are applied only when crop monitoring shows there is a need for them:

- Under light pest pressure, no or few pesticide applications will be required
- Under extreme pest pressure, the number of applications may exceed calendar spraying.

IPM procedures can be divided into three categories that are usually encountered in the following sequence:

- **Prevention** (quarantine, cultural controls, plant resistance, biological control – see Section 3)
- **Decision tools** (pest thresholds, crop monitoring – see Section 4)
- **Intervention** (biological control, chemical control, managing resistance – see remaining Sections).

The integration of IPM procedures is summarised in Figure 1.

CLICK HERE TO SEE SECTION 2 SOURCES

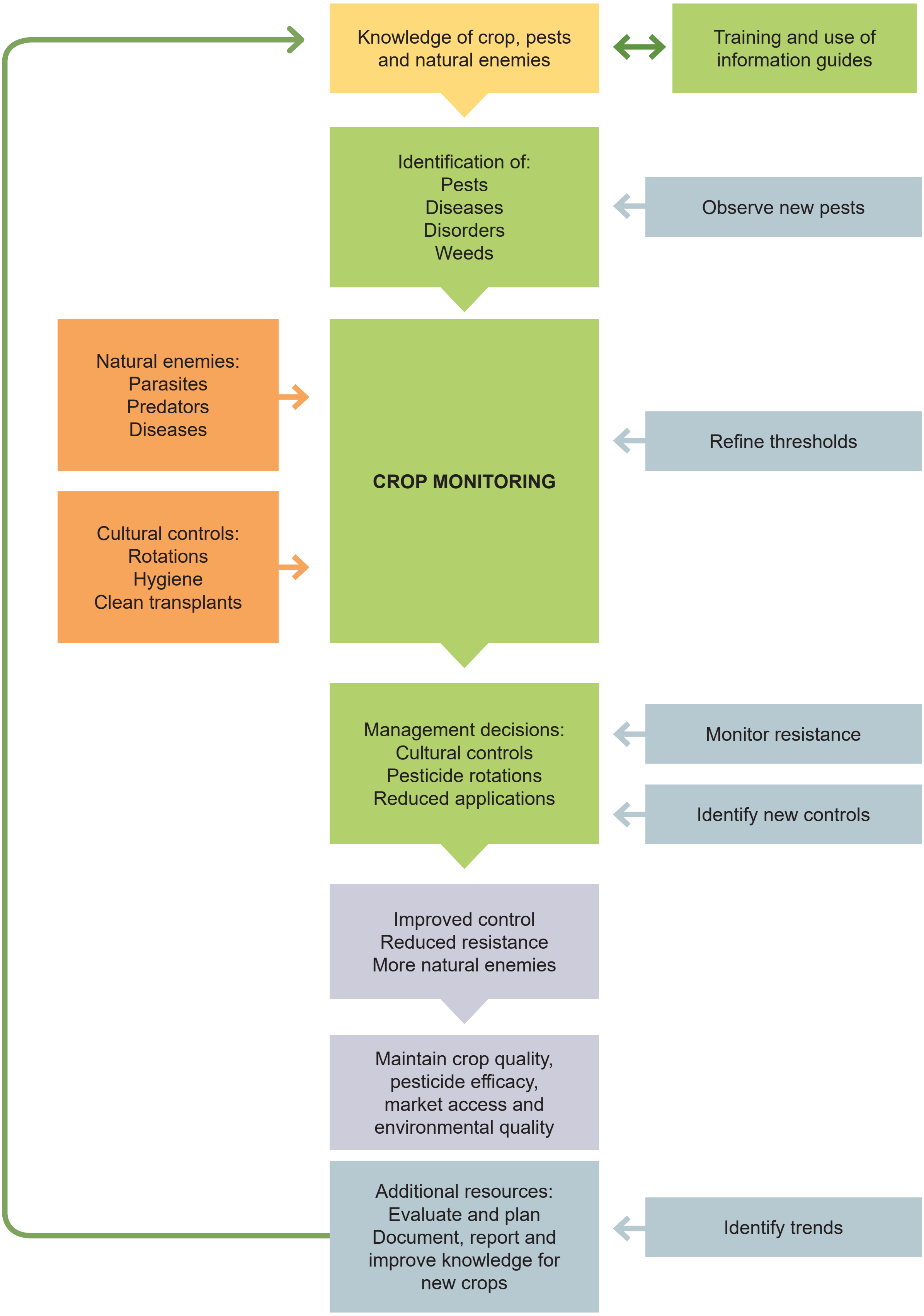


Figure 1. Components of integrated pest management in vegetable crops including knowledge underpinning strategies (blue), grower activities (green), inputs (dark orange), outcomes (grey) and new knowledge (light orange) that can be used to improve IPM strategies.

SECTION 3
PREVENTION

SECTION 3
PREVENTION

A range of techniques can be used to help prevent pest and disease populations from developing to numbers where they cause significant problems in vegetable crops.

3.1 QUARANTINE

This method aims to prevent the entry of a pest into a region or onto a farm. For example, insecticide-resistant thrips, new aphids and new viruses can be transported to new areas on seedling lettuce transplants or plant produce. Transfer of such organisms is best limited by the use of reputable suppliers and careful monitoring of all transplants for pests and diseases. Many diseases and weed seeds can also be spread on boots, tools or machinery, so effective disinfestation and cleaning procedures should be used. Insect pests can be quarantined from greenhouses by the use of pest-proof mesh screens and double door systems.

3.2 CULTURAL AND MECHANICAL CONTROL

Changing growing practices can minimise pest and disease pressure:

- **Sowing dates**, e.g. winter brassica crops are generally less affected by insect pests than summer crops (5) and late planting of potatoes, to avoid cold soils can reduce powdery scab (9).

- **Crop rotation** to limit build-up of pest populations by rotating to crops that do not support them, e.g. for lettuce crops, useful rotations in New Zealand include onions and maize, to minimise diseases such as Sclerotinia rot (2).

- **Cultivation** destroys insect pest pupae in soil and buries pathogen inoculum, reducing populations in subsequent crops (1, 5). However, intensive cultivation can reduce the stability of most cropping soils over time, so prevention of pests must be balanced with soil management (6). Using a cover crop (a crop planted after harvest) that does not support the build-up of pest populations (similar to crop rotations) may be more appropriate than intensive cultivation. A longer fallow period between crops can reduce pest infestations e.g. a fallow after pasture can dramatically reduce subsequent damage in establishing sweet corn crops by Argentine stem weevil (7).

- **Drainage.** Good drainage minimises many diseases. See NZGAP "Erosion & Sediment Control Guidelines for Vegetable Production" (5).

- **Hygiene,** for example in greenhouse capsicum and tomato crops, all crop waste should be removed from the greenhouse and immediate environment to ensure low carryover of any pests and diseases into the next crop. This includes removing weed and volunteer plants to ensure no green bridge remains for host pests (4)

- **Irrigation,** for example discourages diamondback moth (DBM) oviposition in brassicas (5) and reduces potato tuber moth damage on potato tubers. Irrigating potatoes for a 3 week period after tuber initiation provides good control of common scab (10).

- **Interplanting or intercropping** can mask plant odours. Insect pests use odours to locate plants. Crops chosen for interplanting can provide other benefits, such as improving soil fertility (5). Border plantings can be used as trap crops for pests or to increase numbers of beneficial species (e.g. provide nectar/pollen resources for hoverflies, refugia for predatory beetles and spiders).

- **Disease forecasting** systems that use the relationship between the duration of wetness or humidity and temperature to determine disease infection periods and to predict disease risk have been developed for vegetable diseases including downy mildew of onion (8).

3.3 PLANT RESISTANCE

Using or selecting resistant cultivars can prevent infection, delay or prevent disease development, or produce a crop that tolerates infection (1). Some cultivars of some crops are also resistant to pests.

Examples include:

- Some onion varieties with firmer skins that may prevent thrips invasion (1)
- Resistant cultivars in lettuce including, resistance to lettuce aphid and several diseases such as downy mildew and some viruses (2)
- Clubroot-resistant and -tolerant lines have been identified for brassicas (5).

3.4 BIOLOGICAL CONTROL

Biological control of pests makes use of the control provided by natural enemies or biological control agents. For insect pests, these agents are predators, parasitoids, and pathogens. For plant diseases, these agents are antagonists and competitors.

Biological control agents may:

- Occur naturally in New Zealand, for example the predatory Tasmanian brown lacewing and hoverflies (Figure 2).

- Arrive by self-introduction or with new pests, such as ash whitefly parasitoid, onion thrips parasitoid.

- Be deliberately imported – this is known as classical biological control. Examples of introduced BCAs include *Heliothis* parasitoids; *Cotesia rubecula*, a parasitoid specific to white butterfly; and *Tamarixia triozae* (3) a parasitoid and predator of tomato potato psyllid (TPP) (Figure 3).

Figure 2. Hoverfly larva (left), brown lacewing larva (middle) and adult (right) are generalist predators of aphids and other small soft-bodied insects.

Figure 3. The parasitoid *Cotesia rubecula* attacking a white butterfly larva (top) and the parasitoid, *Tamarixia triozae* with its host, a tomato potato psyllid nymph.

Biological control procedures include:

- Conserving and encouraging existing natural enemies (e.g. ladybirds, lacewings, hoverflies)
- Classical introduction of a new species from overseas (e.g. *Tamarixia triozae* (3) – the species is introduced and when established it can act as a new natural enemy).
- Inoculation into a new area, often while pest numbers are low (e.g. predatory mites (Figure 4) in greenhouses)
- Inundation through rearing and mass releases (e.g. *Encarsia formosa* parasitoid released in greenhouses to suppress populations of whitefly).

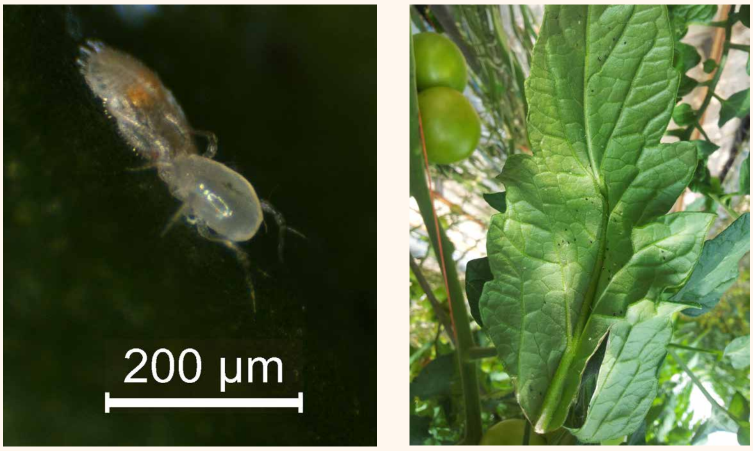


Figure 4. The predatory mite, *Amblydromalus limonicus* feeding on a small tomato potato psyllid nymph (left) and whitefly nymphs (black spots) parasitized by *Encarsia formosa* on a tomato leaf (right).

CLICK HERE TO SEE SECTION 3 SOURCES

SECTION 4
DECISION TOOLS

SECTION 4
DECISION TOOLS

4.1 CROP MONITORING

Regular crop monitoring and good record keeping are the cornerstones of successful IPM programmes. This section describes general information on crop monitoring tools, including trapping, plant sampling, thresholds and record keeping. Detailed monitoring methods have been developed for some specific crops, including brassicas (2) and lettuce (1), which could be adapted to suit other vegetable crops.

Crop monitoring involves collecting the information needed to identify pest problems in a crop for use when you make management decisions. The process involves careful continuous surveillance of crops (Figure 5), monitoring pest and pathogen population trends, and monitoring for fresh damage.

Crop monitoring includes:

- Making notes on crop development and pest damage
- Making notes on cultural practices
- Identifying pests and diseases present
- Using traps to capture mobile stages of pests
- Examining plants systematically to estimate pest numbers. Together with other records, this is often referred to as crop scouting
- Noting prevailing weather conditions to determine infection periods for diseases including downy mildew of onion (4).

Figure 5. Insect-damaged leaves observed during monitoring of a broccoli crop.

4.1.1 Traps

The number of pests caught in traps may indicate the seasonal appearance of pests in a crop and sometimes gives an idea of the density of pests in a crop. Records over time are usually required to relate trap catches to pest density in a crop. This is because weather or temperature may affect insect activity and alter the proportion of the population that is caught in a trap. Traps may also provide early warning systems that can be used to initiate more monitoring such as crop scouting.

Several types of traps have been used in various vegetable crops for different insects:

- Light traps and suction traps are usually operated by larger organisations to give regional information
- Pheromone traps, water traps and sticky traps are used to give local information.

Figure 6. Desire® pheromone traps (above) (image courtesy of ETEC Crop Solutions) and Scentry® pheromone traps (below) can be used to predict pest infestations.

Light traps

Light traps catch a wide range of moths, including some of the night flying noctuid moths that are pest species in lettuce (1) and brassicas (2). Because many species are attracted to light, the moths caught in traps need to be identified and sorted before the data can be interpreted.

Pros: new pests can be identified more quickly from trap catches than from plant sampling and comparisons of long-term trapping and plant sampling can show when damaging population numbers might be expected.

Cons: Light traps have not been used in recent years because of the costs of operation and identification. However, they have provided valuable information on the seasonality of pests as well as warning of new immigrant pests such as the soybean looper, a pest of lettuce and brassica crops (1,2).

Pheromone traps

Traps that use synthetic copies of female moth sex pheromones to attract males have been developed for a number of pest species.

Pros: Pheromone traps reduce or even eliminate by-catch of other insects, so require less technical knowledge to identify insect species, compared with other trapping techniques that catch a wide range of insect species (e.g. sticky traps). Pheromone traps catch male insects and increases in numbers caught give an indication of when a new generation is appearing. The traps can indicate more precisely when the damaging generation or flight of insects is present and when you should be on the lookout for eggs and larvae. Currently pheromone traps are available for potato tuber moth, greasy cutworm, tomato fruitworm, tomato stemborer, green looper, tropical armyworm and diamondback moth, based on Desire® technology from a commercial supplier in New Zealand (www.etec.co.nz) (Figure 6). Scentry® pheromone traps for Heliothis are available from the USA (www.scentry.com) (Figure 6).

Cons: Pheromone traps are not available for all insect pest species of vegetable crops (only those species listed above).

Suction traps

Suction traps use a fan to sample small airborne insects (Figure 7). Plant & Food Research had a network of 7.5-m tall suction traps (Auckland region, Hawkes Bay and Canterbury), but now run only one suction trap in Canterbury to provide weekly counts for several aphid pests that vector viruses in arable crops (funded through the Foundation for Arable Research).

Pros: Suction trap samples could be used for monitoring several pests in various crops, in particular, aphids and thrips, which require specialist training to identify species.

Cons: Suction traps require a power source. Additionally there are running and maintenance costs for suction traps.

Figure 7. In Canterbury, 7.5-m high suction traps capture a range of small insects and are predominantly used to monitor flights of aphids.

Sticky traps

Yellow sticky traps are used to catch aphids, leaf-miners, sciarids and other flies, whitefly, thrips, and psyllids (Figures 8), and blue traps are used for thrips.

Pros: They are used in nurseries both to monitor pests and to provide some control, and in field crops to monitor these pests. Yellow sticky traps can also be used for giving a quick assessment of comparative tomato potato psyllid (TPP) activity in greenhouses and field crops for given periods. They are widely available from commercial sources.

Cons: Sticky traps need to be used with caution because the yellow colouring, in particular, is also very attractive to many natural enemies that can be trapped in large numbers, thus reducing their potential as effective biological control agents in that local area.

Figure 8. A yellow sticky trap hung above a tomato crop. Yellow is attractive to a range of small insects, both pest species and beneficial species (natural enemies and insect pollinators).

Figure 9. Water traps for monitoring winged insects are generally yellow pans or bowls containing water with a detergent.

Water traps

These traps usually consist of yellow pans or bowls containing water with a detergent to trap winged insects (such as aphids and thrips) attracted to the colour (Figure 9).

Pros: These traps are cost effective and require minimal effort to set up. Traps are placed in fields, and routine identification and counts of the species present can show when they are infesting a crop.

Cons: Samples left too long in the field may decay, overflow in heavy rain or dry up in hot weather.

4.1.2 Plant sampling

The number of plants sampled is a compromise between the need for good information and the costs of sampling. The more plants that are sampled, the more information will be gathered and the more precise the estimate of the pest population. Sampling must be representative of the field and give reliable information on the pests present, when they occur, or how abundant they are and when a pest infestation should be treated. The pests must also be correctly identified. An incorrect identification will give inaccurate estimates of how much damage will occur and possibly result in the incorrect selection of pesticide.

Regular crop scouting may use one of two main systems:

- **Percentage infested:** records only the presence or absence of pests on a plant. A control response is initiated when a predetermined percentage of plants is infested – this is a quick and easy scouting method.
- **Pest counts:** counts all the pests present on a plant. A control response is initiated when an action threshold (defined as a number per plant) is exceeded – this is more time consuming but gives more information.

Systematic field observations from crop monitoring provide data that can be used to make consistent decisions on the use of additional control procedures such as spraying.

These decisions are based on economics (the degree of damage that can be tolerated) and thresholds (the numbers of pests that cause this damage).

4.1.3 Thresholds

The presence of a pest may not mean that economic losses will occur in a crop. Plants can compensate for some damage, especially damage to non-marketable parts of the plant such as outer wrapper leaves of lettuce and brassicas. Pests or pathogens that damage these areas of a plant are indirect pests, and can be tolerated at higher densities. However, pests that damage marketable parts are direct pests and can cause extensive damage at lower densities. Therefore, different pests are tolerated at different thresholds.

Crop monitoring provides systematic field observations that can be used to make consistent decisions on intervention with control procedures such as spraying. Such control decisions are usually based on action thresholds (Figure 10).

Three types of threshold

- **Damage threshold –** the pest population size at which damage of harvestable produce is detected
- **Action threshold –** the population density at which control measures should be applied to prevent pest densities from reaching the economic injury level
- **Economic injury level –** the pest numbers at which control gives an economic return. The economic injury level is the break-even point when the economic losses are equal to the total cost of control

All these thresholds may vary according to crop type, weather, stage of plant development, crop management, beneficial species and market factors. Therefore, action thresholds often require interpretation according to the current crop conditions.

To implement a successful IPM programme, growers need:

- **A defined action threshold for each pest in a crop.** In practice such thresholds may be:
  - The presence or absence of a pest or disease
  - A nominal density based on experience or
  - An experimentally derived pest density
- **A sampling technique to detect the rate of pest infestation simply and reliably.**

For **insect pests,** trials have shown that some minor infestations can be tolerated without economic damage, and application of insecticides only when they are necessary can significantly reduce insecticide use.

For **plant diseases,** control is often difficult once infection occurs, so many control procedures still rely on preventative applications. The timing of control measures for diseases can be based on weather information or plant development. The use of biological control agents (antagonistic and competing micro-organisms) is increasing and these may also be applied as a preventative strategy.

Natural enemies can have an impact on action thresholds in two ways:

- They can prevent insect pest populations from reaching the action threshold
- They can modify the existing threshold by being abundant enough to change a prediction of damage, i.e. if the population is close to the action threshold but parasitoids and predators are in abundance, experience can suggest that spraying can be delayed and the crop reassessed at a later stage.

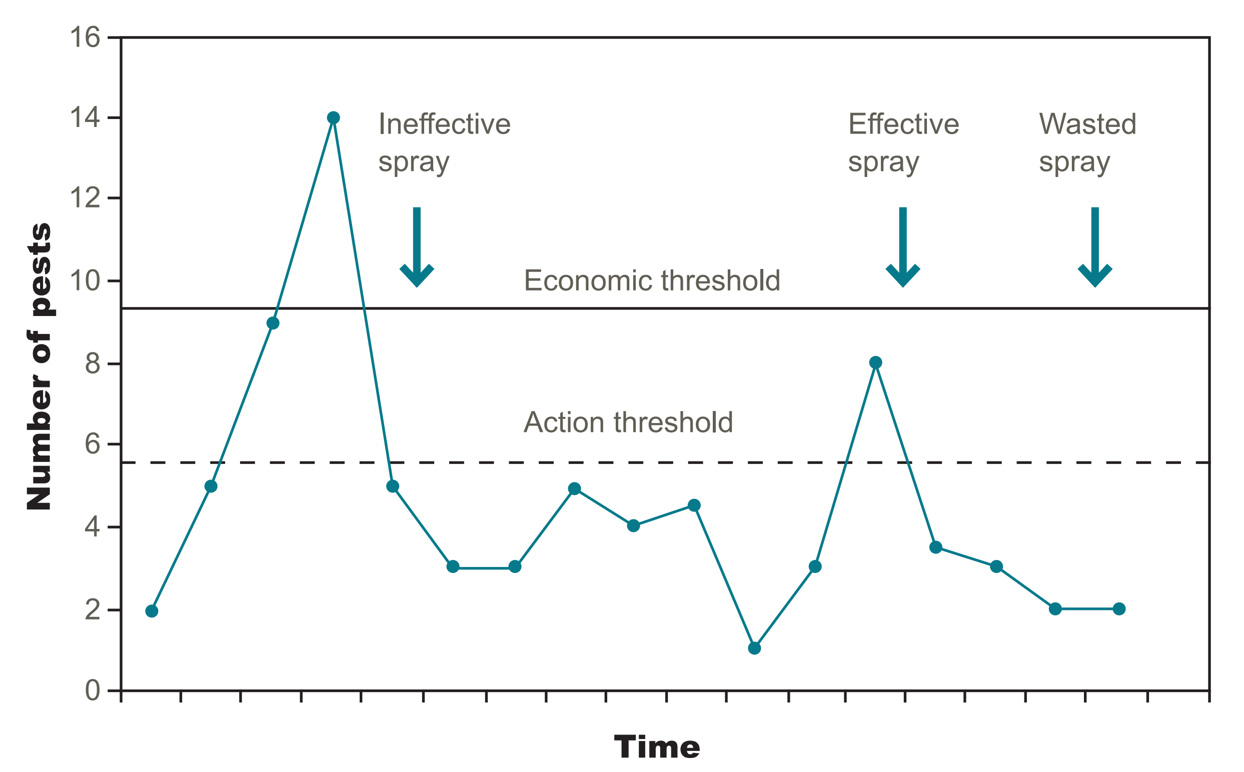


Figure 10. Spraying of pests at the action threshold avoids economic damage and saves unnecessary treatments.

4.1.4 Record Keeping

Crop monitoring records should be filed so that over time a historical database develops. This may allow pest problems to be anticipated based on what has occurred in previous seasons. For example, a pest may regularly appear in a particular part of the field or the appearance of a pest may be related to an event such as the harvest of a nearby crop. A common example of this is the infestation of other vegetable crops by thrips after the harvest of nearby onion crops.

To implement a successful IPM programme, growers need:

- An accurate sampling/monitoring method to detect the rate of pest infestation
- A defined action threshold for that crop
- An efficient record-keeping system.

4.1.5 IPM Decision Pathway

An IPM Decision Pathway (Figure 11) can be a very useful tool to aid vegetable growers in making management decisions for the control of pests and diseases in their crops. An example of a flow diagram is provided below for insect pests in vegetables. The diagram combines prevention techniques, decision tools and control strategies available to growers (Sections 3 and 4) allowing a grower to make the best management decisions for their crops, with the aim of applying insecticides only when necessary (selective insecticides in preference to broad spectrum) and at the most appropriate time.

CLICK HERE TO SEE SECTION 4 SOURCES

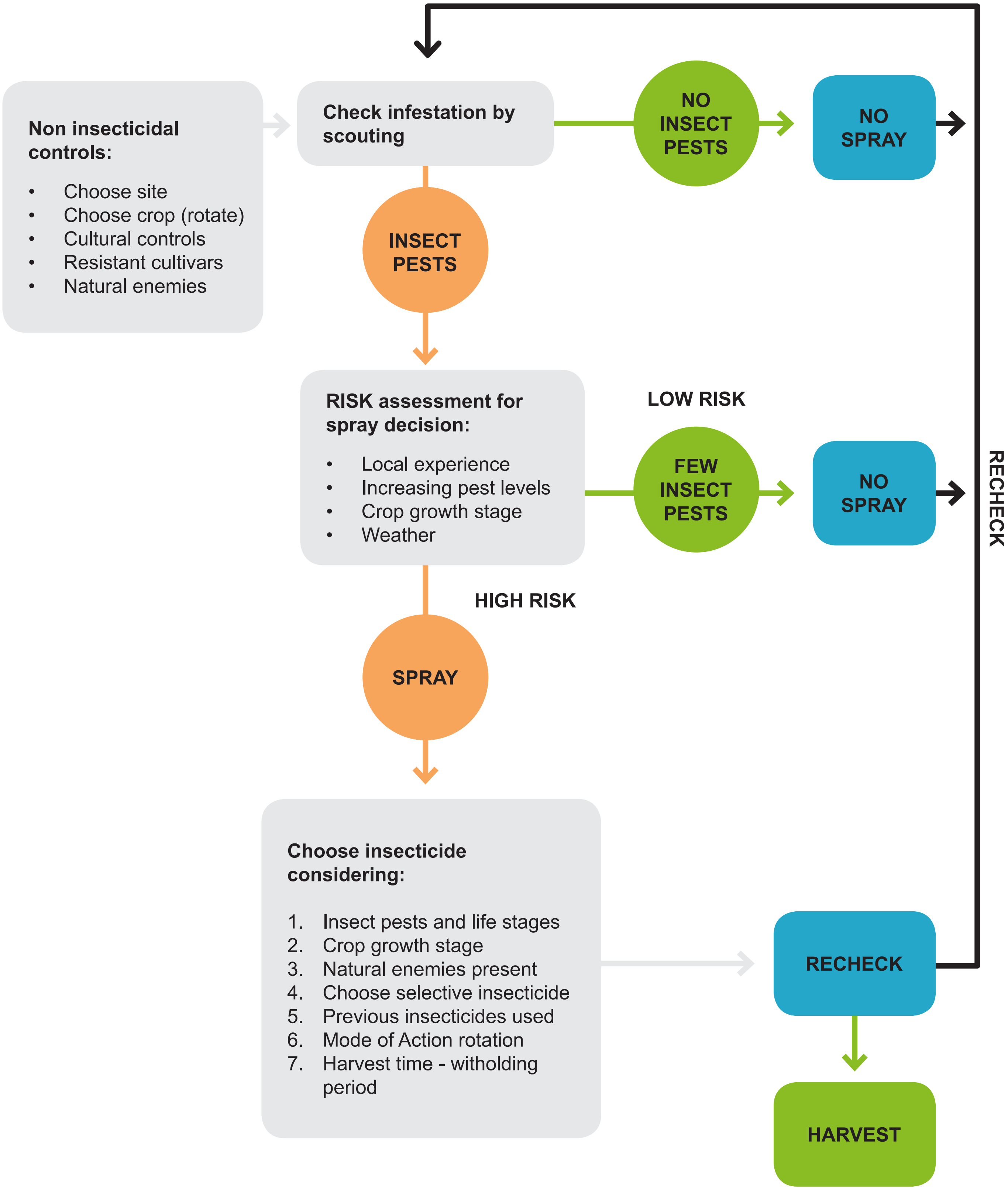


Figure 11. An example of a decision pathway for Integrated Pest Management (IPM) of insect pests in vegetables (courtesy of G. Walker, Plant & Food Research).

SECTION 5
CULTURAL CONTROLS

SECTION 5
CULTURAL CONTROLS

A range of cultural techniques can be used to minimise the establishment, spread and persistence of insect pests, diseases, and weeds in vegetable crops.

Management of insect pests, plant pathogens and weeds in vegetable crops relies upon making appropriate decisions regarding crop rotation, site selection, land preparation, hygiene, seed and seedlings, and irrigation. These techniques will vary considerably among different vegetable crop types.

This section provides some general information and examples for some specific vegetable crops grown in New Zealand. Care should be taken when applying the information to other vegetable crops and crops grown in different locations. These techniques are grouped below by the main cropping operations.

5.1 SITE SELECTION AND CROP ROTATION

5.1.1 Site Selection

Use records of previous pests, diseases, weeds, growing conditions, alternate hosts and neighbouring infestations to guide your choice of field for a new crop. For example:

- **Avoid sites with a history of herbicide-resistant weeds,** e.g. in lettuce, avoid fields heavily infested with groundsel, prickly lettuce, and sowthistle, as these are sources of virus, and are hard to control with herbicides used in lettuce (3).
- **Avoid sites with a history of disease.** New plantings should not be made adjacent to crops or weeds infected with easily transferable diseases, or in poorly drained wet sites that will encourage many diseases, e.g. for lettuce, beans, tomatoes and brassicas, avoid planting in fields with a history of Sclerotinia problems (3, 7, 8, 14).

5.1.2 Crop Rotation

Limit populations of pests and pathogens by rotating to crops that will not support them or be infected by them. Such crops may be effective simply because they are not food/host sources for pests or pathogens, do not provide shelter/resources when needed, or do not require cultural practices that deter or destroy pests or pathogens (6). Crop rotation is likely to have more impact on populations of pests or pathogens that have a narrow plant host range and limited mobility.

When disease organisms persist as resistant stages in the soil or crop trash, rotation to non-host plants provides a mechanism for reducing inoculum (13). For example, *Sclerotinia* spp. can have a wide host range but populations may decline under non-hosts such as grasses and grains (4, 5).

To prevent the land becoming dominated by a particular weed species, plan for a rotation of crops with widely differing growth habits, time in the ground, cultivation requirements and sowing dates (2).

- Include pasture in the rotation, if possible, because the soil seed bank of many vegetable weeds declines under pasture because of fatal germination (a weed seed germinates, but the seedling dies before reaching the soil surface), predation of seeds and lack of new seeds introduced (14).
- The longer the pasture remains, the lower the weed density in a later-sown crop. The seeds of arable land grass weeds, e.g. wild oat, Phalaris and brome grasses will decline particularly quickly under pasture (14).

5.2 PLANT DIVERSITY & HABITAT MANAGEMENT

The area surrounding crops, weed margins or strips within crops may be manipulated to enhance the abundance and effectiveness of natural enemies (Figure 12) (12). The activity of natural enemies may be increased by providing alternative host plants (such as *Phacelia*, buckwheat, sweet alyssum) that provide natural enemies with a food source (pollen and nectar), and shelter to attract them into a crop (14, 15). Before introducing alternative host plants, check they are not a risk as weeds or as sources of pests and diseases (12).

A second or companion crop can be grown as a physical barrier or to disrupt insect pests of the primary crop. Several plant species have been shown to reduce damage, but widespread use has been restricted by their lack of suitability for commercial farming systems. In brassicas for example, intercropping with garden sage, thyme and white clover has consistently reduced damage by DBM to Brussels sprouts in overseas crops (12).

Planting of a second crop that is preferred by a key pest species provides a trap crop that may spare your main crop from damage (14) or may be used to aggregate and manage the pest population before the vulnerable stage of the primary crop (17).

Figure 12. A field margin adjacent to a farm with native plants established to provide habitats and resources for beneficial insects (natural enemies and insect pollinators).

5.3 LAND PREPARATION, MECHANICAL METHODS & HYGIENE

5.3.1 Insects

For outdoor vegetable crops, cultivation of soil and incorporation of crop trash can destroy soil-dwelling insect pests, remove food sources, breeding grounds, hibernation sites and refuges of insect pests, and fill crevices that provide shelter (13).

For example:

- A fine soil tilth may minimise soil cracking and reduce crevices for slugs (14)
- Reflective foil mulches may slow colonisation by winged aphids (14)
- Removal of crop residues will reduce populations of some insect pests (14).

Note: Care must be taken to avoid excessive cultivation as this will damage soil structure, resulting in a loss of plant nutrients such as soil nitrogen by leaching, and disruption of beneficial soil biota. It will also deplete soil organic matter, release carbon into the atmosphere and promote topsoil loss by wind erosion (14).

For greenhouse vegetable crops, preventing insect pests from entering the crop through good hygiene practices is essential, and needs to commence before the end of a crop to ensure low carryover of all pests. All crop debris should be removed from the greenhouse and immediate environment. Weed and volunteer plant removal is required to ensure no green bridge remains for hosting pests. Adequate sanitation is essential before the new crop arrives, and during the cropping period good hygiene practices should be observed at all times (11). Double door systems and pest-proof screens can stop pests entering production areas.

5.3.2 Diseases

For both outdoor and greenhouse vegetable crops, removing the remains of harvested plants, crop debris, volunteer plants, and weeds reduces the sources of several diseases (4, 5, 14).

For example:

- Removing or burying crop residues can reduce the inoculum of disease organisms (14)
- Machinery and equipment should be cleaned and disinfected to limit mechanical movement of the pathogen between fields and greenhouses (14)
- Movement of soil between fields or greenhouses on machinery, seedling trays, vehicles or workers should be avoided, to minimise the spread of the resting stages of several disease causing organisms (14).

5.3.3 Weeds

In outdoor vegetable crops:

- Cultivation of soil and incorporation of crop trash can reduce populations of perennial weeds (14). However, as mentioned above, cultivation can result in adverse impacts on the soil. The use of cultivation to manage pests (insects, diseases and weeds) should be balanced against the availability of other sustainable pest management strategies, and impacts on the soil.
- Stimulating weed seeds to germinate and then killing the seedlings before sowing your crop (or before emergence) reduces the weed potential of the soil (2).
- Sterilising soil by thermal (rather than chemical) techniques (e.g. steam, solarisation) prior to planting can kill weed seeds and young germinating weeds, reducing weed infestations in your crop (10).
- Control of weeds around drains and silt traps can reduce weed seed loading in soil removed and spread back onto cropping fields.

In both outdoor and greenhouse vegetable crops:

- Movement of soil between fields or greenhouses on machinery, seedling trays, vehicles or workers should be avoided, to minimise the spread of weed seeds or other reproductive parts of weeds (3, 14).

5.4 SOWING/PLANTING TIMES AND PATTERNS

5.4.1 Insects

Avoid flight times of an insect pest, or ensure a less susceptible growth stage of a crop is present when an insect pest is migrating (1).

Winter crops are generally less likely to be infested by insect pests than summer crops (14).

5.4.2 Diseases

Some diseases are favoured by certain climatic conditions that are more likely to occur at certain times of the year. Sowing/planting crops at these times may encourage epidemics of the diseases in question (14).

For example, cool wet conditions favour leaf spot and downy mildew in brassicas (Figure 13) (14), and seed rot, damping-off, seedling blight and rust in sweet corn (12).

Figure 13. Downy mildew on broccoli.

5.5 PLANT RESISTANCE

Where available, use pest-resistant or pest-tolerant plant varieties that can prevent, delay or reduce insect invasion or disease infection of a particular crop (1).

5.6 CLEAN SEED AND SEEDLINGS

Seedlings are potential sources of insect pests such as caterpillars and aphids (14):

- Screen greenhouse seedlings to prevent infestation (14).
- Locate seed beds or greenhouses away from production fields (14).
- Inspect seedlings for infestations of insect pests (14).
- It is important to use clean seed and transplants to prevent the development of seed-borne diseases. It is therefore important to obtain seed and transplants from a reputable source, and to check them for infestation or infection before planting (14).

5.7 IRRIGATION AND DRAINAGE

Wet or dry conditions can encourage or reduce various pest or disease problems in vegetable crops (1).

For example:

- Overhead irrigation can be used to disrupt insect pest populations physically or to encourage the development of fungal pathogens that attack insect pests (14).
- Excess moisture favours many diseases of vegetable crops. This problem may be reduced by choice of site, preparation of well-drained seed beds, or correct timing of irrigation (9, 14).

Decisions on the amount of irrigation also influence plant health. For example, in lettuce, too little water can result in small plants, slower growth and premature bolting, and plants less able to tolerate pests and most diseases (3).

5.8 FERTILISER

Some nutrient deficiencies can cause symptoms similar to those caused by pathogens, so correct diagnosis of diseases should also consider the potential effects of nutrients. Many resources on crop disease identification and management also contain descriptions and illustrations of nutritional disorders (e.g. 5,6). Refer to the Nutrient Management for Vegetable Crops in New Zealand handbook (16) for more crop-specific information on optimal fertiliser applications.

CLICK HERE TO SEE SECTION 5 SOURCES

SECTION 6
CHEMICAL CONTROL

SECTION 6
CHEMICAL CONTROL

Intervention following a decision to control a pest or disease sometimes involves the use of pesticides or additional materials such as pheromones, attractants and repellents.

Pesticides include insecticides, miticides, fungicides, bactericides, herbicides, and molluscicides. Ideally, chemical control aims to remove pest species selectively while maintaining high quality produce and leaving no harmful residues. Natural enemies are often more susceptible than pests, and their elimination can lead to the resurgence of pests when they recover more quickly from a pesticide application – this is known as pest resurgence. Elimination of natural enemies can also cause some species that are not normally pests to reach pest status – these are known as secondary pests.

Care is required in selecting and applying chemicals so that minimal damage is caused to beneficial organisms, and risk of resistance of pests to the chemical is minimised. Crop protection specialists should be consulted for advice on product selection, application and rotation with products from different modes of action (2).

6.1 PESTICIDE CLASSES

The different pesticide classes represent groups of insecticides or fungicides with a similar mode of action. This classification is based on a basic chemical structure common to all members of the class. This chemical structure often affects one main target site in the organism. For example, in insects, organophosphates affect transmission between nerves. In fungi, demethylation inhibitors interfere with biosynthesis processes and this interference controls powdery mildews, leaf spots and storage rots.

Each of the common classes of pesticide has a different mode of action. This means that an insect that is resistant to one class is usually not resistant to another class. However, resistance to one member of a class often confers some resistance to other members of the same class. This is called cross-resistance. Alternating between pesticides that are in the same class creates a risk of resistance developing. Pesticides should be rotated between different classes (modes of action).

Websites grouping pesticide active ingredients by mode of action classes can be found at:

Insecticides: www.irac.org
Fungicides: www.frac.org
Herbicides: www.hrac.org

6.1.1 Insecticides

Insecticides include biological and chemical compounds that are designed to kill, injure, reduce the fertility of, or modify the behaviour of insects. They comprise contact, stomach poison and fumigant insecticides. A single insecticide may act in more than one of these ways.

Contact insecticides penetrate an insect's body surface through direct contact with the insecticide during application or when an insect walks over a sprayed surface (1).

Stomach poison insecticides are ingested by an insect and absorbed into its body. There are two types of stomach poisons: those on the surface of plant tissues that are eaten by the insect pest, and **systemic insecticides** which are absorbed by the plant tissues and may be translocated around the plant (1).

Fumigant insecticides are volatile and produce a gas or vapour which is released into the air around an insect and is then absorbed through the insect's breathing system (1).

Other chemicals used against insects include:

- Attractants – baits or food substances to attract pests to traps or to provide food for natural enemies to make them more effective.
- Repellents – These are not widely used in crop protection, compared with attractants. One example is the use of the aphid alarm pheromones. However, these are still at the experimental scale.
- Pheromones – traps for monitoring to detect seasonal trends (attract male insects only); or when used at a higher density than for monitoring, excess pheromone in the environment can disrupt mating (4).

6.1.2 Selective Insecticides

Selective insecticides are less toxic to natural enemies than are other insecticides and they therefore help to conserve these beneficial species. In New Zealand conditions, where insect populations do not increase as rapidly as in hot climates, parasitoids and predators tend to give better control of pests such as caterpillars and aphids. Using selective insecticides early in the season can therefore be a useful technique. For example, the aphicide, pirimicarb is considered to be specific to aphids, and conserves natural enemies, and insect growth regulators have very low activity against parasitoids and predators (3).

6.1.3 Biopesticides

Biopesticides (biological pesticides) are considered safe for people, animals and the environment. They contain natural organisms or substances derived from natural material. They can include microbials, pheromones, macrobials/invertebrates (such as insects and nematodes), and plant extracts/botanicals (4).

- Microbial pesticides contain microorganisms:
  - Bacteria (e.g. insecticides containing *Bacillus thuringiensis*, bio-fungicides containing *Bacillus subtilis*) (5).
  - Fungi (e.g. insecticides containing *Beauveria bassiana* (6), fungicides containing *Ulocladium oudemansii*) (5).
  - Viruses (e.g. insecticides containing *Cydia pomonella granulovirus*) (5).
  - Nematodes such as *Steinernema feltiae* (infect thrips species).

- Biochemical pesticides such as pheromones including the sex pheromones described in section 14, can be used to disrupt mating, thus preventing population development in some insect pests (e.g. codling moth sex pheromone).

- Plant extracts/botanicals, such as azadirachtin (Neem).

Note, some definitions of biopesticides do not include macrobials/ invertebrates, but do include plant-incorporated protectants including genetically modified plants with pesticidal substances (e.g. Bt corn), additional microorganisms, such as protozoa and algae, and other types of biochemical pesticides such as semiochemicals (i.e. volatile compounds that can be used to attract pests to bait stations) (7).

6.1.4 Fungicides

Fungicides are chemical compounds designed to prevent infection, kill or impair the fungi. They comprise protectants, systemics and soil fumigants.

Protectant fungicides are commonly older fungicides whose mode of action is to prevent fungal spores from germinating and infecting plants. To be effective, protectants must be applied to all plant surfaces to form a protective barrier. Protectants only kill pathogens on the outside of the plant.

Systemic fungicides can enter a plant and kill fungi that have already infected the plant. Their action can be restricted to the leaves to which they were applied, but some systemics can travel up inside the plant and can therefore be applied through the roots.

Soil fumigants are used to treat the soil before planting to kill spores or other resting stages of fungal pathogens.

CLICK HERE TO SEE SECTION 6 SOURCES

SECTION 7
PESTICIDE RESISTANCE

SECTION 7
PESTICIDE RESISTANCE

If a pesticide is not giving the degree of control required, the most common reasons are ineffective spray coverage, equipment failures or incorrect rates.

If all these factors are correct, then the development of pesticide resistance by the pest may be the problem. Given perfect spray coverage under ideal conditions, control failure indicates resistance. The only way of confirming resistance is with a standard laboratory assay. Such assays compare the mortality of a field pest population with a reference culture (a population of the pest with known susceptibility to the insecticide) to provide a measure called the resistance ratio.

Definitions

Pesticide resistance
is present when the dose required to kill 50% of the pests (the LD_{50}) from a test population is significantly greater than the LD_{50} of a reference susceptible population.

Field resistance
is present when the rate of resistance is sufficient to cause control failures. Note: Field resistance is very variable because differences in application and plant stage affect the dose reaching the pest, and variations in the pest size and stage affect its response.

The resistance ratio
is calculated by comparing the mortality of a test population with the mortality of a reference population.

Insect resistance
can also be assessed by comparing the mortality of populations at recommended rates of insecticides.

7.1 HOW DOES RESISTANCE DEVELOP?

Resistance develops when a gene (either existing or a new gene mutation) in a few individuals favours their survival (Figure 14). This gene may normally produce a characteristic that serves another purpose, but when a pesticide is sprayed, the new characteristic eg. (thick cuticle, an enzyme, or ability to shelter under leaves) becomes an advantage. From this point, the use of a given pesticide will kill individuals without the gene, and resistance becomes detectable when the new gene spreads through the population and is common enough to cause control failures. In these circumstances, the use of that pesticide (or those from the same class) causes increased resistance, and increased pesticide use only accelerates the rate of resistance development in the pest population.

1

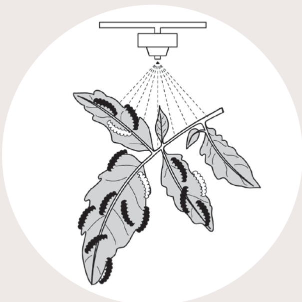
Repeated pesticide application from the same pesticide class.

Black = resistant pest
White = susceptible pest

2

Results in selection of individuals resistant to the pesticide

3



Increase in the number of resistant (black) individuals

Figure 14. Development of resistance. Routine spraying with pesticides from the same class leads to an increase in resistant individuals (black caterpillars) as susceptible individuals (white caterpillars) are selectively killed.

The degree of resistance is determined by the proportion of resistant individuals in a population, but control depends on degree of resistance and the density of pest populations.

For example, at a given rate of resistance, say 30% of the population:

- Spraying at 3 caterpillars/plant would reduce populations to 1/plant, and give adequate control; whereas
- Spraying at 30 caterpillars/plant would reduce populations to 10/plant, resulting in poor control.

7.2 WHAT CAN BE DONE TO LIMIT PESTICIDE RESISTANCE?

Resistance management is based on techniques that limit selection for genes that favour resistance. This basically means **limiting the use of pesticides** by relying instead on a range of non-pesticidal techniques. This is one of the main aims of IPM – to not rely solely on pesticides to control pests.

The following IPM procedures, combined with selective use of pesticides, can limit the development of pesticide resistance.

- Always use transplants from nurseries with pest and disease management plans.
- Monitor crops regularly – identify and assess the problem.
- Use action thresholds to make a control decision.
- Select controls if necessary:
    - Use selective pesticides
    - Apply pesticides at the recommended rate with good coverage
    - Rotate pesticides from different classes and co-ordinate the use patterns within regions (see Rotation Strategies next page).

Do not use chemicals at doses other than those recommended on the label. High doses will usually not control resistant individuals (they will often survive 10–100 times the label rate) but will make the situation worse, as they will speed the development of resistance. High rates will also increase the risk of residues in harvested produce.

7.3 PESTICIDE ROTATION STRATEGIES

The use of different pesticide classes in various combinations is a traditional way of attempting to maintain their efficacy.

Combinations include:

- **Mixtures.** This is the worst way to use insecticides. When resistance does occur, both insecticides in the mixture are lost at the same time, so the efficacy of each insecticide lasts for a shorter time than it would have had it not been used in a mixture.
- **Alternations.** Alternating between pesticides is effective as long as:
  - The pesticides are from different classes,
  - The interval before using the same class again is greater than one pest generation (for example. about 3 weeks for thrips to about 6 weeks for caterpillar species)
- **Rotations.** The rotation strategy aims to limit mixtures by defining lists of pesticides to be used within a region at different times (windows) of the year.
  - Different classes of pesticide are retained for different parts of the year throughout a region, i.e. different *windows*. This is often called a rotation strategy.

If growers within a region each use individual alternations, pests moving between areas will encounter different pesticides. This mosaic pattern effectively forms a mixture, which favours the development of resistance (as noted above).

7.4 RESISTANCE MANAGEMENT STRATEGIES

Resistance management strategies have been published or recommended for pesticides used against the following specific pests and diseases and general groups (see numbered sources and the New Zealand Plant Protection Society website, http://resistance.nzpps.org/

Specific pests
Diamondback moth (12)
Tomato fruitworm (6)
Green peach aphid (5)
Currant lettuce aphid (14)
Melon aphid (11)

Specific diseases
Grey mould (3,4)
Sclerotinia (3,4)
Botrytis (3)
Allium white rot (1,3)
Blossom rot (4)
Powdery mildew (1,4)
Ringspot (4)
Celery leaf spot (4)
Leaf mould (1)
Downy mildew (2,8)
Late blight (2)
Spear rot (2)
Crown rot (2)

General groups
Whiteflies (10)
Spider mite (7)
Thrips (9)

7.5 FUNGICIDE USE AND RESISTANCE MANAGEMENT STRATEGIES

Resistance has been recorded to some of the fungicide groups used against vegetable diseases in New Zealand. Fungicides at risk from resistance are mainly the synthetic chemicals developed since the 1970s that are specific in the way they affect their target fungi. Many older fungicides, such as captan, thiram, mancozeb, metiram, copper and sulphur, which have a non-specific mode of action and are active against a broad spectrum of diseases, are not considered to be at risk from resistance development in fungi. Instances of resistance in New Zealand have been recorded to the following fungicide groups (see numbered sources and the New Zealand Plant Protection Society website, http://resistance.nzpps.org/

- Benzimidazoles (4)
- Dicarboximides (3)
- Demethylation inhibitors (1)
- Phenylamides (acylalanines) (2).

There are instances around the world of pathogens developing resistance to particular fungicides. Resistance can often be managed because the resistance of pathogen populations often decreases if use of the at-risk fungicide is reduced or stopped. Strategies for managing risks of fungicide resistance are summarised in the website Fungicide Resistance in New Zealand: http://resistance.nzpps.org/index.php?p=fungicides/introduction.

Strategies include:

- Always follow label recommendations
- Apply fungicides with care
- Avoid the use of products where strains of resistant pathogens are known to occur
- If resistance frequency to a particular class is nil or low, use only up to two applications per crop; if medium to high, do not use that class of fungicide
- Use systemic fungicides in the **field**, and use protectants in the seed bed or when raising cell plants
- When buying seedlings, check which fungicides have been used and, if possible, specify the purchase of those that have not been treated with systemic fungicides. This will give a greater freedom in planning field schedules
- Avoid using fungicides as “salvage” treatments in an attempt to save markedly infected crops, as this accelerates the development of resistance and will cause bigger problems in later crops
- Individual fungicides are similar to insecticides in that they belong to groups or families with the same or similar modes of action. Resistance to one fungicide in a group may mean resistance will occur to all those fungicides belonging to the same group. Therefore, always rotate groups of fungicides. Do not merely change from one member of a group to another of the same group
- Groups of fungicides that are presently at risk of causing control failures include the dicarboximides, phenylamides, benzimidazoles and demethylation inhibitors (DMIs). See the most recent New Zealand guide to agrichemicals for resistance management strategies for each of these groups and the New Zealand Plant Protection Society website, http://resistance.nzpps.org/.

7.6 HERBICIDE RESISTANCE MANAGEMENT

Detailed information on weed control and herbicide resistance management is not covered in this guideline; however, the following external resources provide very useful information for growers:

- New Zealand Plant Protection Society Website - Herbicide resistance in New Zealand: http://resistance.nzpps.org/index.php?p=herbicides/introduction
- Foundation for Arable Research Website – Herbicide Resistance https://www.far.org.nz/research/weeds_and_pests/weeds/herbicide_resistance
- Foundation for Arable Research Website - Guidelines for minimising the development of glyphosate resistance in weeds in arable and vegetable crops https://www.far.org.nz/assets/files/editable//43ce016b-af9a-4470-a2c1-8e5ad58c33f8.pdf

CLICK HERE TO SEE SECTION 7 SOURCES

SECTION 8

PLANT PEST GROUPS

SECTION 8
PLANT PEST GROUPS

A pest is defined as any living organism that is harmful to plant growth and crop production.

These organisms include:

- **Arthropods -** insects, mites, millipedes, symphilids, slaters
- **Molluscs** - slugs, snails
- **Nematodes -** eelworms
- **Pathogens** - fungi, bacteria, viruses
- **Plant disorders** (these should not be confused with pests)
- **Weeds**

Crop plants may also show symptoms of physiological disorders caused by environmental stresses (e.g. high or low temperatures, shortage or excess of water or nutrients).

8.1 ARTHROPODS

Insects occur in great variety. There are more than one million species in the world and over 10,000 in New Zealand. Only a few are considered pests and many insects are beneficial.

Other arthropods include several groups of small animals related to insects that also possess an external jointed skeleton. Like insects, they moult at intervals as they grow but none show complete metamorphosis.

The more important types are:

- **Mites** – very tiny (< 0.5 mm) with compact bodies, and the nymphs and adults have eight legs. They are as numerous and widespread as insects. Some are plant feeding and some are predatory on the plant feeders.
- **Millipedes** – have many body segments, most with two pairs of legs per segment. They mostly scavenge under dead plants and are minor plant pests.
- **Symphilids** – are 6-8 mm long with 14 body segments and 12 pairs of legs (less in immature stages). They feed mainly on roots and can cause discolouration and stunting of plant growth in seedlings or seedling transplants of a number of crop species e.g. spinach and tomatoes.
- **Slaters** – are minor plant pests.

8.1.1 Insect pests

What is an insect pest?

Only a small proportion of insects are plant pests. Many insects in crops are important in recycling, are beneficial predators or parasitoids, or are innocuous. The presence of a pest may not mean that economic losses will occur in a crop. Plants can compensate for some damage, especially damage to non-marketable parts of the plant such as outer wrapper leaves of lettuce (1) and brassicas (2). Pests or diseases that damage these areas of a plant are *indirect* pests and can be tolerated at higher densities. However, pests that damage marketable plant parts are *direct* pests and can cause extensive damage at lower numbers. In addition, stages of insects that do not feed on the crop may still cause economic damage by contaminating crops.

Importance of correct pest identification

The basis of crop protection is correct identification of the problem. For example, many insects are beneficial species rather than pests, and some disease-like symptoms are caused by soil deficiencies rather than by disease organisms. Closer definition of a problem also allows a choice among control measures (biological, cultural, varietal resistance or chemical). If pesticides are chosen, the correct class (insecticide, fungicide, herbicide) must be used for each pest, because the activity of each class is usually limited to specific pest groups. In addition, the activity of individual products within classes may be limited to particular pests. For example, the selective insecticide pirimicarb is only really active against aphids. Correct identification therefore assists control as well as limiting the negative ecological effects of pest control.

For diagnosis of pests and diseases, you can courier or post samples to:

PestLab, AsureQuality Ltd,
131 Boundary Road, Blockhouse Bay,
Auckland 0600
Phone: 0508 00 11 22
Email: pestlab@asurequality.com

Plant Diagnostics Ltd
185 Kirk Road, Templeton,
Christchurch 7678,
Canterbury
Phone: 03 377 9026
Email: enquiries@plantdiagnosticslimited.co.nz

AsureQuality, Plant Health Lab,
South Drive, Lincoln University,
Canterbury 7674
Phone: 0508 00 11 22
Email: pathology@asurequality.com

Costs apply to identifications. Accompanying forms and sampling instructions are available at:

https://www.asurequality.com/our-industries/horticulture/pest/

http://www.plantdiagnosticslimited.co.nz/

For information on common insect pests in specific vegetable crops, refer to crop-specific IPM manuals and insect identification webpage links listed in Section 9 – extension resources.

8.2 MOLLUSCS

Slugs and snails move on a flat foot, which leaves a diagnostic trail of slime on affected plants. They have no marked metamorphosis and reproduction is hermaphroditic. Damage to plants is caused by a rasp-like “tongue”, which causes rough-edged wounds in soft plant parts. Slugs and snails are little affected by most insecticides and require specific chemicals (molluscicides) for their control.

8.3 NEMATODES

Nematodes are members of the animal kingdom but are often classified as plant pathogens because the symptoms they cause are similar to those of fungal and bacterial plant diseases. Plant-damaging nematodes are microscopic (< 1 mm), non-segmented, cylindrical worms sometimes called eelworms. Plant damage symptoms produced by nematodes include dark patches on leaves, and stunting and deformity of stems or roots, depending on the type of nematode. Some nematodes can survive for many years in soil, so crop rotation is the key method of control.

8.4 PLANT DISEASES

Plant diseases are caused by micro-organisms (plant pathogens) that cause disease by interfering with normal plant structure, function or economic value. Plant diseases have many different causes. Some plant diseases can be controlled by suitable agrichemicals; others cannot, so it is very important to distinguish the main types. Knowledge of conditions that favour development of particular plant diseases is important, as attention to good crop hygiene will make conditions less suitable for disease development.

Plant diseases are biotic (caused by a living organism), whereas disorders are abiotic (the causal agent is some chemical or physical factor in the environment). The visual symptoms associated with plant diseases and disorders can overlap, but treatments are quite different. Correct diagnosis is therefore essential. A plant disease condition is the result of interaction among the causal agent, the plant and the environment. This interrelationship forms what is known as the disease triangle, i.e. presence of inoculum (the pathogen), a susceptible host plant, and favourable environmental conditions form the three sides of the triangle (Figure 15).

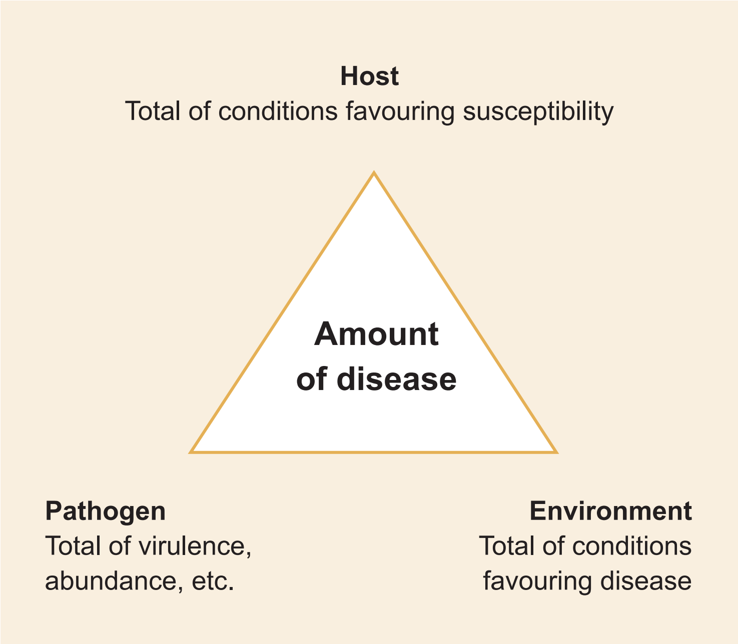


Figure 15. The plant disease triangle.

Many different terms are used to describe disease symptoms. These are useful in distinguishing one type of symptom from another, but give no indication of the causal agent, which may vary widely for closely similar symptoms.

Some common terms are:

- **Blights –** rapidly spreading areas of dead tissue, especially on leaves
- **Spots –** discrete spots of a different colour (usually darker) from the rest of the leaf, stem or fruits
- **Cankers –** dark, sunken areas especially on stems or roots
- **Galls –** swellings or enlargements often of distinct form. Galls can also be caused by some insects and mites
- **Rots –** usually soft, wet breakdown of tissue
- **Wilts –** above-ground parts of plant wilting and drooping
- **Dieback –** shoots dying back progressively from the tip
- **Mosaics –** patchy mottling of the foliage, variegated patches of dark and light tissue forming a mosaic.

The main groups or organisms responsible for diseases are fungi, bacteria and viruses.

8.4.1 Importance of correct disease diagnosis

The basis of successful crop protection is correct diagnosis of the problem.

For example, some disease-like symptoms are caused by soil nutrient deficiencies and do not require pesticide applications. A careful visual inspection of symptoms helps to facilitate the correct diagnosis of a problem, allowing you to select the appropriate control measure(s) (biological, cultural, varietal resistance or pesticides). If pesticides are chosen, the correct class of fungicide or nematicide must be used for each disease, because the activity of some classes is limited to specific disease groups. Publications on plant diseases may assist you with diagnosis, but symptoms vary greatly, so plant diagnostic services may be required for confirmation or authoritative identification. Disease control will not be successful unless the disease is correctly identified.

8.5 PLANT DISORDERS

Plant disorders are not caused by micro-organisms but are instead initiated by nutrient imbalance, extreme weather, or side effects of pesticides. Plant disorders are caused by chemical and physical factors in the environment that can produce damage symptoms on plants resembling those caused by fungi or bacteria. Disorders can reduce yields and sometimes kill plants or prevent them from reaching maturity, and many disorders are often confused with plant diseases.

The main causes of disorders are:

- Lack of nutrients, including trace elements. It may be possible to correct the condition by applying a suitable mineral salt, probably by spraying, e.g. magnesium deficiency.
- Environmental extremes, such as frost, drought, or salt-laden winds.
- Harmful chemicals, especially drift or residual action of herbicides.
- It is important to distinguish plant disorders from diseases or pest damage so that appropriate corrective actions can be taken without unnecessary pesticide use.

CLICK HERE TO SEE SECTION 8 SOURCES

SECTION 9
EXTENSION RESOURCES

SECTION 9
EXTENSION RESOURCES

Extension Resource 1

What is Integrated Pest Management (IPM)? Crop & Food Research Infosheet No. 3-30 2006. Click here to open/view PDF.

Extension Resource 2

Walker G, Wright P, Berry N, Walker M, Cameron P. 2015. Integrated pest management in vegetable brassicas: an information guide. Plant & Food Research, PFR SPTS No. 12388. Vegetables New Zealand Incorporated. The pocket guide (updated February 2016) to pests, natural enemies, diseases and disorders of vegetable brassicas in New Zealand is available for PC use: https://www.freshvegetables.co.nz/assets/J005621-HANDBOOK-Brassica-FINAL-highres.pdf and for Smartphone/Tablet use: https://www.freshvegetables.co.nz/assets/J005621-HANDBOOK-Brassica-FINAL-medres.pdf

Extension Resource 3

New Zealand GAP Integrated Pest Management Principles Code of Practise 2017. https://www.newzealandgap.co.nz/NZGAP_Public/NZGAP_Public/Growers/Guidelines.aspx

Extension Resource 4

New Zealand GAP Checklist, 2018. https://www.newzealandgap.co.nz/NZGAP_Public/Growers/Checklists/NZGAP_Public/Growers/Checklists.aspx?hkey=d4d1f8e3-b9f1-483e-bed5-8106815d32a2

Extension Resource 5

New Zealand GAP Erosion & Sediment Control Guidelines for Vegetable Production. https://www.newzealandgap.co.nz/NZGAP_Public/Growers/Guidelines/NZGAP_Public/Growers/Guidelines.aspx?hkey=4dcf643d-8138-43cb-9c22-6d3a3d2f2f80#Environment

Extension Resource 6

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Extension Resource 9

Desire® technology pheromone traps www.etec.co.nz

Extension Resource 10

Scentry® pheromone traps www.scentry.com

Extension Resource 11

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https://www.freshvegetables.co.nz/assets/Sweet-Corn-Toolkit-Manual-V2-1-Part2.pdf

Extension Resource 12

New Zealand Plant Protection Society Website – Pesticide Resistance Strategies https://resistance.nzpps.org/

Extension Resource 13

Arthropod Pesticide Resistance Database https://www.pesticideresistance.org/index.php

Extension Resource 14

Insecticide Resistance Action Committee (IRAC) website – Resistance management for sustainable agriculture and improved public health https://www.irac-online.org/

Extension Resource 15

New Zealand Plant Protection Society Website - Herbicide resistance in New Zealand: http://resistance.nzpps.org/index.php?p=herbicides/introduction

Extension Resource 16

Foundation for Arable Research Website – Herbicide Resistance https://www.far.org.nz/research/weeds_and_pests/weeds/herbicide_resistance

Extension Resource 17

Foundation for Arable Research Website - Guidelines for minimising the development of glyphosate resistance in weeds in arable and vegetable crops https://www.far.org.nz/assets/files/editable//43ce016b-af9a-4470-a2c1-8e5ad58c33f8.pdf

Extension Resource 18

AsureQuality Ltd, Pest and Disease identification services https://www.asurequality.com/our-industries/horticulture/pest/

Extension Resource 19

Plant Diagnostics Ltd, Pest and Disease identification services http://www.plantdiagnosticslimited.co.nz/

Extension Resource 20

PGG Wrightson – Vegetable Crop Monitoring Programmes https://www.pggwrightson.co.nz/Services/Fruitfed-Supplies/Vege-Crop-Monitoring

Extension Resource 21

Landcare Research – What is this bug? https://www.landcareresearch.co.nz/resources/identification/animals/bug-id/what-is-this-bug

Extension Resource 22

AgPest™ from agresearch - a free tool to assist New Zealand farmers and agricultural professionals in decision-making regarding weed and pest identification, biology, impact and management. http://agpest.co.nz/

Extension Resource 23

iNaturalistNZ – a free online resource to help identify and learn about all the species living around you https://inaturalist.nz/

Extension Resource 24

Veg Pest ID – free Google Play app to help farmers and agricultural professionals identify pests on Australian vegetable crops. https://play.google.com/store/apps/details?id=com.ahr.layout

Extension Resource 25

PestNet Community – free online network that helps people worldwide obtain rapid advice and information on crop protection, including the identification and management of plant pests. Join here: http://www.pestnet.org/PestNet.aspx

Guideline
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RETURN TO SECTION 8

NOTES




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