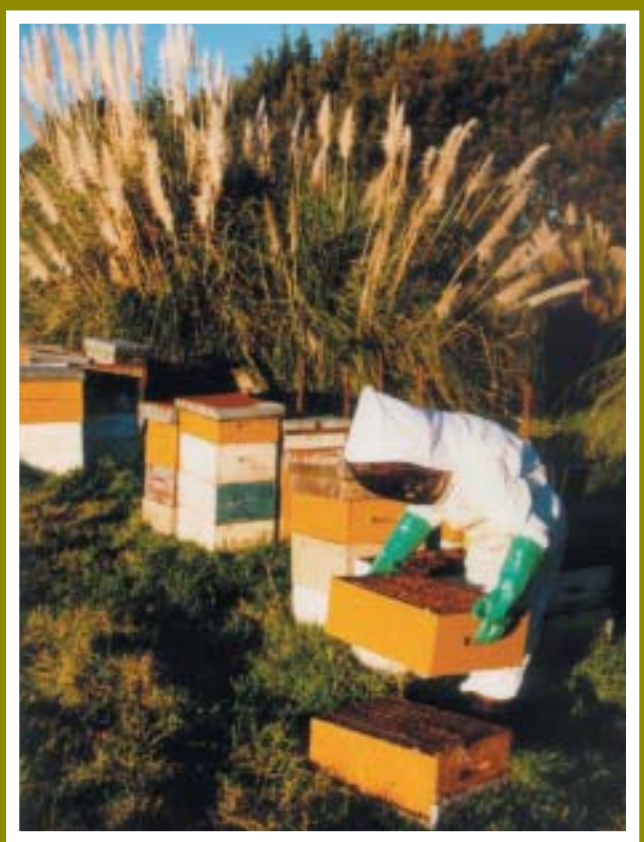

CONTROL OF VARROA

A Guide for New Zealand Beekeepers

Ministry of Agriculture
and Forestry
Te Manatu Ahuwhenua,
Ngaherehere

CONTROL OF VARROA
A Guide for New Zealand Beekeepers

has been published by the Ministry of Agriculture and Forestry as part of its on-going assistance to the New Zealand beekeeping industry following the recent discovery of this important new honey bee pest.

The guide aims to give beekeepers the practical tools they will need to minimise the effects of varroa while continuing to produce wholesome bee products and provide vital pollination services.

The guide reviews the world literature on varroa control and puts the information in a straightforward, easy-to-reference form that will be useful to all beekeepers, whether they are hobbyists, or commercial producers.

With 7 diagrams and 24 colour plates.

Mark Goodwin is a senior scientist at the Horticulture and Food Research Institute (HortResearch), and is playing a leading role in New Zealand's research efforts in varroa control.

Cliff Van Eaton is also an apiculture scientist at HortResearch, and is a long-time advisor to New Zealand beekeepers.

Together they have also written *Elimination of American foulbrood without the use of drugs*, published by the National Beekeepers' Association of New Zealand in 1999.

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A Guide for New Zealand Beekeepers

by

Mark Goodwin and Cliff Van Eaton

New Zealand Ministry of Agriculture and Forestry

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IMPORTANT DISCLAIMER

This book is a guide on the range of control methods available for the treatment of varroa. The control methods discussed will not be appropriate in every situation.

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The following products mentioned in this guide are registered trade names:

Apicure
Apiguard
Apilife VAR
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Apitol
Apivar
Bayvarol
Check-Mite+
Folbex
Mavrik
Mite Away
Perizin
Tween

It is illegal in New Zealand to use a chemical substance to control varroa that has not been registered or approved by the New Zealand government.

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Mark Goodwin is a senior scientist with the Horticulture and Food Research Institute of New Zealand Ltd (HortResearch), and is stationed at the Ruakura Agriculture Centre in Hamilton. Mark and his team have conducted extensive work in the fields of honey bee pollination and American foulbrood control, and he is now playing a leading role in New Zealand's research efforts in varroa control.

Cliff Van Eaton is an apiculture scientist with HortResearch. Cliff has been an Apicultural Advisory Officer with MAF Quality Management, and was national manager for the American Foulbrood Control Programme from 1991 to 1998. He is co-author with Mark Goodwin of *Elimination of American foulbrood without the use of drugs*, published by the National Beekeepers' Association of New Zealand in 1999.

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Ambrosiushoeve Research Centre for Insect Pollination and Beekeeping – Figure 2.4

Bee Research Laboratory, US Department of Agriculture – Figure 2.1

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Keith Pegram – Figure 8.2

Mid-Atlantic Apiculture Research and Extension Consortium – Figures 2.6, 3.1, 5.3

University of Nebraska Institute of Agriculture and Natural Resources – Figure 5.6

HortResearch – all others

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Why should you control varroa?

If left uncontrolled, varroa will eventually kill your honey bee colonies. You can successfully keep bees in areas where varroa has become established, but you will need to use control methods on a regular basis to reduce mite numbers so they do not seriously affect your hives.

What follows is a very brief summary of varroa control methods presented in this guide. The numbers in brackets identify chapters and sections where important information is discussed in greater detail.

Do your bees have varroa?

The first step is to determine whether your honey bee colonies have varroa. To do this you need to know what varroa looks like and be able to distinguish it from melittiphis, a smaller mite that is also found in hives.

Varroa mites have a reddish to dark brown body that is flattened and oval (2.1). Melittiphis is about one quarter the size of varroa and is different in shape. It does, however, tend to be similar in colour to varroa (5.2).

How should you look for varroa?

Don't rely on visually inspecting adult bees for varroa. Because varroa often hide between the plates of a bee's abdomen, you are not likely to see the mites on bees unless the varroa population in the colony is very high (2.1 and 5.3.2).

Change your beekeeping management to effectively sample your hives for varroa on a regular basis. There are a number of very good methods you can use (5).

What varroa sampling method should you use?

If varroa hasn't been reported in your area, you should use a very sensitive sampling method. The most accurate and easiest is Apistan or Bayvarol put into a hive for 24 hours, together with a sticky board to collect the mites that are killed (5.3.9). Since varroa prefer to reproduce on drone brood, checking capped drone brood with a cappings scratcher can also be a sensitive test (5.3.3).

If varroa is in your area, you need to survey your hives throughout the beekeeping season to determine if mite populations are reaching potentially damaging levels. Washing a sample of bees in soapy water (5.3.5), using the sugar shake method (5.3.6), or checking natural mite fall with mesh bottom boards (5.3.8) are all reliable methods.

To decide if mites are reaching damaging levels, you can use the thresholds for these sampling methods presented in chapter 5, or you can calculate the total mite population for a colony using the formulas in appendix 1.

When should you apply a varroa control?

If mites have only just moved into an area during the year and your colonies have very few mites (less than 20 per hive), it probably isn't worth applying a varroa control immediately.

However, in the second and following years after varroa has been found, it is very important to survey hives in every apiary on a regular basis to ensure mite numbers don't sneak up on you. In the acute phase (4.2.3), mite invasion from other colonies can be very high, especially in late summer and early autumn (4.2.2).

During the acute phase, you should treat all of your hives for varroa as a matter of routine, rather than relying solely on survey results (11.2.2). Control should always be carried out at least in the spring and autumn, and at other times during the season if surveying shows that it is required.

What should you do differently in spring?

It is important to have good mite control in spring because the large amounts of brood in the hive will provide ideal breeding conditions for the mite. Not providing a high level of control in spring can result in colonies collapsing before the autumn treatment (11.6).

When inspecting your hives in spring, parasitic mite syndrome may make it more difficult to diagnose other brood diseases. Get a laboratory diagnosis if half-moon shaped larvae are found in a colony because both parasitic mite syndrome and European foulbrood can have the same symptoms (3.2.2).

What should you do differently in summer?

Because mites can invade your colonies after the treatment, you should sample at least once in the summer between treatments in case mites have built up to damaging levels again very quickly. If this is the case, you will need to remove the honey from the hives and treat them again.

What should you do differently in autumn?

Don't be complacent just because your hives have strong populations and are producing a good honey crop. If honey isn't removed as soon as the flow has ended and treatment carried out, good colonies are likely to collapse suddenly during autumn as a result of mite invasion (3.2.3).

You may need to change your beekeeping management to remove your honey earlier than you have in the past. Even forgoing some honey production is not as bad as losing colonies to varroa (11.4).

Beekeepers around the world have been caught out by varroa invasion in autumn. Don't let strong colonies fool you. Apply an effective varroa control.

What control methods should you use?

A number of organic (6.3) and synthetic chemicals (6.2) are used world-wide to control varroa. It is very important, however, to only use compounds that have been registered or approved for varroa control in New Zealand.

Make sure you follow control product label directions exactly. They have been written to protect you, your bees and the people who consume your bee products (6.1).

There are also a number of control methods that rely on hive manipulation (8). However, most of these methods are time-consuming, and may not by themselves provide adequate varroa control, especially during the acute phase.

During the acute phase, you will not only want to control varroa in your hives, you will also want to reduce mite invasion. Choosing a method that offers control for an extended period of time is therefore important. Apistan (6.2.1) or Bayvarol (6.2.2) both provide very good mite control and also offer protection over six to eight weeks. Formic acid in a pouch (6.3.2.1) can also provide good extended control, although handling formic acid is potentially hazardous (appendix 2).

How can you tell if the control method has worked?

After applying a mite control, it is important to sample some of your colonies again to make sure mite populations have been reduced to low levels (10.4). If mite numbers are still high, you will need to re-apply a control, even if this means removing the honey from your hives.

How can you minimise residues from mite control chemicals?

You need to be careful when using mite control chemicals to minimise residues in bee products (6.4). The best way to do this is by carefully following the instructions on the product label. It is especially important not to use control chemicals when there are honey supers on a hive.

How can you help avoid mites developing chemical resistance?

Varroa can develop resistance to chemical controls (7). To help avoid resistance, you should use different control products in the spring and autumn (7.6).

All varroa control products should also be used according to the label, and they should especially not be left on hives for longer than recommended (7.4).

If your control does not appear to be working, a sample of mites from your colonies should be tested for resistance (7.7).

When can you start reducing your use of chemical controls?

Integrated pest management programmes are designed to reduce beekeepers' use of mite control chemicals (10). However, it is important to apply these chemicals on a regular basis until varroa has destroyed most feral colonies and mite invasion has reduced.

Once the acute phase is over, you will better be able to predict mite population growth in your colonies and tailor your control programme accordingly. You will also be able to use a greater variety of control methods, including biotechnical measures, which together may provide effective control.

Varroa Control – Simple Do's and Don'ts

Do:

- ✓ Change your beekeeping to regularly survey for varroa.
- ✓ Routinely apply a control in the spring and autumn during the acute phase.
- ✓ Survey hives at least once in the summer in case mite levels have built up quickly again.
- ✓ Apply mite control if varroa numbers are high, even if honey supers have to be removed.
- ✓ Remove your summer honey crop earlier than in the past.
- ✓ Follow varroa control product label directions exactly.
- ✓ Choose a control method that offers control over an extended period to reduce mite invasion.
- ✓ Use a different control product in the spring and autumn.
- ✓ Have a sample of mites tested if a control product doesn't seem to be working.

Don't:

- ✗ Rely on visually inspecting adult bees for varroa.
- ✗ Be complacent about varroa just because your hives are strong and are producing a good crop.
- ✗ Take your honey off late in the season and only then decide to apply a varroa control.
- ✗ Get caught out by varroa invasion.
- ✗ Use compounds that haven't been registered for varroa control.
- ✗ Assume your mite control has worked without checking.
- ✗ Apply control chemicals when there are honey supers on the hive.
- ✗ Leave a control product on hives longer than the label says.
- ✗ Consider reducing chemical controls until after the acute phase is over.

Words of Wisdom from Overseas…

Colonies infested with varroa can appear completely normal, lulling you into a false sense of security.

But when population levels of the mite build up, damage can occur suddenly and swiftly, often wiping out colonies and catching you by surprise.

The failure to appreciate this fact is the main reason beekeepers lose colonies even after they know they have varroa.

1. INTRODUCTION

1.1 History of varroa

Varroa disease, or 'varoosis', is caused by the external parasitic bee mite *Varroa destructor*, known until recently as *Varroa jacobsoni*. Varroa's scientific classification was changed in 2000 when it was determined that the mite commonly infesting the European honey bee (*Apis mellifera*) around the world was actually a different species from the one first identified on the Asian honey bee (*Apis cerana*) in Java in 1904.

Varroa mites were originally parasites of *Apis cerana*, and the two species have probably existed together for hundreds of thousands of years, with the mite killing a few colonies but never enough to endanger *A. cerana* as a species. The reason, of course, is that without the bees the mite would also die. Evolution treats harshly any parasite or predator that does not obey this basic rule.

However, by 1963 varroa had jumped species and could be found on *Apis mellifera* in the Philippines, Japan, Vietnam and Russia. On a new honey bee species that had little resistance to it, varroa didn't follow the parasites' rule, and since then it has killed millions of European honey bee colonies in Asia, Europe, the Americas and Africa.

By 1999, varroa had been reported in most beekeeping areas of the world with the exception of Australia and New Zealand. This changed in April 2000 when the mite was found in Auckland. The survey that followed confirmed a large number of colonies infested in the Auckland region and northern Hauraki Plains. Isolated infestations were also found in hives in the Hokianga, Te Puke, Otorohonga and the Taumarunui area (figure 1.1).

After consultation, the New Zealand government decided an attempt to eradicate varroa would be unlikely to succed, and adopted a managed control programme instead. Varroa can be expected to spread over all of the North Island and eventually to all of the South Island, although it is hoped that the movement controls established by government will help to slow this spread.

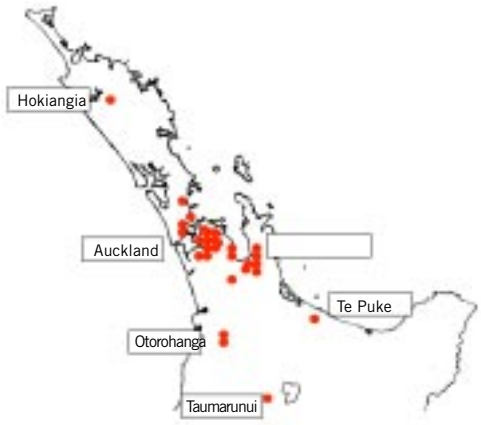


Figure 1.1 Reported distribution of varroa in New Zealand in October 2000 (red spots).

1.2 The future

The finding of varroa has changed forever the practice of beekeeping in New Zealand. We have always prided ourselves on the high-health status of our honey bee stocks and the fact that we do not use antibiotics to control American foulbrood disease. Our beekeeping industry has benefited greatly from these things, and we have developed world-respected trades in honey bee stocks and value-added honey bee products.

We still have a beekeeping industry that is the envy of most, but we also have a new test of our abilities and resources. Now, like most of the rest of the world, we must face one of the most devastating parasites of honey bees.

While the finding of varroa has been a tragedy for everyone involved in beekeeping in this country, we are at the same time fortunate to be one of the last places on earth to feel the effects of the mite. Varroa has been the greatest topic of beekeeping research world-wide in the last 20 years. Much has been learnt about the mite's biology, its impacts, and most importantly how it can be controlled.

The presence of varroa in New Zealand will result in greater changes in beekeeping practices than it has in many other places. This is because beekeepers here have generally not resorted to chemicals to control the relatively few honey bee diseases and pests that are present.

The need to control varroa will require a shift in the belief systems for most New Zealand beekeepers – a shift from being 'natural' producers, to producers that cannot survive without the use of pesticides; from thinking of pesticides as something that kills bees, to thinking of them as products that ensure the bees' survival. And with this change in belief systems comes a whole range of new concepts such as monitoring, economic thresholds, timing of treatments, resistance and residues.

Although the change is large for beekeepers, we have a well-organised and sophisticated industry that is better placed than many to meet the challenge. Our world-leading approach to AFB control and our highly organised pollination industry are just a couple of examples of what we know we can do.

There is no simple recipe that will win the battle against varroa. The mite has so far proven too resourceful for that, and much more investigation and innovation still needs to take place. However, in New Zealand we can employ methods well-proven overseas to reduce the effects of the mite, and we can also trial more speculative techniques to develop a uniquely 'kiwi' approach that will carry on our reputation of beekeeping excellence.

The success with which individual beekeepers meet the challenges ahead will depend on how well they are able to adapt to the changes required. Unfortunately, varroa is a problem that cannot be ignored. There is no doubt that beekeepers who learn from overseas experience with varroa, and in time the experience of their fellow beekeepers here in New Zealand, will cope with the mite and maintain profitable beekeeping. However, those who chose to ignore the mite, or hope it will go away, will also likely follow the path seen overseas, and will no longer remain part of the beekeeping industry in the years to come.

Success in fighting varroa will depend on how well beekeepers are able to adapt to changes required in their beekeeping management.

Overseas experience has shown that many beekeepers go through a learning process with varroa that has the following steps:

1. do nothing about varroa control because their hives look good (large populations, good crops);
2. experience sudden colony collapses and large losses;
3. carry out regular varroa control treatments following the calendar;
4. begin to monitor their hives in an attempt to reduce chemical use;
5. develop a good understanding of varroa population growth in their own area; and finally,
6. develop a good varroa control programme based on this understanding.

The purpose of varroa control education is to minimise the effects of the first two steps in this process, and to ensure management changes are made so that the endpoint of the process is reached as soon as possible.

1.3 Aim of this guide

This guide aims to provide beekeepers with the practical tools they will need to minimise the effects of varroa while still maintaining the industry's core values of environmental responsibility and the need to remain economically viable.

As authors, we are certainly not specialists in varroa control, and like almost everyone keeping bees in this country we only have a small amount of experience of the mite in New Zealand conditions. The purpose of this guide is therefore not to offer a proven set of New Zealand-based prescriptions along the lines of the authors' book entitled *Control of American foulbrood without the use of drugs*.

The guide is instead an attempt to review the world literature on varroa and put it in an orderly, easy-to-reference form that makes sense to beekeepers. There are a number of concepts that will be foreign to most New Zealand readers, which is expected given the newness of the mite to our beekeeping. However, we hope we have explained them well enough so they become part of our normal vocabulary as we all learn to deal with varroa. The guide also does not attempt to provide a complete summary on all that is known about the subject. We have instead only included information we considered useful for understanding how varroa can be controlled.

While this guide is based on overseas research, it is important to remember that it is difficult to predict how the mite will behave throughout New Zealand. Although the conditions within our beehives are very similar to overseas, our bees have been genetically isolated from the rest of the world for more than 50 years, we have fewer pathogens for varroa to interact with, and there are differences in the way we manage our bees. Climatic differences between the northern and southern areas of New Zealand may also cause varroa to have varying effects, and the situation in New Zealand is also changing quickly as varroa spreads and new pesticides are being registered and used.

Nevertheless, utilising international experience is an invaluable first step as we learn to live with varroa in New Zealand. Using and adapting overseas techniques is better at the outset than trying to develop local methods from scratch.

At the same time we hope that the guide will be revised in several years as new research findings and management techniques for varroa control are developed, both overseas and particularly in New Zealand.

This guide is a review of the world literature on varroa; produced for New Zealand beekeepers, not a proven set of New Zealand-based varroa control methods.

2. VARROA BIOLOGY

This chapter describes varroa and explains its lifecycle.

2.1 Varroa on adult bees

Adult female varroa mites (figure 2.1) are fairly large (1.1 x 1.6mm) and have a hard, reddish to dark brown body that is flattened and oval in shape. Male mites are smaller than females, and are rarely seen since they are only found inside brood cells.

Varroa are quite fast moving when not in brood cells and can run quickly over the comb surface. When they are being carried on adult bees, they frequently crawl under the overlapping abdominal plates where they feed on haemolymph (bee blood). Because of this behaviour, mites can reach a high population within a colony even though only a few varroa will be easily visible on adult bees (figure 2.2).

Figure 2.1 Adult female varroa mite.

An example from work carried out by HortResearch illustrates how hard it is to see varroa on adult bees. As part of a trial in South Auckland, samples of 200 bees were needed that were heavily infested with mites. However, the colonies themselves didn't appear to have many varroa. So the researchers made sure they put three bees that visibly had mites into each sample jar before filling the jar with other bees from a hive. This ensured each sample had at least three varroa, even though it took quite a while to find the visibly infected bees. However, when the 200 bee samples were processed for varroa in the lab, between 100 and 150 varroa were recovered from each jar.

Figure 2.2 Two varroa mites on a bee. The top-most mite has crawled between the bee's overlapping plates of the bee's abdomen and is partially hidden.

Varroa usually only stay on adult bees for about 7 days before entering an uncapped cell with a larva. They do, however, stay on bees for much longer than this when there is no brood in a colony. Very few of these mites are removed and killed by worker bees. Studies show that varroa can only survive away from bees or honey bee brood for about $5^{1}/_{2}$ days, but they can live on adult bees for long periods of time. We know this because the mite is able to survive long broodless periods during severe winter conditions.

Varroa can reach high population levels in a honey bee colony even though few mites are visible on the adult bees.

Mites find their way into colonies through beekeepers exchanging equipment between hives, bees with varroa drifting between colonies, and bees robbing colonies weakened by varroa.

Although varroa has been seen on other insects (and sometimes even on beekeepers when they have just finished working a hive), the mites can only reproduce on honey bee brood.

Varroa can survive for long periods on adult bees.

2.2 Varroa on bee brood

The life cycle of varroa is presented in figure 2.3. Adult female varroa leave adult bees and invade either worker cells about 20 hours before they are capped, or drone cells 40 hours before they are capped. The mites prefer to invade cells containing drone larvae. Drone cells are 8 to 10 times more likely to contain varroa than worker cells.

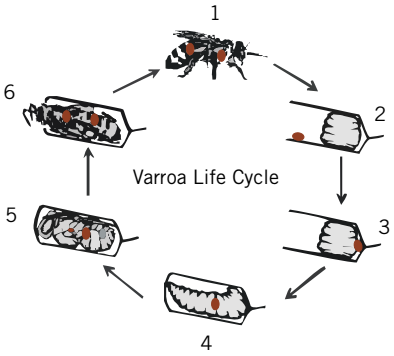


Figure 2.3 Varroa life cycle (clockwise from top). Step 1 – varroa mites are transferred to new colonies on adult bees. Step 2 – the mite then leaves the adult and crawls into a brood cell. Step 3 – once in the cell, the mite submerges itself in the larval food at the bottom of the cell. Step 4 – when the cell is capped, the mite leaves the larval food and starts feeding on the prepupa. Step 5 – the mite then lays eggs, which hatch and go through two juvenile stages before taking on the adult body shape. Step 6 – the adult mites leave the cell when the bee emerges. The mites are then transported on adult bees until they enter another brood cell.

On entering a cell, the female mite crawls down to the bottom and submerges itself in the larval food. Within the first 4 hours of the cell being capped, the mite leaves the larval food and starts feeding on the haemolymph of the prepupa (figure 2.4). 'Feeding sign' (which is actually mite faeces) appear as white dots at the hind end of the prepupa. Feeding sign can also be seen on the walls of brood cells once the adult bee has emerged.

The mite lays its first eggs about 60-70 hours after the cell is sealed. Varroa usually deposit 5-6 eggs in a cell, the first of which is usually a male, with the remainder female.

After the egg hatches, the mite goes through two juvenile stages (protonymph and deutonymph) before finally reaching maturity and taking on the adult body shape (figure 2.5).

The mother mite establishes a feeding site on the pupa that her offspring then use to obtain food as they grow. The mites also add to the feeding sign of mite faeces on the hind end of the pupa.

Usually only 4-5 of the eggs that are laid (1 male and 3-4 females) have time to hatch and complete their development before the bee is ready to emerge. The new generation of mites mate in the cell before the host bee hatches. Only mature female mites survive to leave the cell when the bee emerges (figure 2.6). Males and juvenile

Figure 2.4 Varroa on drone prepupae.

Figure 2.5 Adult female varroa on a drone pupa.

females die in the cell. Some female mites can produce more than one generation by invading a second brood cell, and small numbers are even able to invade a third cell.

Since not all the new females survive, the reproduction rate is usually only about 1.3 new mature female mites per mother mite in worker cells and 2.6 in drone cells. This rate of reproduction decreases if more female mites invade each cell.

Figure 2.6 Juvenile (white) and adult (brown) varroa mites feeding on a bee prior to emergence. The bee has been removed from its cell for this picture.

Varroa prefer drone brood.

3. EFFECTS OF VARROA

This chapter explains the effects of varroa on brood, adult bees, and honey bee colonies. The chapter includes a description of parasitic mite syndrome.

3.1 Effects on bees

The effects of varroa on adult bees come about either:

- from the mite feeding directly on the haemolymph (blood) of the adult bee; or
- as a result of feeding by the mother mite and her offspring on bee larvae or pupae in the cell, and the subsequent effect this feeding has on the development of the pupae into adults.

3.1.1 Effects of varroa feeding on adult bees

Effects stemming from mites feeding on adult bees can include:

- **Consumption of haemolymph** – An individual mite consumes about 0.2 microlitres of bee haemolymph during its life. However, this blood loss doesn't appear to have a direct negative effect on an otherwise healthy bee.
- **Changes in the haemolymph** – (see also 3.1.2). There appear to be some changes in the immune components of haemolymph in bees fed on by varroa. The reason is unknown, although it may be due to the reduction in the amount of haemolymph or the reaction of the bee's immune system to the hole made where the mite feeds.
- **Introduction of viruses** – (see also 3.1.2). Acute paralysis virus (APV) is normally not thought to cause disease symptoms in bees (i.e., it is 'inapparent'), but there are suggestions that the virus can increase in bees when it enters their haemolymph as part of the varroa feeding process. It is also believed that bees with high levels of APV can then pass on the virus to other adult bees and larvae through food exchange and feeding. APV appears to kill adult bees in varroa-infested colonies, as well as larvae fed by nurse bees with high levels of APV caused by varroa.

  Increased levels of chronic paralysis virus (CPV) have been found in bees infested with varroa. CPV can also produce disease symptoms (crawling, shaking, 'hairless black' coloration caused by bees pulling at the hairs of the diseased bee) in bees that are not infested with varroa.

  In the laboratory, Kashmir bee virus (KBV), like APV and CPV, has been shown to cause death in bees from injection, and it is speculated that KBV may be spread by varroa. KBV and APV are very closely related viruses. Other viruses also appear to have associations with varroa (e.g., slow paralysis virus, deformed wing virus, cloudy wing virus).

  Bee viruses known to be present in New Zealand include sacbrood, chronic bee paralysis, acute bee paralysis, Kashmir bee virus, black queen cell virus, bee virus X, bee virus Y, cloudy wing virus and filamentous virus. Not all of these are likely to become associated with varroa.

Varroa can seriously affect adult bees by introducing viruses into the bees' blood.

3.1.2 Effects of varroa feeding on honey bee larvae or pupae

Varroa feeding on honey bee larvae or pupae can have several effects:

- **Decreased body weight of adults** – The greater the number of mites in a cell with a pupa, the lower the weight of the emerging adult bee and the bee at 6 days old. Those with 1-3 mites weighed 10% less than uninfested pupae, and those with more than 3 mites weighed 22% less. Worker bees suffer greater weight loss from varroa than drones (drones had only a 7% weight loss in one study).
- **Deformed wings and abdomens** – The number of bees with deformed wings and abdomens increases with the number of mites on the pupa (figure 3.1). However, some studies have shown low wing deformity even when mite levels are very high, and deformed wings can also be caused by a virus. (See also *Introduction of viruses* below.)
- **Smaller hypopharyngeal glands** – Hypopharyngeal glands are partly responsible for producing royal jelly. Pupae with 1-3 mites had 13% smaller hypopharyngeal glands as adult bees, and those with more than 3 mites had 31% smaller glands.
- **Loss of protein in the haemolymph** – A study showed that protein in the bee's blood decreased as the number of mites on the pupa increased, with a 27% reduction for 1-3 mites and up to 50% with more than 3 mites.

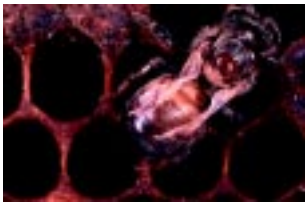


Figure 3.1 A bee with deformed wings caused by varroa previously feeding on the bee in the brood

- **Introduction of viruses** – Mites have been shown in laboratory studies to be able to transfer acute paralysis virus (APV) and other viruses to pupae. Deformed wing virus (DWV) has been found in pupae infested with varroa and also in non-infested pupae. However, not all deformed wings in varroa-infested pupae are caused by DWV, and pupae with high levels of DWV also often do not display deformed wings. Mites are able to transfer DWV from an infected pupa to a non-infected pupa.
- **Reduced emergence rates of drones** – Drone brood is 8 to 10 times more likely to be parasitised by varroa than worker brood, and the effects on drone brood can be much more severe. In one study, while the amounts of drone brood produced in both types of colonies were similar, significantly fewer drones from varroa-infested colonies were alive after one day (60%) compared to non-infested colonies (97%). In another study, the figures were 65% alive for non-infested pupae, 37% for pupae with 1-3 mites, and 23% for pupae with more than 3 mites. A large percentage of surviving drones from infested pupae could not fly, although they looked normal (57-64% non-flying compared with 5% in non-infested pupae).
- **Changes in drone physiology** – Slight changes have been recorded for sperm amount and sexual gland weights in drones from varroa-infested colonies, although in a study of drones developing from non-infested pupae, and those with 1-3 mites and more than 3 mites, the figures were more significant (i.e., 8.8 million sperm for non-infested compared with 5.3 and 4.3 million for the two infestation rates).
- **Drone flight times and ability to mate** – No significant difference between infested and non-infested colonies was found in drone flight times and duration of flights, as well as the ratio of sperm in queens from drones from the two types of colonies.

Drones suffer the most significant effects from varroa infestation.

So it would appear that drones from infested colonies that do survive and mate are fully functional, and that queens ensure their mating requirements are met on the basis of total sperm amount received, not the number of drones they mate with.

- **Changes in the age foraging begins** – One study showed foraging began at 7 days old with varroa infested bees compared to 12 days old for uninfested bees, although other studies showed no difference in the age foraging begins.
- **Difference in return to hives following orientation flights** – 20% of bees from non-infested colonies did not return, whereas 36% of bees from infested colonies did not return.
- **Reduction of lifespan of workers** – Adult bees developing from uninfested pupae live longer, with 1/3 of these bees still alive after 35 days, compared to 8% for bees coming from infested pupae. However, the reduction appears to be related to the time of year. One study showed a big difference in lifespan towards the end of summer (when there is a greater natural die-off of bees), whereas at the beginning of summer there was no significant difference. As well, no correlation has been found between differences in bee weight and lifespan of bees coming from infested pupae, or between the protein content at emergence and lifespan. The lack of correlation suggests a more important influence may be viruses such as APV, although a range of other factors may also come into play.
- **Reduction of lifespan of drones** – The difference in emergence rates for drones (see above) continues over the rest of their lifespan, with about 50% of drones from non-infected colonies remaining between 5 and 11 days, compared with about 30% for drones from infected colonies. At 12 to 18 days, the figures drop to 37% and 20% respectively.
- **Reduction in foraging** – Some studies have shown less flights of shorter duration for bees coming from infested pupae, resulting in less total foraging time. Other studies have shown no difference in frequency and duration.
- **Reduced wax secretion** – Abnormalities have been found in the wax secretion of bees coming from infested pupae, although little research has been done in this area.
- **Reduced tolerance to pesticides** – Bees from infested pupae showed less tolerance to two common pesticides (endosulfan and coumaphos). This is thought to be due to reduced weight of fat bodies in these bees compared to bees from non-infested pupae. A bee's fat bodies can absorb and neutralise the effects of small amounts of pesticides.

Varroa can reduce the lifespan of worker bees.

3.2 Effects on colonies

Taken together, the effects on individual bees can result in a rapid reduction in the number of adult bees in the hive, abnormal brood, robbing of the colony and/or absconding of the bees. The final outcome, unless treatment is used to reduce the population of the mites, is usually colony death.

However, caution is needed when using research results on the effects of the mite on individual bees to make predictions about honey bee colonies as a whole. Studies have

Honey bee colonies will die from varroa infestation unless treatment is used to reduce the population of mites.

shown that the lifespans of adult bees infested as pupae are not always reduced, which suggests to some observers that the mite itself is not the only (or even major) reason for these negative effects. Other factors suggested include climate, food sources and secondary infections of other diseases. It is also important to consider the build-up in both mite populations and honey bee populations in a colony (see 3.2.3 *Effects on colony production* below).

The effects of varroa on individual bees do not necessarily translate to similar effects on the colony as a whole.

3.2.1 Effects on feral colonies

It is commonly assumed that if a honey bee colony infested with varroa is left untreated, it will eventually die. This is because varroa was originally a parasite of *Apis cerana* and it is said that *A. mellifera* has so far not developed sufficient defences to the mite through natural or human-assisted selection to survive infestation.

Feral colonies are the most likely to succumb since they are by definition not managed by humans and treated to control mites. A study carried out in California tracked the survival of feral colonies both before and after the introduction of varroa. In 1990, 208 colonies were tested and none had varroa. By 1993, 75% of the colonies no longer existed and all remaining colonies had varroa. On average, varroa was shown to reduce the life span of feral colonies to between 6 months and 1 year. Interestingly, the mite was found more widely spread in feral colonies in areas where there was substantial commercial beekeeping, suggesting managed colonies were a major source of infection back to the ferals.

A similar study in Arizona showed a somewhat different picture, however. Feral colony losses increased dramatically in the early 1990s, but this appeared to be caused by tracheal mite rather than varroa. In 1996, all but two of the feral colonies had varroa, and the population went from 155 in the summer of 1995 to 12 in spring 1996. The population then increased again to 59 in the summer, falling back to 22 in spring 1997.

The re-establishment of ferals the next spring shows that feral colony populations are never static. We can assume that even in areas where varroa is widespread, managed colonies will still produce swarms each spring that will take up nest sites.

Varroa infestation results in the loss of many feral colonies, although the population of feral colonies is always being renewed from managed colonies.

3.2.2 Parasitic mite syndrome

'Parasitic mite syndrome' is a name given to a range of abnormal brood symptoms that began to be noticed by beekeepers and the US Department of Agriculture Bee Research Laboratory in the mid-1990s. The symptoms were found in association with infections of both varroa and tracheal mite. Parasitic mite syndrome has also been found in varroa-infested colonies in New Zealand.

Important points to note about parasitic mite syndrome:

- Affects both brood and adult bees.
- May be associated with colony collapse.

- Symptoms can appear at any time of the year, although they are more prevalent in mid-summer and autumn.
- Not all symptoms described below are necessarily present in a colony that has the syndrome.

Adult symptoms of parasitic mite syndrome include:

- Presence of varroa in the colony.
- Reduction in colony population.
- Crawling bees leaving the hive.
- Supersedure of the queen.

Brood symptoms of parasitic mite syndrome include:

- Presence of varroa on pupae.
- Typical brood symptoms for American foulbrood (AFB), sacbrood and/or European foulbrood (EFB) (Note: EFB has not been found in New Zealand, but a condition resembling EFB called half-moon syndrome is sometimes present in colonies).
- Symptoms can sometimes disappear if the colony is fed with the antibiotic oxytetracycline or sugar syrup, or if Apistan strips are used (Note: feeding oxytetracycline to honey bee colonies is not permitted in New Zealand).
- The age of brood affected by the syndrome can vary from larvae 'c-shaped' in the bottom of the cell through to prepupae (larvae lying out along the side of the cell).
- Affected brood can be found anywhere on the comb.
- Larvae can be:
  - twisted up the side of the cell (this is also a symptom of EFB and half-moon syndrome) (figure 3.2);
  - molten/slumped down in the bottom or along the side of the cell (this is also a symptom of sacbrood);
  - light brown, grey or black in colour.
- Larvae can look like the early stages of AFB (light brown in colour, slumped down along the side of the cell), but do not rope out when a stick is inserted into a larva and then slowly removed.
- Scales (dried down larval remains along the side of the cell) can be formed, but they are soft and can be easily removed. AFB scales are brittle and stick strongly to the side of the cell.
- The larvae do not have any particular smell.

Parasitic mite syndrome is a sign of heavy varroa infestation.

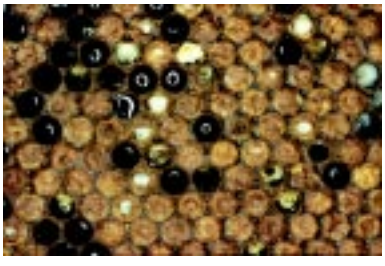


Figure 3.2 Parasitic mite syndrome (discolored cells).

Larvae affected by parasitic mite syndrome have been analysed for various bacteria and fungi, but no specific causative organism has been found and no bacterial type is dominant.

It has also been speculated that parasitic mite syndrome is caused by acute paralysis virus (APV), with varroa injecting the virus into adults, where it builds up to lethal proportions and where the virus is also passed on by infected adults to the brood by feeding.

However, the USDA has analysed samples of adult bees from colonies with parasitic mite syndrome and has found that in a majority of the cases neither APV, Kashmir bee virus (KBV), nor any of 9 other bee viruses were found. Their conclusion is that while these viruses may be one of the causes of the syndrome, other factors cannot be ruled out.

It is still unclear what actually causes parasitic mite syndrome.

The finding of larvae twisted in a half-moon shape along the side of the cell is quite similar to both half-moon syndrome found in New Zealand and the symptoms of EFB, which is not present in New Zealand. There is a suggestion that in all three cases the common cause of the symptom may be starvation of the larva.

It is known that the causative bacterium of EFB competes with the larva for nutrients in the larval gut, and it is suggested that the larva moving in the cell in search of food causes the twisting. It is possible that a lack of nurse bees and proper feeding in a colony with parasitic mite syndrome may lead to similar behaviour on the part of the larva.

The large number of both adult bees and larvae affected by parasitic mite syndrome certainly suggest it is caused by a communicable disease. Researchers do not understand why drugs used to control brood disease or the feeding of sugar syrup can alleviate symptoms, but the positive effects that result from the use of Apistan certainly suggest a strong link with varroa.

The larval symptoms of parasitic mite syndrome are likely to cause problems when attempting to make a field diagnosis of AFB. Microscopic diagnosis is also not recommended, since some of the many bacteria found in larval samples of the syndrome closely resemble AFB spores. It is therefore important to carry out a laboratory culture test on suspect larval samples to make a definitive diagnosis of AFB.

The presence of parasitic mite syndrome in a hive can make the diagnosis of other brood diseases such as AFB very difficult.

The twisted half-moon shape of larvae also complicates making a diagnosis between EFB, half-moon syndrome and parasitic mite syndrome. In all cases, larval samples should be taken and sent to a bee disease laboratory for examination.

It is important to get a laboratory diagnosis when half-moon shaped larvae are found in a hive.

3.2.3 Effects on colony production

It seems a contradiction that while varroa can have such a wide range of significant effects on individual bees, and while both parasitic mite syndrome and colony collapse are the normal fate of most varroa-infested honey bee colonies unless treatment is carried out, major reductions in honey production are not usually recorded as an early effect of the pest.

The reason is that the population of mites builds up in a colony over time, and in the initial stages of infestation mite numbers are not high enough to significantly affect colony productivity. Rapid colony development in the spring and summer can 'out-breed' the mite, and with large numbers of unaffected foragers, infested colonies can produce normal honey yields.

However, with the natural decline in both brood and bee population in a colony going into autumn, the existing population of mites is likely to infest a greater proportion of the brood. At the same time, more mites are likely to enter individual brood cells. The mite level in the colony can also drastically increase suddenly as a result of invasion from outside (both from robbing of heavily infested colonies and as the result of the transfer of infested bees from these colonies).

At this time of the year, even a few weeks can see the emergence of a large number of young bees that have suffered significantly from the effects of the varroa's feeding. The bees are unable to carry out normal hive activities, robbing can occur, and the colony suddenly collapses.

Unfortunately, the production of honey crops by varroa-infested colonies can lull the beekeeper into thinking infestations are not severe, even though the same colonies can collapse in autumn after the honey has been produced.

Varroa can be present in a honey bee colony without producing noticeable effects, but can then cause the sudden collapse of the colony, especially in autumn.

Studies investigating the effects of different levels of varroa infestation on honey production provide conflicting results. Researchers compared honey bee colonies from eastern Russia that had an average varroa infestation rate of 7% of worker brood 15 months after Apistan treatment, to US colonies with a 33% infestation rate 12 months after treatment. Honey production in the year following the treatment was nearly identical in the two groups of hives. In Canada, on the other hand, a study showed that mite infestation levels of 3-7% of brood in early spring resulted in significantly less honey production. Another Canadian study found there was no difference in honey production between colonies treated with Apistan and those not treated. In Austria a study found no significant differences in honey production between colonies with significantly different mite infestation rates, and a breeding programme in Germany found lower spring honey production in colonies with less mites, but similar levels of summer honey production regardless of mite level.

3.2.4 Effects on numbers of managed colonies

Varroa has been identified as the cause of significant losses of managed colonies in a number of areas of the world. The losses are usually in the late autumn, or more generally over winter. However, winter losses from varroa are not easy to isolate from 'normal' losses caused by starvation or other diseases such as tracheal mite.

In 1995-96, thousands of managed honey bee colonies died in parts of the United States. The die-off was partly due to the long winter and poor spring, but beekeepers who didn't treat colonies for mites in the state of Pennsylvania reported losing about 30% more colonies than those who did treat. A previous study in the state showed 11% over-wintering losses in uninfested operations and 31% in operations with varroa.

A three-year study on mite-infested hives in Wisconsin showed over-winter losses of 29 to 45%. Colonies that were treated twice per year had a better survival rate than colonies treated once a year. At the same time, a survey in Ontario showed only 20% winter losses in the 1995-96 winter, and winter losses of infested hives the next year of 10% with

another 2% considered too weak to manage the next spring. Most beekeepers in this study treated their hives for varroa. A study in Indiana showed beekeepers who treated their hives for varroa lost between 30% and 50% fewer colonies over winter than those who did not.

The question is often asked, if beekeepers experience such major losses due to varroa, why doesn't this have a dramatic impact on hive number and honey production statistics? The answer would appear to be that commercial beekeepers normally have to replace winter hive losses and have well-developed management techniques (splits, nucs, packages) for this purpose. They have generally been able to use these same practices to overcome increased winter losses due to varroa, though obviously at greater expense. At the same time, varroa has lead to many hobbyists giving up beekeeping, although because they have few hives the impact on total hive numbers is not significant.

Hive losses from varroa certainly occur, but they are often made up for by splitting surviving hives the next spring.

Varroa has also required an improvement in overall beekeeping management and forced beekeepers to become more efficient. Because of varroa, beekeeping is certainly not as easy as it once was in many parts of the world, and some commercial operators have left beekeeping because of the management changes required.

3.3 Effects on pollination

Few scientific studies have investigated the impact of varroa on pollination. There is no doubt, however, that the number of feral colonies has declined in areas where varroa has become established, and this has reduced background (unpaid) pollination of home gardens and some crops.

It is also well known that prices for rental of hives used in pollination of commercial crops increased in the United States in the 1990s. The reason given was the decline in colonies available for this purpose, particularly in the early spring, with varroa and tracheal mite both being blamed.

In 1998, 1400 colonies used in commercial pollination in the early spring in California were surveyed. The sample represented 112 beekeepers from 19 states. About 25% of the beekeepers had infested colonies, and for those that did, just under 50% of the colonies were infested. Half of the beekeepers also had Apistan treatments in the colonies. The study showed that in general the colonies were in good condition.

If effective varroa control measures and pollination hive standards are used, hives used for paid pollination should provide a good level of service.

4. VARROA POPULATION GROWTH

This chapter describes the link between varroa reproduction and population growth, and explains why population growth rates are the key to understanding both how varroa affects honey bee colonies and how the mite can be controlled.

4.1 Reproduction rates

Chapter 2 explained the varroa reproduction process and how not all new female mites survive to reproduce (in other words, the 'reproduction rate'). The reproduction rate is influenced by whether reproduction takes place in a worker or a drone cell, how much brood is present, and also how many mated females enter a cell.

Small changes in the rate of reproduction have large effects on mite population growth. Over a 4 month breeding period, a single mite can potentially result in 6 female mites at a reproduction rate of 1.2 mites per brood cycle, 200 mites at a rate of 1.7 per cycle, and 20,000 mites at a rate of 2.7 per cycle. The reproduction rate is much higher on drone brood, and therefore mite numbers can increase more rapidly when it is present.

Mite numbers can increase more rapidly when drone brood is present.

Since varroa needs brood to reproduce, and since it reproduces more successfully on drone brood, the amount and type of brood present in a colony will have a large impact on mite population growth. In situations where there is no brood rearing in colonies, mite populations cannot increase. Mites die and get lost outside the colony. The longer a colony is broodless, the greater will be the reduction in mite numbers.

Mite numbers in a hive will decrease when there is no brood present.

Mite numbers will, however, increase again as soon as there is brood (slowly when there is only worker brood, and faster when there is also drone brood). Varroa populations therefore increase faster in climates that support brood rearing all year round and drone rearing for most of the season.

Varroa populations increase faster in climate areas that support brood rearing all year round.

4.2 Understanding varroa population growth

In order to decide how frequently colonies should be treated for varroa, it is important to have some understanding of the speed of varroa population growth. The population of varroa inside a colony can increase as the result of:

- varroa reproduction inside the colony; and,
- the invasion of mites from other colonies.

4.2.1 Reproduction and population growth

Varroa can reproduce only when there is capped brood in a colony. The mite reproduction rate is also much higher on drone brood than on worker brood. Because in New Zealand the amount and type of brood varies with the season and the location, we should expect varroa population growth rates to also vary considerably.

In the winter in locations where there is no brood present, the only mites will be those carried on adult bees. During this time, the number of varroa in a colony will decrease as varroa die, drop to the floor board, get lost outside, or are carried out on dead or sick bees. It has been calculated that varroa can survive on bees without brood for between 80 and 100 days, although longer survival times have been suggested. About 10% of the original mite population present when brood-rearing stops will die each month that the colony remains broodless.

About 10% of the original mite population present at the end of brood-rearing will die each month that the colony remains broodless.

When varroa reproduces, the population grows 'exponentially'. What this means is that the number of varroa within the colony will increase very slowly at first, and then more and more quickly as times goes on. The blue line in figure 4.1 shows how varroa populations increase when the mite reproduces on worker brood. In this theoretical example, mite numbers increase from 1 mite to 11 in the first 50 days. In the second 50 days the population increases by a further 115 mites, and by 1330 mites in the next 50 days.

Varroa populations increase 'exponentially' when not limited by the amount of brood.

The growth curves will eventually slow down when the amount of brood in the colony becomes a limiting factor. As the number of varroa in each cell increases, their ability to reproduce decreases. However, by this time the mite infestation will be causing serious damage to the colony.

Since varroa show a preference for drone brood and can breed more successfully on it, the population will grow much faster if drone brood is present (purple line in figure 4.1). Where one mite results in a population of 1456 mites after 150 days on worker brood, over the same time period the mite population would be 6000 mites if they reproduced exclusively on drone brood.

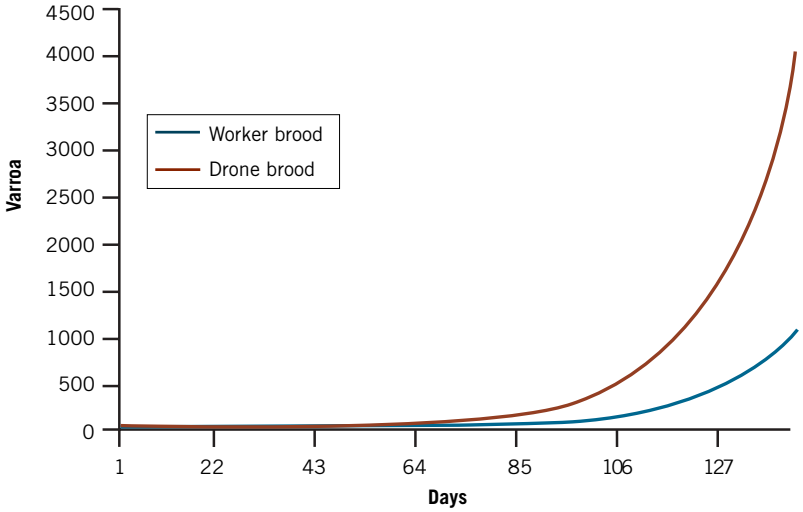


Figure 4.1 Theoretical population growth curve for varroa during the summer when it is reproducing on worker brood and drone brood.

Since varroa reproduction rates are higher on drone brood, varroa populations increase much faster when drone brood is present in a colony.

4.2.2 Invasion and population growth

Beekeepers spread varroa by transferring queens, combining colonies, swapping frames of brood between colonies, and transporting inadequately screened hives and boxes of honey. The spread of varroa around the world has been greatly assisted by humans moving honey bees from place to place.

Varroa can also enter a honey bee colony in a number of other ways. Probably the most common is through worker bees and drones drifting between colonies. Worker bees frequently drift between colonies in the same apiary and between apiaries. Drones also drift, although not as far as is often believed. The varroa carried by drifting workers and drones leave the bees and infest the brood of the new colony.

Varroa is also spread by worker bees robbing colonies weakened by varroa. The mites attach themselves to the robbing bees and then infest the robbing colony when the bees return from their robbing foray.

The main sources of 'invasion' of mites into other colonies are through drifting and robbing. Even though a colony may only be invaded by a few mites per day, their invasion can have a huge effect on varroa numbers because of the mites' exponential growth rate. Two mites invading a colony per day can result in the varroa population in a colony reaching 1000 mites a month earlier than if no invasion had taken place (figure 4.2).

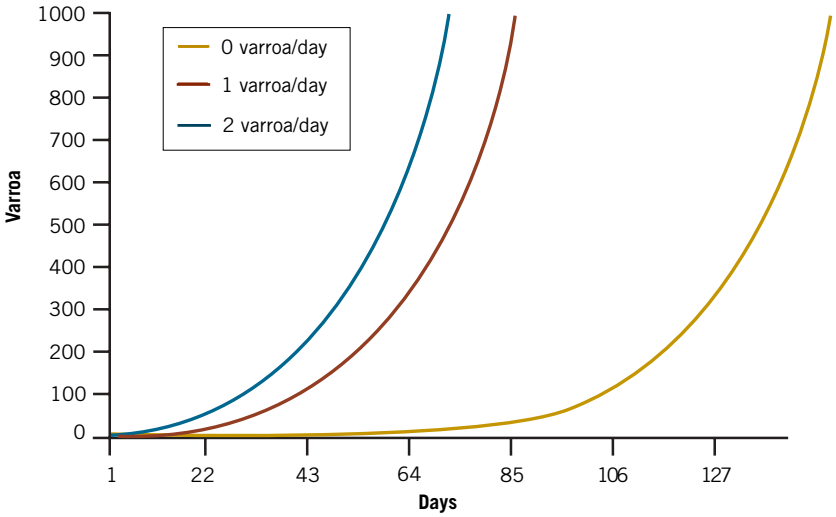


Figure 4.2 Theoretical population growth curve for varroa during the summer when it is reproducing on worker brood and 0, 1 or 2 varroa are invading the colony each day.

Even low invasion rates can greatly increase the varroa population growth rate within a colony.

A single large invasion of varroa can also have a major influence on the population growth rate. For example, in an infestation starting with 1 mite, an invasion of 50 mites on day 10 can halve the amount of time it takes for the population to reach 1000 mites (figure 4.3).

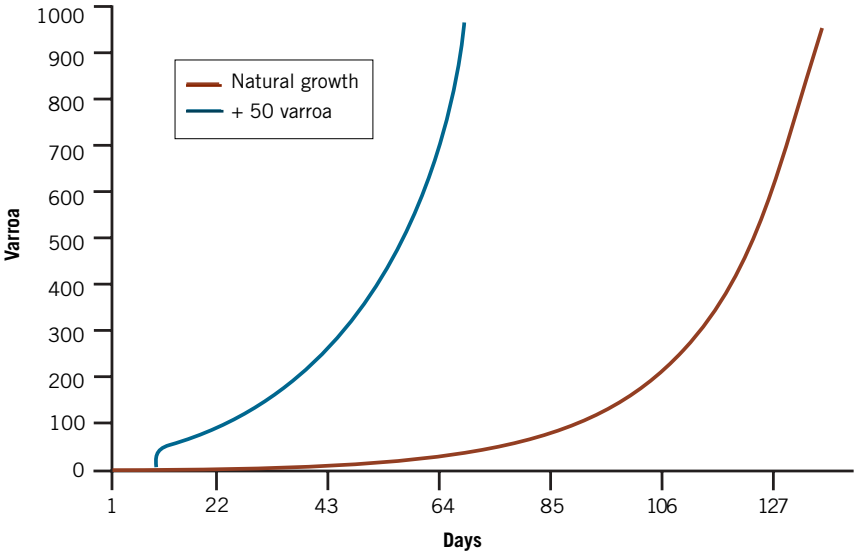


Figure 4.3 Theoretical population growth curve for varroa during the summer when it is reproducing on worker brood and 50 varroa invade the colony on day 10.

A study in Italy showed just how high invasion rates can be. The invasion rate was low during the spring, increased to between 1.6 and 13.7 mites per day during summer, and reached a peak of 75.6 mites per day during early autumn.

A small number of varroa invading a colony on one day can greatly increase the population growth rate of the mite.

4.2.3 Acute versus chronic infestation

Figure 4.3 also explains why varroa infestations often appear more severe (the 'acute' stage) when varroa first comes into an area, and then settle down several years later to a more predictable pattern requiring routine control ('chronic' stage).

In areas where there are large numbers of feral colonies or untreated hives, these colonies act as a major source of mite invasion when they become sufficiently weakened by infestation that they are robbed by managed hives. Mite populations in these managed hives can increase dramatically, with the mites that are transferred to these hives greatly increasing the population growth curve. It is therefore very important in the period following varroa coming to an area to treat hives on a routine basis (especially in the autumn). The chemical treatment will guard against unpredictable increases in mite population that can lead to substantial hive losses.

During the acute phase, it is very important to carry out varroa control treatments on a routine basis, especially in autumn.

4.2.4 Effects of control on population growth rates

The effectiveness of a control method can also have a large influence on mite populations because of the exponential growth rate of varroa. Using a control method that kills only 80 or 90% of mites, rather than 100%, may seem adequate. However, even small differences in the percentage of surviving mites can have a large effect on how soon the varroa population in a colony will reach high levels again. In the example in figure 4.4, where control measures are used when mite levels reach 1000 mites, with 99% control it will take 94 days for varroa population levels to reach 1000 again, and only 48 and 35 days respectively with control measures that are 90% and 80% effective (assuming no re-invasion).

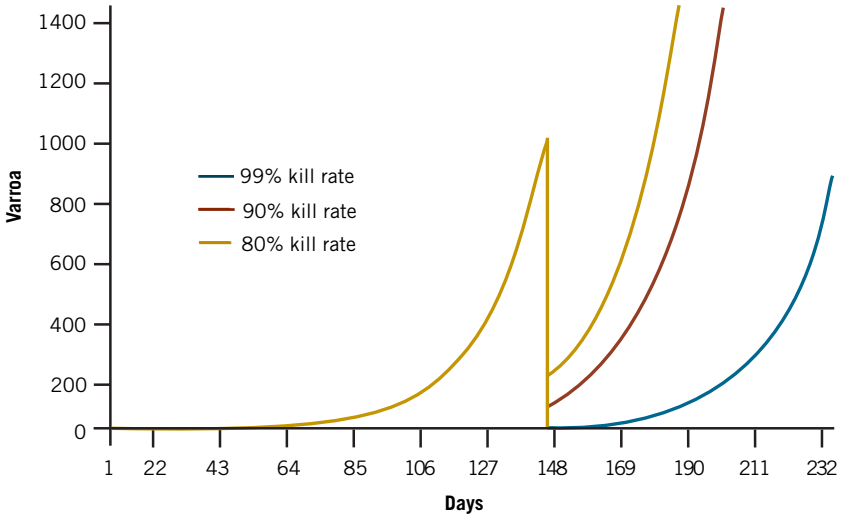


Figure 4.4 Theoretical population growth curve for varroa when it is reproducing on worker brood, there is no re-invasion, and a control method is used on day 144 that is either 99, 90 or 80% efficient.

Small variations in the effectiveness of a control method can have a large effect on how soon varroa populations will reach damaging levels again.

Some control measures work on the principle of making small reductions in mite numbers on a daily basis. However, when such measures are analysed using population growth curves, it is evident that they may not have a significant effect on keeping mite population levels below economic thresholds. For instance, a method that on a daily basis removes 15% of mites per year will have little effect on mite population growth.

Nevertheless, a combination of methods that each reduce varroa by a small amount may possibly act together to provide adequate control.

A control measure that only removes a small number of varroa throughout the year may by itself have little effect on how quickly varroa populations reach damaging levels.

5. DETECTION AND EVALUATION OF INFESTATIONS

This chapter describes how beekeepers can sample their hives for varroa, and how they can use the results of the sampling to determine the likely population of mites in individual hives.

5.1 Why sample hives for varroa

Beekeepers need to detect and evaluate infestations of varroa for four important reasons:

- **Surveillance in the South Island Disease Free Area** – while the government is carrying out an extensive 'active' surveillance programme to verify the varroa-free status of the South Island, beekeepers need to play their part by looking for the mite on an on-going basis. This type of surveillance is called 'passive' surveillance, and it is essential to ensure that any incursion of the mite is found early enough so that an eradication or containment operation can be contemplated. Because varroa is not easily seen until it has built up to large populations in the hive and is causing direct colony effects, beekeepers throughout the South Island should use simple detection techniques at least twice per year (spring and autumn) to search for the mite. Sampling brood with a cappings scratcher (see 5.3.3) can be done whenever hives are inspected.
- **Surveillance in North Island areas not known to have varroa** – the best way beekeepers in the North Island can prepare themselves for the impact of varroa is to carry out on-going passive surveillance in areas not known to have the mite. Again, because varroa is not easily seen until it causes direct colony effects, beekeepers need to know when the mite actually reaches their area so they can begin proper control programmes. In these areas, beekeepers should also use simple detection techniques at least twice per year (spring and autumn), and brood sampling whenever hives are inspected.
- **Determining when to treat hives for varroa (thresholds)** – once varroa has arrived in an area and the acute (high invasion) period has passed, beekeepers need to know how quickly varroa is building up in their hives and when to apply treatments. Simple detection techniques can be used, particularly in the spring and autumn, to determine if mite population levels have reached economic thresholds that require treatment. This type of evaluation is an important part of integrated pest management (IPM) programmes designed to reduce the frequency and costs of treatments. See chapter 10 for more information on IPM programmes.
- **Determining the effectiveness of treatments** – just because a treatment has been given to hives doesn't necessarily mean it has been effective. Simple detection techniques can be used to determine the number of remaining mites in the hive and whether further treatment is necessary. This type of evaluation is particularly important in control programmes using biotechnical methods or organic miticides. It is also useful to help identify if varroa has developed resistance to a particular control compound.

All beekeepers in New Zealand should routinely check their hives for varroa whether or not mites have already been found in their area.

5.2 Identifying varroa

To detect varroa and evaluate its population in hives, it is important to be able to identify the mite and tell it apart from other objects of similar size and shape.

Varroa is oval in shape and in the adult form is reddish brown to dark brown in colour. Immature stages (normally only found on pupae) are light brown to off-white. A mature female varroa measures 1.6mm from side to side, and 1.1mm from front to rear. Mature males are smaller, but are usually only found on pupae.

Varroa can be mistaken for the melittiphis mite, although melittiphis is smaller and different in shape.

In New Zealand varroa can sometimes be mistaken for *Melittiphis alvearius*, a mite often seen running quickly on the top bars of hives particularly just after the hive mat is removed. Melittiphis is not a parasite of honey bees. It is thought to be either a scavenger of pollen and hive debris or a predator of tiny pollen mites that also live in beehives.

Melittiphis is about one quarter the size of varroa, and is different in shape. It does, however, tend to be quite similar in colour to varroa (figure 5.1).

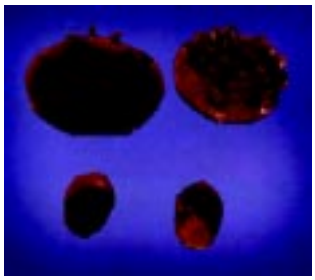


Figure 5.1 Comparison between varroa (top) and melittiphis (bottom).

Figure 5.2 Varroa mites spread amongst hive debris on a bottom board. The larger yellow object in the foreground is a pollen pellet.

Varroa can also sometimes be mistaken for bits of hive debris (figure 5.2), and dark brown flecks from the sides of cells on older brood comb or small pieces of propolis. It is important to check these flecks by picking at them with a sharp corner of the hive tool or with forceps. The flecks will usually be quite irregular in shape, whereas varroa is smooth and rounded, and if the mite is turned over and examined closely legs will be obvious.

5.3 Detection methods

There are a wide range of varroa detection methods, with at least one new method (the sugar shake) having been developed quite recently. All the methods have their advantages and disadvantages, and some are more accurate than others. It is important to pick a method that fits with beekeeping workloads and also provides the sort of information needed to make good decisions.

There are a number of important factors to be considered when deciding on which mite detection method to use, including:

- **cost** per hive;
- length of **time** required to process a sample;
- number of **visits** needed to the apiary;
- ability of the method to detect low mite numbers (**sensitivity**); and
- ability of the method to **reliably** determine the number of mites in a hive.

Choose a varroa detection method that fits with your workload and the sort of information you need to make good decisions.

For each detection method, these factors have been summarised in Table 5.1.

Table 5.1 Summary of detection methods

Method	Section	Cost	Test time	Total time	Visits	Sensitivity	Reliability
Bees - visual	5.3.2	nil	1 min	2 min	1	very low	very low
Drone brood	5.3.3	nil	5 min	5 min	1	high	low
Ether roll	5.3.4	low	5 min	5 min	1	low	medium
Washing	5.3.5	low	5 min	5 min	1	high	high
Sugar shake	5.3.6	low	5 min	5 min	1	high	high
Smoke	5.3.7	moderate	5 min	30 min	1	low	low
Mesh boards	5.3.8	moderate	5 min	24 hrs	2	low	high
Miticide	5.3.9	high	2 min	24 hrs	2	very high	very high

When determining whether there are mites in an area for the first time, it is important to use a technique that has the sensitivity to detect very small numbers of mites. On the other hand, when determining whether or not there are enough varroa to be worth treating, being able to detect small numbers of mites is not as important as the reliability of the method to detect mite populations before they reach damaging levels.

In the descriptions of the following sampling methods, information on economic thresholds is provided from overseas sources where it is exists. However, we do not yet know how fast varroa reproduces in New Zealand. Also, the thresholds do not relate to the acute stage when mite invasion is a problem. As a result, the information below on reproduction rates and thresholds needs to be treated with caution by New Zealand beekeepers. For more information on economic thresholds, see section 10.3.

Data on varroa reproduction rates and thresholds from overseas should be treated with caution.

5.3.1 Sampling bees

Studies have shown that varroa are not evenly spread throughout the hive, and that the distribution depends on the time of year. Obviously when there is no brood in the hive, all the mites are on adult bees, and methods that sample bees can be very accurate at predicting the total number of mites in the hive.

When there is a large amount of brood in the hive in spring and early summer, however, at any given time a high percentage of the mites will be in the brood rather than on adult bees. Conversely, when the brood amount declines in late summer and autumn, large numbers of mites will be found on adult bees, making it seem as if there is a major increase in the mite population.

Varroa are twice as likely to be found on adult bees taken from the brood nest compared with bees taken from honey supers. It has also been shown that to get a good representation of the number of mites distributed on adult bees, bees have to be taken from at least three brood frames.

The easiest way to sample bees is to:

- up-turn a hive lid;
- shake the bees from 3 brood frames into the lid (make sure not to include the queen);
- turn the lid slightly on its side and give it a bump to dislodge the bees;
- scoop the jar along the bottom side of the lid to collect the dislodged bees.

Always take an adult bee sample for varroa from at least three brood frames. Don't take bee samples from honey supers.

5.3.2 Visual inspection of bees

Even though good beekeeping management involves constant examination of bees and brood for diseases, visual inspection of adult bees is not a recommended method for varroa detection. This is because mites often crawl between the hard segments of a bee's abdomen to feed, leaving only a small portion of the mite exposed. Varroa can also move fairly quickly from the top of the bee (especially on the thorax) underneath to where the legs are attached. In this position the mites are much harder to see. It can even be difficult to see mites when bees are taken out of the hive and carefully examined individually.

What can be said with certainty is that if significant numbers of mites are detected by visual inspection, it is a sign that the mite population in the hive is dangerously high and urgent treatment is required.

Visual inspection of bees is not a good varroa detection technique.

5.3.3 Visual inspection of brood

This is certainly a more sensitive technique than visual inspection of bees, especially if drone pupae are examined, since varroa show a preference for reproducing on drone brood. When brood is sampled, it should always be examined from at least three brood frames to ensure accuracy of results.

Method – The best tool to use is either a cappings scratcher (used during honey extraction) or a wide-blade shearing comb mounted on a handle. Push the tines through a patch of capped drone brood and then lever the tool to pull a large patch of pupae out all at once (figure 5.3). It takes some getting used to, but if care is taken about 200 pupae can be pulled out in 10-15 goes. Check the pupae for mites. Mites are easier to see on pupae at the pink-eye stage than on ones that have taken on adult colouration. Pupae that are younger than the pink-eye stage tend to be too soft and fall apart when the scratcher is levered.

It may also be worthwhile banging the comb over a piece of white card once you are finished removing all the pupae. Varroa that do not come out with the pupae may fall onto the card. A study showed the cappings scratcher technique to be about 1.5 times more efficient in detecting mites than the ether roll (see 5.3.4 below), but certainly not as good as soapy water/alcohol wash or miticide strips (see also 5.3.5 and 5.3.9 below).

Figure 5.3 Using a cappings scratcher to sample drone pupae for varroa.

Advantages – Sampling drone pupae is better than either visual examination of bees or the ether roll. It is also fairly fast compared to some other methods, and can easily be carried out as part of routine hive inspection. The method samples mites on brood, which can give a more accurate picture of infestation levels during the main beekeeping season than sampling adult bees.

Disadvantages – Sampling drone pupae destroys drones that may be needed for queen mating

(especially if hives are being requeened on site with cells). The method is also not as reliable as some others. Even though varroa prefer drone brood to worker brood, there are times in infested colonies when very few varroa can be found on drone brood.

Thresholds – Researchers in Britain have worked out population thresholds for varroa using the drone brood sampling method. The threshold depends on the number of cells of drone brood in the colony and the time of year. As an indication, in a colony with 500 cells of drones at the beginning of summer, if more than 10 drone pupae are found to be infested when 200 pupae are examined, then the mite population could build up to a level (2500 mites) needing treatment by the following autumn.

Sampling drones with a cappings scratcher can be a worthwhile technique for finding varroa, although it is not highly reliable in determining mite population levels.

5.3.4 Ether roll

The ether roll technique is one of the oldest and most popular techniques for detecting varroa.

Method – Use a 500ml preserving jar with a metal ring. Cut a piece of wire mesh (3mm openings) in a circle to cover the jar, then friction fit it into the metal ring. Collect about 300 bees in the jar (about 1/3 full) and cover with the ring and mesh. Make sure to take your bees from at least three brood frames. Spray the bees through the jar with ether from an aerosol can (sold as engine starter at car parts stores) (figure 5.4). Shake the bees in the jar for about 30 seconds, then gently rotate the jar 2 or 3 complete turns. The mites will come off the bees and will stick to the inside glass walls of the jar. Finally, empty the bees out of the jar and spread them on a piece of white card to expose more mites. If the jar is going to be used repeatedly for sampling, the contents (bees and mites) should be removed immediately. Mites can stick to the glass if they are left for any length of time and this will give you false readings on subsequent hives. (Warning: ether is highly inflammable, so it should not be used near bee smokers).

Advantages – The ether roll is quick, easy to use, and can be done in the apiary in one visit. It is regarded mostly as a means of detecting mites if they are present at fairly high levels.

Figure 5.4 Spraying bees with ether to sample them for varroa.

Disadvantages – Ether is inflammable and potentially dangerous. Also, the ether roll may not give a very accurate estimate of the number of mites in the hive. A study showed this survey technique to be only about 78% effective at removing varroa from bees compared with Apistan strips placed in hives for only 4 hours, so it is not a very sensitive technique. Another study showed that very high colony mite populations can yield low ether roll readings. Finally, it has been shown that not all mites that are on the bees cling to the inside of the glass container (only 59% in one study). This can be improved by washing the sample with alcohol or soapy water and then filtering (see 5.3.5 below). The ability of the test to predict the actual number of mites in the hive can also be increased by taking several samples from the hive.

Thresholds – One source states that if 15 or more mites per 300 bees are recovered from an ether roll, mite control measures should be carried out. This was based on a detailed study of mite levels in southeast USA. Another source suggests that if no mites are found with the ether roll test in autumn once the flow has ended, no varroa treatment needs to be carried out going into winter. A third source sets the limit at the end of summer at no more than six mites, with 1-5 mites meaning that treatment can be delayed until late autumn or next spring.

The ether roll is a quick technique for varroa detection, but it is also not very accurate in determining mite population levels.

5.3.5 Soapy water or alcohol

Washing adult bees in alcohol was one of the first methods devised for measuring mite populations in beehives, and it is still one of the most accurate. Alcohol (25%) is often not available, and is also costly, so a technique has now been devised using soapy water instead. Methylated spirits (25%) can also be used, but care is needed to avoid breathing in the fumes.

Method – Mix a level tablespoon of liquid or dry laundry detergent in one litre of water. Select a detergent that doesn't foam very much, since foaming can make the procedure more difficult. Collect 200 or more bees from the brood nest (about $^1/_4$ of a 500 ml jar), making sure to take bees from at least three brood frames. Put the lid on the jar and shake the bees and the soapy water for one minute. Expect to remove 80-90% of the mites in that time period, but it takes a full 30 minutes to free almost all of the mites (99%). Pour the contents of the jar over a piece of cotton cloth (e.g., a piece torn from an old bed sheet) placed above a bucket to catch the soapy water (figure 5.5). Count and carefully remove the bees, then count the number of mites. Finally work out the number of mites per 100 bees. To save time, you can use a piece of 8 mesh for the lid, as in the ether roll, and pour the bees and liquid through it. The mesh will collect the bees, but let the varroa come out with the liquid onto the cloth. Another way to improve accuracy is to thoroughly wash the bees with a sprayer into a bowl. Use a strong spray and count the number of mites that float on the top of the water in the bowl.

Figure 5.5 Pouring soapy water soaked bees over a piece of cotton cloth stretched over a bucket.

Advantages – The soapy water/alcohol method is both low-cost and accurate, and involves only one trip to the apiary.

Disadvantages – The method takes more time than the ether roll because the contents of the jar have to be filtered.

Thresholds – The same British researchers who worked out thresholds for varroa populations based on examining drone brood have also developed thresholds for using the adult bee washing technique. The threshold depends on the size of the colony and the time of year. In a colony of 20,000 bees in the winter, if more than one mite is found in 300 bees, the mite population could build up to a level (2500 mites) needing treatment by the following autumn. For a colony with 60,000 bees at the end of the honey flow, the threshold number of mites is between two and ten in 300 bees. This threshold is variable since it depends on when the honey flow ends and the amount of worker brood and drone brood present in the colony in the preceding weeks.

The soapy water washing technique is an accurate technique for determining varroa levels in a hive, but it is fairly time-consuming.

5.3.6 Sugar shake

This is a new method developed as a more bee-friendly alternative to the ether roll. The method doesn't kill the bees.

Method – Use the same type jar and mesh lid as for the ether roll. Collect about 300 bees in the jar (about $^1/_3$ full) and add about 1 tablespoon of icing sugar on top of the bees. Gently roll the sugared bees for 3-5 minutes, ensuring each bee is coated with sugar. Let the jar sit for a few minutes, then turn the jar upside down and shake the jar above a piece of paper. The mites and sugar will pass through the mesh, but the bees will remain in the jar (figure 5.6). The bees won't be killed, so they can be put back in the hive. If the sugar makes the mites hard to find, put the sugar through a fine sieve. This will allow the sugar to escape but the mites will be retained. The mites can then be dumped onto a piece of paper for counting. Recovery is said to be 70% of mites for a brief shaking. A study showed 79.8% recovery if the bees are shaken 3 times, or until no more mites fall out. It is best not to reuse the same icing sugar between hives, since the very fine particles are the ones that dislodge the mites and these particles cover the bees and also blow away in the wind.

The reason the sugar works has not been determined, but it may be that either the sugar interferes with the sticky pads on the legs of the mites that help them cling to the bees, or the sugar makes the mites stop feeding on the bees and attempt to groom themselves.

Advantages – The sugar shake method is a simple, quick technique that doesn't kill bees. It also only requires one trip to the apiary. The method doesn't produce chemical residues.

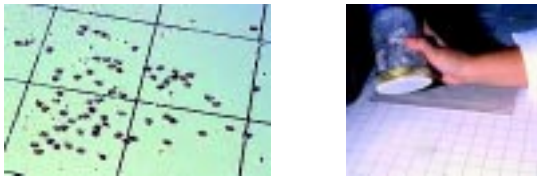


Figure 5.6 Sugar shake method of varroa sampling, including a close-up of mites on a counting card.

Disadvantages – Although recovery rates of mites have been suggested, there are very few published studies verifying them.

Threshold – A US researcher suggests a threshold of 65 mites recovered from 300 bees, which is similar to an ether roll figure of 15 mites per 300 bees.

The sugar shake method is quick and kind to bees, but there is little information on its accuracy in determining mite population levels.

5.3.7 Tobacco smoke

This technique has been used in Europe, both as a survey method and as a varroa treatment.

Method – Light a smoker using your standard smoker fuel. Insert a sticky board through the hive entrance (see section 5.5). When the smoker is going well, add about 2-3 g of smoking tobacco (pipe tobacco), which should be enough for 2 hives. Blow 60 strong puffs into the entrance of the hive at about 1-second intervals. Don't open the hive for 30 minutes. Mites will fall onto the sticky board. A study showed this technique to be about twice as efficient in detecting mites as the ether roll.

Advantages – The technique uses natural substances (but potentially toxic ones) and standard beekeeping equipment. It requires only one trip to the apiary.

Disadvantages – Tobacco is costly, and if too much smoke is used the bees in the colony can drop to the bottom board causing most of the colony to asphyxiate. The technique is also quite time-consuming.

Thresholds – Unknown.

The tobacco smoke technique is not recommended because it is costly and can kill a colony if not used properly.

5.3.8 Mesh bottom boards

This method is also being investigated as a control measure for varroa, and is often used as part of an integrated pest management system for varroa control.

Method – (see section 8.3 for a description of mesh bottom boards). The screen board can be used either in association with a sticky board, or the bottom board debris can simply be examined for mites since a certain number fall to the bottom board every day (often called 'natural mite fall'). A piece of white plastic (Corflute or similar) is often used to make the mites easier to see.

British researchers believe that the method is most accurate when a colony has either no brood or a good-sized brood nest (equivalent to more than 5 frames of brood 60% covered). The board should stay on for 3-5 days, so that the daily mite fall more accurately represents the total number of mites in the hive. If the board stays on for a longer period, the mites may be difficult to count because of debris or total mite fall (especially during the invasion period). Manipulating the hive once the board is on also increases the amount of debris on the board.

Make sure to divide the total number of mites on the board by the number of days the board has been in place. A Canadian researcher has found that 24-hour mite fall correlates very strongly with total mite population.

Advantages – Mesh bottom boards provide very accurate estimates of mite populations, and according to some authors they are the best technique for making varroa control decisions. The method also reduces mite numbers, but does not provide sufficient control without the addition of other control measures.

Disadvantages – Mesh bottom boards can be expensive to make. For mite sampling, they also require at least two trips to the apiary.

Threshold – Various European scientists have developed threshold information on natural mite fall. According to the British team, colony collapse is likely by the end of the season if the average daily natural mite fall is greater than 0.5 mites/day in winter/early spring, 6 mites/day in spring, 10 mites/day in early summer, 16 mites/day in mid-summer, 33 mites/day in late summer and 20 mites/day in autumn.

According to Danish researchers, control should be undertaken immediately if daily mite fall is greater than 8 mites/day. For 2 mites/day, control should be undertaken within 2 months, and for 1 mite/day, control should be within 3 months or at least before winter. All of these figures are for the chronic stage once invasion pressure has reduced.

Mesh bottom boards are an accurate way to determine mite population levels, and may offer some mite control.

5.3.9 Apistan, Bayvarol and formic acid

These chemicals are used in mite detection and survey work. Apistan or Bayvarol with a sticky board is the technique of choice for government surveillance programmes in the South Island Disease Free Area and the North Island Surveillance Area.

Apistan and Bayvarol are highly effective at killing varroa mites, and formic acid is also effective. However, none of the chemicals are 100% accurate in determining the presence of mites when varroa is at extremely low levels and most mites are in the brood. Only the mites on adult bees will be killed by the chemicals, although there is some suggestion that formic acid also kills mites in sealed brood (see section 6.3.2.1). When a colony is in full brood rearing, on average only about 15% of the mites are on adults.

Method – For Apistan use two strips per two-box hive, spaced evenly within the cluster of bees. For Bayvarol use four strips per two-box hive. In either case, remove the strips after 24 hours. For formic acid, apply 40 ml of 65% liquid directly onto a few layers of paper towels placed together on the top bars of the top brood box. Remove the towels after 2-3 days. Use the miticides with either a sticky board or white card (plastic or similar) on the bottom board to collect dead mites. Strips can be reused for survey work up to 10 times, provided each application is only for 24 hours and the strips are kept out of sunlight. Strips can be marked with an ear-tag pen to indicate how many times they have been used. When not in use, they should be wrapped in tinfoil and stored in their original box in a cool, dry place.

Advantages – This method is the most sensitive and reliable at detecting varroa since all adult bees in the hive are surveyed. The chemicals cause rapid mite fall, although with formic acid it is necessary to leave the chemical on the hive for longer before counting the mites, since mite fall is at times not as rapid as for Apistan or Bayvarol. A study conducted by HortResearch suggests that about 86% of the mites on adult bees will be killed by either Apistan or Bayvarol in the first 24 hours.

Disadvantages – The method can be expensive, and can even be counter-productive if the reason for surveying is to determine mite threshold levels to reduce chemical control use. Two trips to the apiary are required.

Thresholds – One author suggests that in late summer the threshold is 20-200 mites based on a 24 hour mite fall, whereas in Europe levels as high as 800-1400 mites are considered to be critical.

Apistan, Bayvarol and formic acid are effective detection methods for varroa surveillance.

5.4 Sticky boards

Sticky boards are used in several survey techniques, and are essential in determining natural mite fall (figure 5.7). They can either be purchased or made by the beekeeper.

Figure 5.7 A sticky board with a protection screen to keep the bees from chewing up the cardboard.

To make a sticky board, mix 1 part vegetable oil with 1 part petroleum jelly. Apply over the surface of a piece of white paper or cardboard with a paint brush and then remove the excess with a window squeegee. Alternatively, spray on cooking oil from an aerosol can (Pam or similar), or use A4 adhesive labels (Avery or similar) stapled to the board.

If natural mite fall is being measured without a mesh bottom board, it is a good idea to screen the sticky board if it is going to be left in the hive for any length of time. Unless the board is made of plastic, the bees will chew the board and affect the results. The screen should be elevated about 8mm above the board to keep the bees from removing some of the varroa.

It is also important not to reduce the size of the sticky board (for instance, to half size), since some of the mites will not be collected on the sticky board and this will give a false impression of the number of mites in the hive.

5.5 Using mite population estimates

Specific threshold levels (where available) for the various sampling methods are summarised in table 5.2. Total mite populations in hives can also be determined from these methods by using the calculations presented in appendix 1. It is very important to note, however, that in the acute stage of varroa infestation, mite population estimates (especially in the autumn) should *not* be relied upon to determine whether mite control treatment should be applied. Invasion pressure can drastically alter the mite population in a hive in a short period of time. During the acute stage, mite control should *always* be carried out in the autumn.

In the acute stage of varroa infestation, mite population estimates (especially in late summer/autumn) should not be relied upon to determine whether mite control treatment should be applied.

Table 5.2 Comparison of various mite detection methods.

[Note: the information on threshold levels is based on overseas research and should be **treated with caution** under New Zealand conditions. The information also does not take into consideration invasion pressure during the acute stage.]

Method	Time of year	Sample size	Threshold level	Threshold level comments
Drone brood examination	Early spring	200 drone pupae	>10 drone pupae infested	Mite levels will rise to 2500 in hive by autumn
Ether roll	–	300 bees	>15 mites	Carry out treatment immediately
	Autumn	300 bees	No mites present	No autumn treatment required
	Late summer	300 bees	>6 mites	Treatment needed
		300 bees	1-5 mites	Treatment can be delayed until late autumn/spring
Soapy water	Winter	300 bees	>1 mite	Treatment needed by autumn
	Late summer	300 bees	>2-10 mites, depending on when flow ends and brood	Autumn treatment needed
Sugar shake	–	300 bees	>65 mites	Carry out treatment immediately
Tobacco smoke	No information			
Mesh bottom boards	Winter	Daily mite fall	>0.5 mites/day	Colony collapse likely by end of season
	Spring	Daily mite fall	>6 mites/day	Colony collapse likely by end of season
	Early summer	Daily mite fall	>10 mites/day	Colony collapse likely by end of season
	Mid-summer	Daily mite fall	>16 mites/day	Colony collapse likely by end of season
	Late summer	Daily mite fall	>33 mites/day	Colony collapse likely by end of season
	Autumn	Daily mite fall	>20 mites/day	Colony collapse likely by end of season
	Summer	Daily mite fall	>8 mites/day	Begin treatment immediately
	Summer	Daily mite fall	2 mites/day	Control needed within 2 months
	Summer	Daily mite fall	1 mite/day	Control needed within 3 months, or before winter
Apistan, Bayvarol, formic acid	Late summer	24 hour mite fall	Between 20-200 and 800-1400 depending on study	Begin treatment immediately

6. CHEMICAL CONTROL

This chapter describes the various synthetic and organic chemicals that are used by beekeepers to control varroa.

6.1 Chemical safety

Various chemicals have demonstrated an ability to control varroa in honey bee colonies (table 6.1). Although these chemicals can be divided into 'organic' (found in nature) and 'synthetic' (not found in nature), it is important not to think of organic pesticides as 'soft' or 'safe' and synthetic pesticides as 'hard' or 'hazardous'. Many organic pesticides are quite harmful to both bees and beekeepers if used incorrectly.

There is also a tendency to underestimate the risks posed to human health by agricultural pesticides and chemicals in general. A good example of this comes from the varroa delimiting survey that was carried out around the country using Apistan. Many people handled the Apistan strips without gloves despite having been warned of the hazards of doing so, and despite the label clearly stating that gloves should be worn.

Do not underestimate the risks to human health of handling agricultural pesticides, regardless of whether they are synthetic or organic.

Many of the chemicals used to control varroa are not only toxic to mites; they can also be toxic to honey bees and humans. In addition, some control chemicals are highly corrosive. Although we have an idea of the short-term effects of high concentrations of these chemicals, we can only guess at the impact of many of the compounds when encountered in low concentrations over long periods of time. All agricultural chemicals should be considered as toxic to humans unless there is evidence to show that they are not. Read the labels carefully and follow all safety instructions exactly.

Read miticide labels carefully and follow all safety instructions exactly.

Only pesticides that have been registered or approved by the New Zealand government can legally be used to control varroa in New Zealand. The reason for this is to ensure that if the label directions are followed the product will be safe for beekeepers, bees, the environment and the consumers who buy bee products.

Only pesticides that have been registered or approved can legally be used for varroa control.

Waste pesticides should be considered hazardous to the public and to people handling them. These materials are also potential pollutants of water, air and soil. Used varroa control strips (e.g., Apistan, Bayvarol, Check-Mite+, Apivar) should be taken to a local council chemical waste dump, or the supplier should be contacted for proper disposal instructions.

Dispose of used varroa control strips properly.

It is also worthwhile marking hives with the number of strips used and the date of application so that all strips are removed from the hive at the proper time. Strips can also be marked with an ear-tag pen to make them easy to see in the hive.

Mark hives with the date and the number of strips used so that the strips are removed at the proper time.

Table 6.1 List of chemicals commonly used overseas for varroa control.

Product trade name	Active ingredient	Chemical class
Apiguard, generic	thymol	essential oil
Apilife VAR	thymol, eucalyptol, menthol, camphor	essential oil
Apistan	fluvalinate	pyrethroid
Apitol	cymiazole	iminophenyl thiazolidine derivative
Apivar	amitraz	amadine
Bayvarol	flumethrin	pyrethroid
Folbex	bromopropylate	benzilate
Apicure, Mite Away, evaporators, generic	formic acid	organic acid
generic	lactic acid	organic acid
generic	oxalic acid	organic acid
Check-Mite+, Perizin	coumaphos	organophosphate

6.2 Synthetic chemicals

Synthetic chemicals usually provide the most effective and reliable varroa control. However, they cannot be used by beekeepers producing products under organic certification schemes, and they may not be acceptable to beekeepers who want to avoid using chemicals in their hives. New Zealand has a long tradition of chemical-free control of bee diseases.

The three most common synthetic chemicals used to control varroa are fluvalinate, flumethrin and coumaphos. Less commonly used synthetic chemicals include cymiazole, bromopropylate and amitraz.

6.2.1 Fluvalinate (Apistan)

Apistan is probably the most widely-used varroa control product world-wide. It is relatively expensive, but is very easy to use and extremely effective. Apistan can kill nearly 100% of mites in a honey bee colony if used according to the label directions.

Apistan consists of a plastic polymer embedded with fluvalinate, a pyrethroid. Pyrethroids are a class of synthetic chemical that are similar in chemical structure to natural compounds found in the flowers of *Pyrethrum* spp.

Apistan is extremely effective in killing varroa mites.

Apistan strips should be placed in the hive using one strip for every 5 frames of bees in each brood chamber. The strip is hung between the frames, with the frames separated slightly so that bees can contact both sides of the strip (figure 6.1). The bees rub against the strips as they move through the brood chamber, and then pass the chemical on to other bees as they rub up against each other in the hive.

Apistan is a contact pesticide, not a fumigant, so the strips must be in contact with bees in the brood nest at all times. The chemical is distributed best around the colony when outside daytime temperatures are 10°C or above because the bees are less mobile at cooler temperatures.

Figure 6.1 An Apistan strip being placed inside a hive.

According to the manufacturer it is also important to suspend the strips between the frames rather than just lay them along the top bars. When laid on the top bars, not as much of the chemical is exposed to passing bees, and the efficiency in killing mites drops to 65-75%.

Apistan strips should be removed 6-8 weeks following application because after this time their activity starts to decline. Failure to follow this label direction can result in the rapid development of mites that are resistant to fluvalinate.

The main problem with fluvalinate is that it is fat-soluble and not very volatile. It can therefore be absorbed straight into beeswax where it remains without breaking down for a long time. As a result, Apistan should not be used during the honey flow or while honey supers are on hives.

There are also problems with fluvalinate residues building up and persisting for long periods of time in combs, so periodic replacement of brood combs is very important when the product is used long-term. To avoid fluvalinate residues carrying over in new combs, beeswax used for foundation should ideally come from fresh cappings wax. Fluvalinate residues can also be found in propolis.

Don't use Apistan during the honey flow or while honey supers are on hives.

Apistan strips only require two trips per treatment. No great increase in labour is required since the work can usually be incorporated into standard hive management. A spring and autumn treatment is usually sufficient to provide good varroa control. However, additional treatments may be necessary during the acute (mite invasion) stage.

Fluvalinate residues in beeswax are an important problem in world beekeeping.

6.2.2 Flumethrin (Bayvarol)

Bayvarol strips are another commonly-used product for varroa control. Bayvarol contains flumethrin, which like fluvalinate is a pyrethroid. Bayvarol is similar to Apistan in that the flumethrin is embedded in a polymer strip. Like Apistan, it is also relatively expensive, but is easy to use and only requires two trips to the hive.

Bayvarol's method of use is identical to Apistan (although twice as many strips are required) and it is equally effective in killing varroa. Studies suggest that the flumethrin in Bayvarol tends to accumulate less in beeswax and propolis, since the amount of active ingredient in the product is substantially less than in Apistan.

Flumethrin accumulates less in beeswax and propolis because Bayvarol contains less active ingredient than Apistan.

6.2.3 Coumaphos (Check-Mite+, Perizin)

Coumaphos comes in two formulations for mite control. Perizin is a solution of coumaphos that is trickled over bees. It is best used in the late autumn or winter, ideally in broodless conditions. Two treatments one week apart are recommended. Perizin is used primarily in Europe.

Check-Mite+ is a coumaphos product that is formulated into strips, so it can be used like Apistan and Bayvarol. The strips are also very effective against varroa, are easy to use, and the label instructions are almost identical to Apistan. Check-Mite+ has received preliminary registration in some US states.

Coumaphos is an organophosphate. It acts as both a contact chemical (like fluvalinate and flumethrin) and as a systemic (i.e., it works through the bee's body). Coumaphos is also fat-soluble and can migrate from the wax into stored honey. In Europe, coumaphos is the varroa control chemical most frequently found in honey.

Coumaphos can show up as residues in honey and beeswax.

6.2.4 Cymiazole (Apitol)

Cymiazole is a systemic miticide. It works through the bees' haemolymph. Cymiazole is not a fat-soluble substance, unlike the other synthetic chemicals mentioned. It therefore tends to dilute easily into honey.

Apitol is a granular product that is mixed with syrup, and either fed as normal or applied directly to the bees using a controlled dosage syringe. Two applications are made 7 days apart for effective varroa control. Best results are obtained in the autumn when there is little or no brood in the hive. Apitol should definitely not be used during the honey flow.

6.2.5 Bromopropylate (Folbex)

Bromoprophylate is one of the oldest varroa control substances, but is no longer used extensively in Europe because of concerns about residues in honey. It is a fat-soluble chemical like fluvalinate and flumethrin, and residues were still found in a significant percentage of German honey samples 8 years after its use was voluntarily discontinued in that country. The honey residues come from beeswax containing the active ingredient, either in colony combs or in foundation.

Folbex contains bromoprophylate in paper strips. The strips are lit and the resulting smoke distributes particles of the chemical around the beehive. Folbex has been shown to kill both varroa and tracheal mites. For varroa control, four applications of one strip at 4-day intervals is recommended. The product should not be used during the honey flow, while surplus honey is on the hives, or when the bees are in winter cluster.

6.2.6 Amitraz (Apivar)

Amitraz is a contact miticide, but while it is fat-soluble, it is volatile and unstable in honey. It completely degrades in 3-4 weeks, so it is not found as a residue in honey or beeswax. Beeswax actually has an accelerating effect on the degradation of amitraz. Amitraz is used in some countries in Europe.

Apivar is a plastic strip with amitraz impregnated into it. The strips are placed into the hive in the same way as Apistan, and for the same amount of time. Apivar is highly effective in killing mites, and has the advantage of being able to be used during the honey flow.

6.3 Organic chemicals

The need to develop mite control substances as alternatives to synthetic chemicals stems from both a desire to use more 'natural' compounds, and concerns about residues of synthetic chemicals appearing in bee products. Good mite controls must also be found in addition to ones currently in widespread use because varroa mites have already shown an ability to quickly develop resistance to a range of chemicals.

Two types of organic mite control substances (essential oils and organic acids) have been investigated, and promising ones from both groups are now in common use, particularly in Europe.

Several other substances (including icing sugar and vegetable oil) show some promise, but more research is needed to prove their ability to kill high percentages of mites under field conditions.

6.3.1 Essential oils

These are plant-derived extracts that are highly volatile (they evaporate quickly), and have strong, characteristic odours. They are found in almost all plants, but only those containing more than 0.1% oil are classified as 'essential' oils.

Essential oils perform various functions in plants. They are both toxic to pests and repel them. They also protect plants from bacteria and fungi. Essential oils are now often used in natural pesticide products such as citronella candles and linalool anti-flea pet shampoos.

Essential oils are compounds plants use to protect themselves from pests.

Over 150 essential oil compounds have been tested for their ability to kill varroa mites. Those with high evaporation rates were best at killing mites. However, to be effective, the oils must also not readily kill bees, and under test conditions only nine of 24 high-evaporation essential oils killed less than 10% of bees. A problem with essential oils compared with a chemical such as fluvalinate is the small difference between the amount of the substance that will kill mites and the amount that will kill bees. Fluvalinate is 800-1000 times more toxic to varroa than to bees, whereas the best essential oils are only two to four times more toxic.

While a number of essential oils kill varroa, many of them are also toxic to bees.

Essential oils are generally not considered toxic to humans, although wintergreen is a well-known exception, and thymol can be hazardous if it gets into the eyes. Essential oils can be absorbed into beeswax and then dissipate over time. They can also create taste and odour taints that can be detected by consumers. The Swiss have therefore used human taste panels to develop minimum residue limits for some mite control essential oils.

Essential oils used to control varroa can cause noticeable taints in honey.

Rather than review all of the research that has been carried out on essential oils and varroa, what follows are descriptions of several substances that have shown good results and are in common use as mite control substances. Other products (e.g., wintergreen oil, neem oil, manuka oil) show some promise, but more work is needed on hive application methods before they can be recommended as suitable organic control substances.

6.3.1.1 Thymol

Thymol is an essential oil extracted from the thyme plant. The amount of thymol in the thyme plant depends on the variety of plant. The type of extraction method also has an influence on the chemical composition. Lack of consistency in composition affects the ability of the compound to kill varroa mites.

Thymol is the only essential oil that is widely used, kills high percentages of mites, and does not kill significant numbers of bees. Tests have shown thymol kills 66-98% of mites, and has been shown to be as effective as formic acid in a number of tests. Thymol's effectiveness is similar for various application methods, including powder suspended between frames in mesh bags, liquid poured on a sponge on the top bars, and a continuous evaporator placed between the brood combs.

Thymol is effective in killing mites and is not toxic to bees.

Thymol kills a greater percentage of mites when there is little or no brood, since the vapours do not penetrate the brood. Air temperatures also need to be generally above 12°C and preferably above 15°C. Timing of treatments is therefore very important. Instructions for thymol application are included in appendix 4.

For thymol to be effective in killing varroa, timing of application and outside air temperature are very important.

Thymol leaves taste residues in honey and wax, but the residues do not persist for long periods of time. Studies have shown that if the product is applied after the honey flow, levels approaching the taste threshold (1.1 ppm) will not be reached in honey produced the next season.

6.3.1.2 Apiguard

Apiguard is a formulation of thymol in a gel. The gel is designed to be easy to apply and gives a more controlled release of vapours than other methods. Bees also pick up the gel on their body and move it around the hive, which results in better dispersal. Two formulations are available overseas - a single pack for hobbyist beekeepers and a bulk container with enough for 30 colonies. The dose rate is designed not to harm either bees or brood, although some killing of young larvae has been noted in Canadian trials.

Gel varroa control products have a more controlled release of vapours and are also moved around on the bodies of the bees.

The Canadian trials on Apiguard also showed lower rates (68-82% mite kill) than Spanish studies (98%). However, the Canadian work was conducted during the middle of summer with large amounts of brood in the colony, and the label recommends that the product is used in late summer after honey has been removed. There needs to be low levels of brood, but high enough temperatures, for the product to work effectively.

6.3.1.3 Apilife VAR

Apilife VAR is a combination of thymol (76%), eucalyptol, camphor and menthol, with 20 g impregnated in a vermiculite tablet. A tablet is placed on the top bars at the end of summer after the honey is taken off, and replaced with a fresh one 3-4 weeks later. Temperature and lack of brood greatly affect Apilife's ability to kill mites. Daytime temperatures shouldn't fall below 12°C for long periods.

Under optimum conditions, mite kill can be 97% for one-super colonies, and 90-95% in two-super colonies. Studies indicate that thymol is the ingredient producing most of the effect, and the other essential oils are not important.

Daytime temperature is very important for Apilife VAR to work effectively.

Because the product can give inconsistent results at low temperatures, it is recommended that a treatment with oxalic or lactic acid follows if natural mite drop two weeks after the end of treatment is greater than one mite per day.

Apilife VAR used in conjunction with mesh bottom boards has been shown to kill a higher percentage of mites than Apilife VAR on its own.

6.3.2 Organic acids

Organic acids are also compounds found in nature, and some have uses as pesticides. One organic acid, formic acid, was originally shown to be effective in treating honey bees infested with tracheal mites. It has now also been shown to kill varroa. Two further acids, lactic and oxalic, have been commonly used as varroacides in Europe for years.

All three acids are found naturally in trace quantities in honey. However, when applied for mite control they can each leave noticeable tastes in honey, so the Swiss have also developed maximum residue limits for these products. Honeys with high aroma can tolerate higher levels of organic acids without becoming noticeably tainted than can low aroma honeys.

The organic acids used in varroa control are also found naturally in trace amounts in honey.

6.3.2.1 Formic acid

Formic acid has proved to be a useful tool for varroa control in a number of countries. It does, however, have two disadvantages. The first is that it can have a high labour cost since some methods of application require multiple visits (up to 6 per apiary). The other disadvantage is that it can be hazardous to use.

Formic acid is a hazardous chemical to use and special care needs to be taken to ensure that it is handled safely.

Formic acid is widely used in Canada and Europe. A gel form is also the first organic varroa control substance approved in the United States. Original studies showed that a 65% solution could kill 94% of mites if applied on one or two absorbent pads for 4 days and then repeated three times. However, the number of visits required made use of the substance uneconomic for commercial beekeepers, so various absorbent and slow-release devices were developed to hold more of the product and disperse it over a greater length of time.

A variety of absorbent materials in plastic bags, including newspaper, towelling, potholders and pressed paper board are used in Canada. Most beekeepers produce these themselves. However, a relatively new commercial bagged product called Mite Away is becoming very popular.

The bag, containing 250 ml of 65% solution and the absorbent material, has windows cut in it before being placed on the top bars of a hive. The number of windows depends on the size of the hive. The bag and absorbent provide effective control with one application, although 20 days later another 50 ml of formic acid can be added if mite fall is still significant. The bags are used in either mid-spring, or late summer after honey has been removed. Outside temperatures need to be at least 10°C, but not greater than 30°C (since above this temperature formic acid can cause slight bee toxicity and queen loss). Further instructions are given in appendix 2.

An application device originally developed in Europe involves putting 250 ml of 65% solution on a 20 x 24 x 1.5 cm piece of soft fibre building board (e.g., Pinex), then sealing it in a freezer bag. Holes 1.5 cm across are punched in the plastic with a round tool. The number of holes depends on the hive type and the temperature. Late summer or autumn treatment is normal, with outside temperature at least 10°C.

The effectiveness of the treatment can be judged by weighing the board and bag. If evaporation is 7 g or more per day, 95% of mites can be expected to die during a 14-day treatment period. Effectiveness goes up to 97% at 10 g per day, but decreases significantly below 7 g per day. Boards can be reused by adding more formic acid.

In Europe, a variety of plastic devices have also been developed over the past 20 years to provide controlled slow release and diffusion of formic acid. Some of these devices have adjustable openings to regulate evaporation of the compound.

A gel product called Apicure has also been developed that distributes a given amount of formic acid (30 g of 65%) over time. Concentrations of formic acid in beehives from a single application of the gel were found to be the same or greater than four successive applications of the liquid form. In tests on colonies in the spring, the product killed 70% of mites. Apicure has been registered in the US, but since it has not been shown to have a consistently high degree of varroa control, the label states that it is useful for the 'suppression' of varroa.

An important advantage of the gel product is its relative safety for beekeepers. Formic acid will burn skin and eyes if the beekeeper is exposed to either the chemical or its vapours. It is also harmful or fatal if swallowed. Formic acid vapour is heavier than air, and concentrations of 18-57% are combustible if they come into contact with an open flame or spark. The gel product is safer to handle than liquid formic acid because it has a slower release of vapour.

Formic acid will burn skin and eyes, is fatal if swallowed, and fumes of the chemical can ignite. Always wear acid-proof gloves and eye protection when handling liquid formic acid.

It is often suggested that formic acid is able to kill varroa in capped brood cells as well as mites on adult bees. Tests where brood combs were fumigated in closed plastic foam boxes at 50 ml for 1 hour killed 100% of mites in the brood cells with 90% of the brood surviving the treatment. However, there is dispute as to whether formic acid kills mites in

brood under hive conditions, since not enough of the acid vapour may circulate around the combs and penetrate the brood.

Formic acid also appears to cause drone eggs to be removed from combs and can therefore affect drone production. Application of the compound reduces the survival of adult drones, with about half as many making it to 10 days old (sexual maturity) compared with drones in untreated colonies. Formic acid should not be applied to colonies that are being used for drone rearing (queen mating) purposes.

Formic acid should not be applied to colonies being used for drone rearing.

Residues of formic acid can be found in honey and beeswax, although trace amounts of the compound also appear naturally in honey. The threshold for taste residue in honey is 150-600 ppm, depending on the lightness in flavour of the honey. If formic acid is applied in the autumn, residues in honey stores the next spring are likely to be 40-200 ppm, while residues in new honey are likely to be 25-50 ppm, depending on the type of honey. In Denmark, honey from colonies not treated with formic acid was found to have about 20 ppm, while a sample of retail honey had about 38 ppm. Residues of formic acid do not build-up over time in beeswax in the way chemicals such as fluvalinate do.

Varroa has not yet shown resistance to formic acid, and researchers are not sure how the compound actually kills mites. What is known is that while formic acid is effective (70-80%), it is not as effective as synthetic chemicals such as fluvalinate. Success depends on the amount used, the strength of the colony, and the ambient temperature. Best mite kill rates are obtained when outside temperatures are high enough to achieve good evaporation. Beekeeping practice overseas suggests that for effective control of varroa at levels below an economic threshold, the product should be used either in conjunction with other synthetic or organic chemicals or with biotechnical methods such as drone trapping.

For effective varroa control, formic acid should be used with other chemicals and/or biotechnical controls.

6.3.2.2 Oxalic acid

Oxalic acid is a more recent addition to the arsenal of organic acids used for varroa control. Oxalic acid is a corrosive, poisonous acid like formic acid, and is used in textile finishing and as a cleanser.

Swiss research showed that 3% oxalic acid, sprayed at 3-4 ml per comb side in broodless colonies, killed 98% of mites. In colonies with brood, however, the efficiency was 30-40%. The researchers recommend one treatment at the end of summer if natural mite fall is more than one mite per day during mid-summer. If there are more than five mites falling per day at the beginning of autumn, a second treatment is required. This should generally be sufficient to achieve good mite control, although there may be a significant die-off of over-wintering bees.

A new application method for oxalic acid has recently been developed in Europe. The method involves mixing oxalic acid crystals into 1:1 sugar syrup, and then pouring a measured amount between the combs in early winter, directly on the bees. The colony should be broodless, and the syrup should be lukewarm to avoid chilling bees. Outside temperature should be above 0°C. The oxalic acid does not work through evaporation, so temperature is not as important as it is with essential oils or formic acid.

A mixture of oxalic acid and sugar syrup trickled between combs in winter is a low-cost form of organic acid varroa control.

Research suggests that while there is little difference in effectiveness between 4.2% oxalic acid in the syrup and 3.2%, the lower concentration doesn't affect colony build-up as much the next spring. Higher concentrations can affect over-wintering and spring development in cold climates. Five millilitres of the syrup is applied per frame covered in bees, using a graduated syringe. Instructions for oxalic acid application are included in appendix 3.

The big advantage of the trickle system is the decrease in labour costs, since the frames don't have to be taken out of the hive. The material can also be used to treat newly made-up nucs or splits during the broodless period that occurs prior to a new queen beginning to lay.

As with formic acid, extreme care must be taken when handling oxalic acid because it is corrosive. A dust mask, goggles and chemical resistant gloves must be worn when handling the pure chemical, and the syrup should be mixed only in a well-ventilated room or outside.

Extreme care must be taken when handling oxalic acid because it is corrosive.

Oxalic acid can also produce noticeable tastes in honey, and the Swiss maximum residue limit for taste is 400-900 ppm. However, when applied in autumn no noticeable increase in oxalic acid residue was found in honey produced the following season.

6.3.2.3 Lactic acid

Lactic acid is a compound found naturally in milk, molasses, and various fruits and wines. It is also found in small quantities in honey. Lactic acid is used in a wide range of products, including adhesives, plastics and pharmaceuticals.

In the 1980s, researchers in Germany showed that lactic acid was effective in killing varroa, and field trials using a backpack sprayer with a dosage (drench) gun confirmed that 8 ml of 15% lactic acid applied to each comb face killed 92-99% of mites with very low bee mortality. However, up to 60% of bee eggs were sometimes removed immediately after treatment. The other major drawback identified was the time required, at about 12 colonies per hour.

Since that time lactic acid has become an important component of biological mite control programmes in Europe. Normal mite kill for the product in broodless hives is considered to be about 80%. However, if the material is applied to colonies with brood, the effectiveness drops to 20-40%. As a result lactic acid is normally used as a mite control in late autumn. Hand sprayers are generally used because they can be worked with one hand while the other holds the frame. To apply the required 5-6 ml of 15% lactic acid, four to six pumping strokes are required. Overdosing is said to be a problem, particularly in late autumn, so care is needed in applying the material. Chilling can also occur, although in Germany the material is applied even when the outside temperature is 0°C.

Lactic acid can be effective in killing varroa if it is applied to broodless colonies.

Applicator safety is not as important with lactic acid as it is with formic acid. However, it is still recommended that protective goggles and chemical resistant gloves are worn when handling the bulk product.

Of the three organic acids used for varroa control, lactic acid produces the least noticeable residues in honey. Swiss researchers have determined a maximum residue limit affecting taste at 800-1600 ppm. When lactic acid is applied in the autumn, the levels in stored honey go up to 1500 ppm, but 4 weeks later they are below 500 ppm, less than the maximum residue limit. Lactic acid can also be used in the spring without causing significant residues, provided it is applied more than 8 weeks before the nectar flow.

6.3.3 Vegetable and other oils

Vegetable oils have been shown to be effective in the control of tracheal mites. The oil is administered as vegetable shortening mixed in a sugar patty. The oil doesn't kill the mite directly, but instead makes the bees unattractive or unrecognisable to the mite.

Vegetable oils have been used to control varroa as well, and several commercial formulations have been developed that are claimed to kill good percentages of mites. However, research is somewhat contradictory about their effects.

Danish researchers trialed a formulation (canola/rapeseed oil with an emulsifier), as well as soybean oil with different emulsifiers. The oils were either sprayed on bees or administered in patties. While the oils with high concentration of emulsifier killed high levels of mites (up to 97%), the side effect was significant bee deaths (over 50%). Oil mixtures with less emulsifier were not effective in killing mites. Oil patties similar to those used with tracheal mites did not significantly reduce varroa levels. The researchers' conclusion is that vegetable oils do not seem a realistic alternative to organic chemicals for varroa control.

Studies suggest that vegetable oil, while killing varroa mites, is also toxic to bees.

French researchers have trialed both canola/rapeseed oil and mineral (paraffin) oil with an emulsifier (Tween at 5%). Hives were sprayed with 6-10 ml of the oil frame by frame in autumn when colonies contained only small amounts of brood. The oil was applied once per week for three weeks. The best effect was for the mineral oil and Tween mixture, with 97% mite kill after two applications and 99.5% after three. There was some bee mortality with the mixture, but mostly due to the manipulation of the frames. The substance didn't affect the brood.

The French researchers concluded that the mineral oil/Tween mixture stayed longer and was better spread on the bodies of the bees than the canola/rapeseed oil mixture. This indicates the oil might affect the ability of the mites to remain on the bees. Time required for application seems to be the major drawback, at 5-10 minutes per colony. The product is recommended for use with mesh bottom boards to keep fallen mites from re-entering the hive.

6.3.4 Icing sugar

Since icing sugar has proved to be an effective means of surveying bees for varroa mites, research has recently been conducted in Finland to gauge its effectiveness as a miticide in colonies. Fifteen grams of the sugar was dusted between the combs of two-storey

colonies in mid-summer, with different combinations of days and times between treatments. Mite fall was then measured with paper boards below mesh screens.

The average mite fall on the treated colonies was between 47 and 56 times greater than the control colonies. A treatment once every 3 days showed the best results in reducing mites, although total efficiency of the method was not calculated.

Work still needs to be done to determine the best methods, but it appears that super-fine icing sugar together with mesh bottom boards may offer a bee-friendly (and even bee stimulating) mite control alternative that can be used at all times of the year without fear of residues. Because the sugar interferes with the mite's ability to cling to the bees, the researcher suggests that mite resistance will not develop.

More fieldwork is needed to prove the efficacy of icing sugar as a varroa control substance.

6.3.5 Outlook for organic chemical controls

Because there are significant residue and resistance problems with synthetic varroa control chemicals, beekeeping industries and researchers around the world are working hard to develop effective organic chemical alternatives.

However, these points should be borne in mind when considering organic chemicals as alternative varroa controls:

- Some organic chemicals can kill significant numbers of bees and can be extremely hazardous to beekeepers.
- No organic chemical is currently as effective as synthetic chemicals.
- Any organic chemical at this point needs to be used in conjunction with biotechnical methods or other organic or synthetic chemicals to keep mite levels below colony damage thresholds.
- Application systems for organic chemicals need to be improved to regulate the dose, allow for prolonged application without having to return to the hive, and ensure proper dosage is maintained even when temperature conditions fluctuate.
- Mites can also develop resistance to organic control substances such as essential oils and organic acids.

6.4 Avoiding chemical residues

Residues resulting from the use of chemicals in agriculture are a major problem in food. Beekeepers in New Zealand have already faced residue problems in the past. For example, lead and zinc residues were once a problem for some beekeepers because of galvanised drums, solder on extraction equipment, and lead paint on honey supers.

The idea of having pesticide residues in honey and beeswax runs counter to the philosophy of most beekeepers in New Zealand. However, with the advent of varroa it is certain that miticide residues will be found in bee products produced here. The very high sensitivity of testing procedures means that residues can be detected in many bee products. Modern laboratory analysis can routinely detect chemical compounds in the order of 1 part per billion, or the equivalent of 1 teaspoon of a pesticide mixed into 25,000 drums (nearly 7,700 tonnes) of honey. Some chemicals such as fluvalinate persist in beeswax, so concentrations will increase within the beehive each time a treatment is applied.

The presence of chemical residues in honey has the potential to devalue bee products and create consumer resistance. Honey buyers and importers are also likely to require product to be tested for residues as part of their terms of trade.

Residues can be minimised in five important ways:

- **Choose pesticides that because of their chemical structure are least likely to contaminate the product that is being harvested.** Varroa treatments vary in their tendancy to leave residues in bee products. Consider this factor when designing a treatment programme.
- **Time the use of the miticide so that it will not come into contact with the product being harvested.** Care also needs to be taken with the honey frames that may be in the brood nest. In some beekeeping operations, and especially during manuka honey production, frames from the brood boxes are often extracted. This practice is likely to result in increased residues in honey for fat-soluble mite control chemicals such as fluvalinate and flumethrin.
- **Reduce the total amount of pesticide used by only applying products when mite populations reach economic threshold levels.** However, this should only be done once the acute phase is over and invasion of mites from feral and untreated colonies is not a major problem.
- **Carefully follow the label instructions on the products.** These instructions have been designed to minimise residues. A good example is removing miticide strips at the end of the treatment, rather than leaving them inside the hive.
- **Only use registered products.** For instance, don't use Mavrik instead of Apistan, even though it may appear cheaper. Mavrik has a much higher dose of fluvalinate than Apistan, and home-made products cannot achieve the careful release given by Apistan. Based on overseas experience, Mavrik's use in beehives would result in significant residues in honey and the development of quicker resistance to fluvalinate by mites (see chapter 7).

7. CHEMICAL RESISTANCE

This chapter explains what chemical resistance means in relation to varroa, and outlines what can be done to reduce the chances of varroa developing resistance to chemical controls.

7.1 What is chemical resistance?

Chemical resistance occurs when a pest such as varroa becomes more and more able to withstand a pesticide that is being used, so that the chemical no longer kills most of the pest population.

The word 'resistance' is also sometimes used in association with varroa to describe the ability of honey bee colonies to live with an infestation of varroa. However, the word 'tolerance' has been used throughout this book to describe that ability, in order not to confuse the two terms.

7.2 Why resistance happens

The process of sexual reproduction results in genetic variation. Offspring do not look exactly like their parents because only half of each parent's genes are represented in any egg or sperm, and because there is chance involved in which one of those sperm combines with an egg in the fertilisation process. Random mutations of chromosomes can also add further variation.

Eye, hair and skin colour are a few of the many variations found in the human population. While for us such differences may seem inconsequential, the variation in the characteristics of individual animals or plants in a population is highly important in an evolutionary sense. It means that when conditions change, there will usually be some members of the species that are physically able to survive. If not, the species becomes extinct.

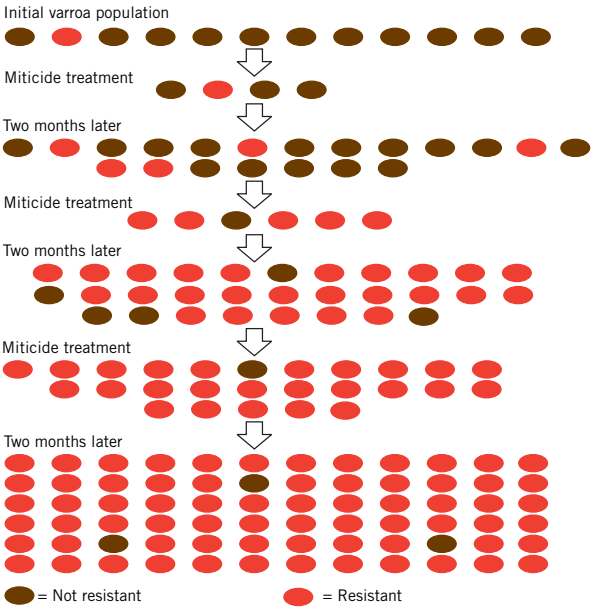
The individuals that are better adapted are more likely to reproduce and pass on their genes to the next generation. These genes then become more and more common in the population, while genes that are not well adapted become less and less common.

It is this process that allows varroa to become resistant to pesticides. Under 'normal' circumstances, the resistant mites are not usually as good at surviving as the non-resistant mites (hence the reason their genes are not well represented in the mite population). However, when mites come into contact with the chemical, most of the susceptible mites die while most of the resistant mites survive. Over time, as more generations of mites are produced, the genes of the resistant mites become widespread in the population, while the genes of the susceptible mites are found less and less.

Interestingly, if the pesticide is no longer used, the percentage of resistant mites in the population will usually decline. The reason is that there is generally some other significant survival advantage inherent in the susceptible mites that allows them to be more successful in breeding more mites at times when the chemical is not in use.

An example of how the populations of resistant mites change with repeated miticide use is presented in figure 7.1. The red dots are the resistant mites.

Figure 7.1 Development of chemical resistance



7.3 Creating resistant varroa in the laboratory

The pesticides used for varroa control have been selected because they kill most or all varroa when the recommended dosage and usage pattern is followed. Before government authorities allow a pesticide to be sold, scientific studies must be carried out to show that the chemical is highly effective in killing mites.

However, by exposing varroa to very low concentrations of the pesticide, scientists have shown that it is possible to select for mites that show some resistance to the chemical. The varroa might have a slightly thicker cuticle that protects them from the pesticide for slightly longer, or they might have enzymes that can break down some of the pesticide before it causes damage.

Scientists have shown that by keeping the varroa in constant contact with low concentrations of the pesticide, only mites with the resistance are likely to breed. Slowly increasing the concentration of the pesticide will result in the selection of more and more resistant mites until mites are selected that are resistant to the full strength of the pesticide.

7.4 How beekeepers have created resistant varroa

Beekeepers have unwittingly created resistant varroa in a very similar manner to the way scientists do it in the laboratory.

7.4.1 Use of Mavrik

Apistan strips contain the pesticide fluvalinate. The strips are formulated to slowly release fluvalinate at a constant rate for a given period of time to control varroa. The strips should be removed after this time. The strips are expensive, however, and it didn't take beekeepers overseas very long to discover that Mavrik, a common horticultural spray, also

contains fluvalinate and is a fraction of the cost of Apistan strips (Mavrik is a bulk liquid rather than an expensive, slow-release plastic strip). Beekeepers found that pieces of cardboard dipped in a very weak Mavrik solution were very effective at controlling varroa in beehives.

However, because Mavrik dissipates quickly (i.e., it is not in a slow-release strip), using Mavrik on cardboard resulted in varroa being exposed to lower concentrations of fluvalinate than with Apistan. Beekeepers found that they had to use increasingly more concentrated Mavrik solutions until not even 100% Mavrik was giving good control. Worse still, because Apistan also contains fluvalinate, Apistan was now also ineffective against the resistant mites. Use of Mavrik to control varroa has also been implicated in findings of fluvalinate residues in honey.

Don't put beekeeping at risk by using non-approved chemicals like Mavrik to control varroa.

7.4.2 Incorrect use of miticide strips

Apistan strips are designed to be left in hives for only 6-8 weeks, during which time they release a constant amount of fluvalinate per day. After that time, the amount of fluvalinate released begins to decline. For this reason, the strips must be removed. Otherwise, the mites will be exposed to low concentrations of fluvalinate and will build up resistance.

Some beekeepers overseas have shown that while they are good at putting the strips in the hives, they can sometimes be tardy in removing them. When they put the strips in hives in spring, they just add them to the strips that were placed in the hives the previous autumn and spring. This practice has probably produced resistant varroa by exposing mites to low concentrations of fluvalinate.

Another practice that can produce resistant mites is to cut Apistan strips in half. The practice may appear to save money, but in the long run it can cost beekeepers dearly.

7.5 Cross-resistance

Cross-resistance is where a varroa mite that becomes resistant to one chemical automatically becomes resistant to another that is either chemically very similar or acts on the mite in a similar way. An example of cross-resistance is where mites that have become resistant to fluvalinate (Apistan) are also found to be resistant to flumethrin (Bayvarol), a pesticide very similar in chemical structure to fluvalinate. Interestingly, some of these mites have also shown resistance to amitraz (Apivar), even though it is from a different chemical class.

7.6 Slowing resistance

Varroa is likely to build up resistance to all pesticides (both synthetic and organic), given enough time and misuse of products. Varroa resistance has so far been reported to acrinathrin, armitraz (Apivar), bromopropylate (Folbex), chlordimeform, coumaphos (Check-Mite+, Perizin), flumethrin (Bayvarol) and fluvalinate (Apistan).

There are, however, a number of things that can be done to slow the resistance process:

- Only use registered products.
- Follow the instructions on the label.

- Only use the pesticide when it is needed.
- Use the recommended concentration of pesticide so that mites are not exposed to low concentrations.
- Remove the pesticide when recommended, again so varroa are not exposed to low concentrations of the chemical. A useful tip is to mark the hive with the date of application and the number of strips so it is obvious when the strips need to be taken back out.
- Do not re-use strips.
- Don't rely on just one chemical. Alternate chemicals that are from different chemical classes to reduce the chance of cross-resistance. An example of this approach is the use of fluvalinate in the spring and formic acid in the autumn, rather than Apistan and Bayvarol (which are from the same chemical class). The formic acid treatment will kill most of the fluvalinate-resistant mites and the next fluvalinate treatment will kill most varroa that have become resistant to formic acid. Eventually, mites might develop resistance to both formic acid and fluvalinate. However, this will hopefully take a long time.
- Encourage other beekeepers to also use techniques that will delay resistance. Any resistant mites they produce will eventually find their way into other beekeepers' hives.

To delay resistance:

- Only use registered products.
- Follow the instructions carefully.
- Alternate control methods.

7.7 How to measure resistance

When resistance occurs, it usually does so slowly and in isolated localities, after which time the resistant mites spread further afield. Early detection of mite resistance is therefore important to avoid major losses of beehives that have been unknowingly treated with an ineffective chemical.

The first sign of resistance is usually a colony or colonies that have high levels of varroa still present after a treatment has been applied. However, because high mite levels can also be caused by invasions of varroa from other colonies, it is important to test suspect mites for resistance. The US Department of Agriculture has developed a test for resistance to Apistan. Directions on how to carry out the test are included in appendix 5.

If your chemical control method does not appear to be working, make sure to test the varroa for chemical resistance.

8. BIOTECHNICAL CONTROL

This chapter describes various non-chemical methods that can be used to control varroa.

8.1 What does 'biotechnical' mean?

'Biotechnical' is a word that is now often used to describe non-chemical mite control methods. There are a number of beekeeping management practices that are likely to affect mite populations, but biotechnical control can probably best be defined as beekeeping management techniques specifically designed to reduce mite levels in a colony.

'Biotechnical' means beekeeping management techniques specifically designed to reduce mite levels in a colony.

Biotechnical varroa control methods have been developed for a number of reasons, including:

- requirements of organic (non-chemical) production;
- fear of chemical residues and chemical resistance; and
- high cost or inability to obtain chemical control substances.

Biotechnical methods are generally not used as a complete means of varroa control. However, they are often incorporated into integrated pest management systems, whether with synthetic chemicals, or more generally with organic control substances.

8.2 Brood removal and trapping

Brood removal for control of varroa is based on the understanding that mites are confined in brood cells once the cells are capped. The mites can therefore easily be removed from the colony without the mites being able to escape back onto the adult bees.

8.2.1 Worker brood removal

Removing all sealed brood over a 24-day period has been shown to have a 90% efficiency in removing varroa from honey bee colonies. Systems have also been developed to isolate the queen on single combs, and then shift the queen to another frame at intervals, so that the brood acts as a trap for mites seeking a place to reproduce. Three brood combs produced in nine-day intervals and then removed in a further nine days will trap about 79% of mites in a normal sized colony. The brood combs themselves are sometimes subjected to formic acid or heat treatment outside of the colony.

The main problem with worker brood removal is that it requires a large number of frames to be removed to achieve good control, and the removal of frames will obviously affect the population and productivity of the colony.

Removal of worker brood can reduce mite levels, but it also greatly affects colony productivity and is labour intensive.

8.2.2 Drone brood trapping

Probably the most well-known biotechnical control method for varroa is drone brood removal and trapping. Drone brood is generally used for this purpose because varroa mites show an 8 to 10 times greater preference for drone brood than for worker brood. Far less

brood needs to be removed from the colony compared to worker brood to achieve good results, and the effects on the colony are not significant (unless drones are required for queen mating purposes).

Drone brood trapping reduces mite populations and doesn't affect colony productivity.

European researchers have produced theoretical models of the effect of drone brood removal on varroa populations. They assumed insertion of a frame with 1500 drone larvae into the centre of the brood nest, followed by the removal of the frame and destruction of the brood 1 week later after the brood had been capped. Their model showed that if this was carried out twice, one month apart at the beginning of summer, the mite population in a heavily infested colony reduced from 16,000 mites to about 1750 (89%), provided there was no reinvasion of mites from other colonies.

The results of the theoretical model have been confirmed in field studies. Drone brood removal can at least temporarily halt the growth of mite populations in the colony. However, a mite population of 1750 in the middle of summer is considered by many observers to still be high enough to require some type of further treatment in the autumn.

The problems with inserting drone brood into a large brood nest are that 1) there are a number of mites already inside capped brood cells that cannot transfer to the inserted drone brood, and 2) the large amount of worker brood in the colony, in addition to the inserted drone brood, competes for mites against the drone brood, even if the drone brood is more attractive to mites.

These problems can be overcome, however. The theoretical model showed that if one comb of drone larvae was inserted into a **broodless** colony and removed a week later (trapping), it would reduce mite populations by 92.5%. Two combs reduced the populations even further to 99.4%, equal to the most effective chemical mite treatment.

Drone brood trapping in a broodless colony can reduce mite populations at a similar rate to chemical controls.

As a result of this modelling, the researchers have now developed methods that incorporate drone brood trapping of mites into beekeeping management systems for swarm control and hive increase.

Drone comb can be made by taking a good, well-drawn comb, cutting a semi-circle out of the bottom portion, and then putting it back into a strong colony just before the honey flow for the bees to draw out. Another good method is to put a $^{3}/_{4}$ depth frame in the middle of a full-size brood super in the late spring. The bees will draw out the remaining bottom quarter with drone cells that can easily be removed once the drone brood is capped.

8.2.3 The hive splitting varroa control method

This method of varroa control using hive splitting was developed by Dutch researchers, and is based on both the theoretical model of varroa population growth and techniques for biotechnical control of varroa that originated in Vietnam (see 12.6). The method should be used during swarm control in the late spring/early summer, or when making 'autumn' splits in the late summer while the honey flow is still on.

Drone trapping can be incorporated into normal beekeeping management for swarm control or the making of splits.

Step 1

- Choose two colonies.
- Place a comb with empty drone cells in the centre of the brood nest of one colony (colony A).

Step 2 (one week later)

- In colony A, shake all the bees off the combs with brood except the drone comb, and put the brood in the other colony (B), after first checking for AFB.
- Put a second, empty drone comb in the centre of the brood nest of colony A.
- Put the queen in colony B above a queen excluder in a further super with empty combs.

Colony A now only has a single frame of uncapped drone larvae and an empty drone brood comb, while colony B has a two super brood nest plus a third super containing the queen.

Step 3 (one week later)

- Remove the comb that now has capped drone brood (and mites) from colony A (the comb that contained uncapped drone larvae the week before). The comb can be uncapped with a knife or cappings scratcher and the drone pupae can be removed from the comb in a small hand extractor, washed out with a hand spray nozzle attached to a garden hose, or simply shaken out on the ground. Drone pupae make excellent chicken feed.
- Put this cleaned comb (or another clean drone comb) into the centre of the brood nest of colony A.
- Shake all the bees off the new brood that has been produced above the excluder in colony B. The brood is all too young to contain any mites. Move the brood to colony A, after first checking for AFB.
- Take the bees and queen from the excluded box in colony B and make a broodless split (colony C). Shake all the bees off the second drone comb in colony A (now containing uncapped larvae), and put it in the centre of the super of colony C.
- Put a protected queen cell in colony B.

Step 4 (one week later)

- Shake the bees from the drone comb containing uncapped drone larvae from colony A, and place it in the centre of the brood nest of colony B.
- Remove the comb that now has capped drone brood (and mites) from colony C and destroy the pupae (see Step 3).

Step 5 (one week later)

- Remove the comb that now has capped drone brood (and mites) from colony B and destroy the pupae (see Step 3).
- Check colony B for a new laying queen.

According to the field trials carried out by the Dutch researchers, on average this method is 83.4 to 93.4% effective in removing mites from all three colonies (depending on the amount of drone brood available for trapping). The researchers have managed 70 colonies using this method for 5 years in Holland without using any additional, chemical control.

Drone trapping using the hive splitting method is a highly effective way to reduce mite populations during the production season.

The researchers found that the time required to carry out colony management was not much more than to manage the colonies they ran as controls in the experiment. The extra time was limited to having to manage the placement and extraction of drone combs.

8.2.4 Queen isolation cages

To increase the efficiency of drone or worker brood as a mite trapping method, beekeepers sometimes put the queen on a comb in an isolation cage. The cage is made from pieces of queen excluder, and allows nurse bees to have access to the queen and larvae. A queen isolation cage can easily be constructed from wood and a sheet of plastic queen excluder.

However, in the hive split method described above, the placement of drone combs into colonies in full lay, when those colonies have had brood removed, was found to greatly enhance the production of drone brood in those combs. As a result, a queen isolation cage was not needed. Using a queen isolation cage is also time-consuming and can affect colony populations because the queen is forced to only lay on the isolated comb.

Using a queen isolation cage can affect colony productivity.

8.3 Mesh bottom boards

The use of mesh bottom boards as a biotechnical control method is based on the observation that about 20% of varroa mites (mothers and offspring) that emerge from cells with newly hatched adult bees fall off those bees to the bottom of the colony in the first 3 days after emergence. This natural mite fall is likely to be caused by bees grooming themselves and each other.

Because not all of these mites are able to re-attach themselves to bees on the bottom board, at least some mite mortality results. However, mesh bottom boards are designed to ensure that a far greater proportion of the falling mites are not able to find a new bee to grab on to, so the mites die of chilling and/or starvation.

Mesh bottom boards are designed to ensure a greater proportion of mites naturally falling off bees aren't able to re-attach themselves and re-enter the hive.

The technique involves either:

a) modifying bottom boards by replacing all but about 100mm at the front and 50mm at the back with 3 mm opening wire mesh; or
b) making inserts using the same mesh to go on top of existing bottom boards.

One way to construct an insert (figure 8.1) is as follows:

- Using 20 mm x 20 mm timber, cut two pieces to 465 mm and two pieces to 405 mm.
- Nail and glue the 405 mm lengths to the ends of the two 465 mm lengths to form a rectangular rim.
- Using mesh with 3mm openings, cut a rectangular piece measuring 405 mm by 505 mm.

- Staple the piece of mesh on top of the wooden rim.
- Using 20 mm x 20 mm timber, cut one piece 365 mm in length, two pieces 505 mm in length, and two small pieces about 60 mm in length.
- Nail the 365 mm piece on top of the mesh at one end of the rim, and the two 505 mm pieces on top of the mesh at either side of the rim. Nail the two 60 mm pieces on top of the mesh at the other end of the rim at either corner.
- The overlap created by the top pieces and the bottom pieces should hold the insert securely together.
- The end of the insert with the two 60 mm pieces in the corners will have a gap of about 285 mm without any top piece. This will act as the new hive entrance when the insert is installed.

To install the insert, disassemble the hive and turn the existing bottom board around so that the entrance faces the opposite direction. Place the insert on top of the bottom board with the four-sided rim down, and the gap in the three-sided rim facing in the direction of the bottom board before it was turned around. This gap will act as the new hive entrance when the hive is reassembled on top of the insert. The opening at what is now the back of the hive created by the old bottom board entrance serves as an easy slot for holding a sticky board or card for counting varroa.

Figure 8.1 A mesh bottom board insert for varroa. When the insert is put on a hive, the bottom board is reversed from its original position and the gap in the rim of the insert (left of picture) serves as the new hive entrance. The old bottom board entrance (right of picture) acts as a slot for easy insertion of the sticky board.

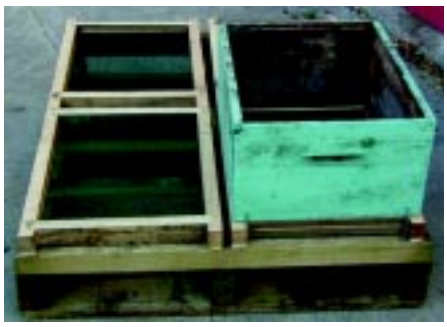


Figure 8.2 Mesh bottom boards without a solid floor designed for use with palletised beehives. The hive entrance is a groove cut into the piece of timber at the front.

A study in the US showed that while mite levels in colonies with mesh bottom boards reduced at between 14% and 28% in the summer months, there was no significant difference in these levels when compared to colonies that didn't have the boards. The study also suggested that the boards were not an effective stand-alone treatment. Since mesh bottom boards are used by many beekeepers as part of their mite control programmes, the effect of these boards on varroa populations needs further investigation.

The authors of the US study say that to ensure virtually no fallen mites are able to re-enter the colony, the total distance from the floor board to the top of the mesh should be at least 50 mm (the insert described above has a total depth of 40 mm plus the depth of the riser on the floorboard). The study also suggested that the boards were not an effective stand-alone control.

For the mesh bottom board to be effective, sticky boards are not required to trap the mites and hold them. However, a white card (paper or plastic) is a worthwhile addition to a mesh bottom board if the board is also going to be used to survey mite populations.

Mesh bottom boards need to be cleaned on a regular basis to avoid a build-up of wax moth on hive debris. Wax moth feeding on debris can be eliminated by using a purpose-built mesh bottom board that does not have a solid floor below the mesh (figure 8.2).

Mesh bottom boards are not an effective stand-alone control method for varroa. They are, however, very useful in monitoring mite levels.

8.4 Pollen traps

Pollen traps have also been studied to determine their effectiveness in reducing mite populations. The principle involved is the same as for mesh bottom boards. Obviously the type of pollen trap would make a significant difference to its effectiveness, since only traps with a screen covering a wide area of the bottom of the hive would collect significant numbers of mites. A US study showed that mite reduction using pollen traps was insufficient to keep varroa numbers in colonies from increasing to damaging levels without the addition of other forms of mite control.

8.5 Heat treatment

Heat treatment to control varroa is based on the observation that adult female mites are more sensitive to temperature increases above normal brood nest temperature (34°C) than are the bee larvae and pupae themselves.

Treating the whole hive (including the bees) has been found to be ineffective, since either the heat will kill many of the adult bees, or the colony will regulate the temperature downwards by fanning, resulting in the mites on both the bees and in the brood surviving. As a result, a method has been developed to treat the brood, once the bees have been removed, by heating it in an incubator.

The method is generally used in conjunction with queen isolation cages, or with nucleus colonies, since all of the worker brood is treated. Studies show that if the brood is heated to 44°C for 4 hours, 100% of the mites in the capped brood will be killed. Only about 5% of the brood itself is killed in the process, mostly in the form of older larvae that crawl out of the cells. Heat can also cause some deformities in adult bees that develop from old pupae that have been treated. There is no noticeable affect on the life-span of bees emerging from heat treated comb.

While heat treatment kills all the mites in the brood, many remain alive on the bees. So the effectiveness of the technique in reducing mite populations depends on the size of the colony and the amount of brood compared with the number of bees. One heat treatment is likely to be between 50% and 80% effective in reducing the total mite population in a hive. The method therefore is insufficient to provide total mite control below economic thresholds. It is also quite time consuming, and is therefore probably not worthwhile for commercial beekeepers.

Heat treatment, while effective in killing mites contained in brood, is time consuming and probably not commercially viable.

8.6 Change of cell size

Varroa prefer drone brood to worker brood, and the longer development of drone pupae allows more varroa females to be produced in each generation. The way varroa choose drone brood, however, is not well understood, although cell size appears to play an important part in the process. Brazilian researchers showed that when a piece of worker comb drawn by non-Africanised bees was put into an Africanised colony, more mites chose the non-Africanised comb, even though both pieces of comb contained larvae coming from the same queen. The non-Africanised comb had bigger cells than the Africanised comb.

A US beekeeper has suggested that a change from 5.44 cm or 5.0 cm/10 cell foundation to 4.9 cm or 4.83 cm/10 cell foundation, combined with drone comb culling, can substantially reduce varroa populations. However, the idea still needs further study and controlled experimentation to determine if it has an efficiency similar to other well-documented mite control methods.

8.7 Eliminating the production of drone brood

Because varroa reproduction rates are much higher in drone brood than worker brood, it is argued that anything that can be done to reduce the amount of drone brood in a hive will affect population development of the mites.

The less drone brood in a hive, the lower the varroa reproduction rate.

Beekeepers therefore often cull drone comb, although there is obviously a natural stimulus on the part of honey bee colonies to make drone comb to ensure that drones are available for queen mating.

It's also important to realise that drone brood removal will not halt the population development of the mites. Female mites will still enter worker brood cells to reproduce regardless of whether drone brood is present or absent. The reproduction rate will just be slower on the worker brood.

9. BREEDING FOR VARROA TOLERANCE

This chapter provides background on how honey bees are able to tolerate varroa, and describes attempts that are being made to breed for varroa tolerance in honey bee stocks.

9.1 What is varroa tolerance?

Varroa tolerance (sometimes called 'resistance') is the ability of a honey bee colony to co-exist with an infestation of the mite. *Apis cerana*, the original host of varroa, has a number of important defensive mechanisms that allow it to develop its colony population, raise worker and drone brood, produce honey surpluses, supersede queens and swarm, all in the presence of varroa. Varroa exists in the colony, but the populations do not grow to damaging levels. Put simply, varroa does not kill *A. cerana* colonies, either as ferals or managed hives.

Tolerance to varroa is the ability of a honey bee colony to co-exist with an infestation of the mite.

There is also a high degree of variability of various varroa defensive mechanisms in *Apis mellifera*. While these mechanisms are not nearly as highly developed as in *A. cerana*, there is hope that through both natural selection and human-assisted selective breeding at least some of the mechanisms can allow *A. mellifera* colonies to also co-exist on a continuing basis with varroa infestations. The goal here is to develop *A. mellifera* colonies that do not allow varroa populations to grow to levels that seriously damage colony performance. Significant effort is being made in a number of countries to develop true varroa tolerant strains of *A. mellifera*. Bee breeding is seen by many scientists as the only viable, long-term solution to varroa control.

9.2 Varroa tolerance mechanisms

9.2.1 *Apis cerana*

The following varroa tolerance mechanisms have been identified in *Apis cerana*:

- Removing mites from infested cells (hygienic behaviour).
- Capped stage in worker brood not long enough to usually produce mated female mites.
- Uncapping cells, removing mites and recapping cells.
- Drone pupae infested with mites becoming weakened and not removing their cappings, thus 'entombing' the mites.
- Short season of drone rearing and low drone brood production.
- Grooming of worker bees by themselves and other bees, including possible damaging of mites.
- Significant absconding and swarming, where the adult bees leave the colony and with it the mites in the capped brood.

When the grooming and mite damaging behaviour was first discovered by researchers, this was thought to be a major reason *A. cerana* was able to successfully limit varroa populations, so efforts were made to assess the grooming and mite damaging abilities of different strains of *A. mellifera*.

However, subsequent research has suggested that the limited and seasonal production of drones, as well as the short capped stage of worker brood, are the main reasons varroa does not reach damaging levels in *A. cerana* colonies.

Apis cerana keeps varroa under control by having a short yearly drone production period and a capped stage for worker brood that is too short for the mites to reproduce.

9.2.2 Hygienic behaviour

Hygienic behaviour in *Apis mellifera* is usually defined as the ability of adult worker bees to uncap brood and remove the contents. *A. cerana* also do this, but they can actually uncap a cell, remove the varroa mites, and then recap the cell.

Hygienic behaviour in *A. mellifera* has been shown to have a significant effect on a colony's resistance to brood diseases such as American foulbrood and chalkbrood. The behaviour has been shown to be genetically based, so strains of bee can be selected that show a greater amount of this behaviour.

Studies have now shown that *A. mellifera* use the same behaviour to remove pupae infested with varroa that they use for brood diseases, even though unlike with brood diseases the pupae have not died. Uncapping behaviour similar to *A. cerana* has also now been observed with *A. mellifera*. In this case, the mites have been seen to leave the cells on their own, rather than the bees removing them. The cells are recapped later on.

Unfortunately, the rate at which *A. mellifera* uncaps and removes varroa infested brood is much lower than with *A. cerana*, and European strains uncap four times less of these cells than Africanised bees (8% compared to 32%). Still, many researchers believe that hygienic behaviour is a worthwhile trait to breed for in developing varroa tolerance in *A. mellifera*.

Hygienic behaviour is not as important for varroa tolerance as for the control of brood diseases.

Honey bees can be selected for hygienic behaviour by killing brood (either with a thin pin, or by comb freezing) and then observing whether the bees uncap and remove the brood. Undertaking a series of tests is recommended, since the strength of the colony can also have an effect on whether bees with a genetic predisposition for hygienic behaviour actually carry out the task. For varroa tolerance purposes, only colonies removing more than 95% of the brood within 48 hours should be considered hygienic.

9.2.3 Duration of capped stage

Although we tend to believe that *A. mellifera* worker brood is capped 8 days after the egg is laid, and remains capped for a further 12 days, there is actually a great deal of variability in this time depending on the strain of bees, and the difference in time is genetically based. The Cape bee (*A. m. capensis*) has a capped stage that is 2 days shorter than European strains, and differences of 1.1 days have been observed even with Italian bees.

The length of time brood stays in the capped stage has a significant bearing on how varroa populations develop in the hive. Male mites don't survive outside the cell, and since mating can only take place in the cell, a reduction in the duration of capping stage

means that fewer mated females are produced. The fewer mated females per brood cycle, the fewer new infested cells there will be in the next cycle. Studies have shown that even a one-hour reduction in the length of the capped stage can produce a 0.9% reduction in mite offspring per cycle. Calculated over a number of cycles, the result can be 8.7% fewer mites at the end of the season.

The problem with beekeepers selecting breeder queens with shorter capping stages is that it is very painstaking and labour-intensive.

Selection for shorter brood development time can reduce varroa production rates, but it is difficult and time-consuming to measure.

9.2.4 Suppression of mite reproduction

Not every female mite that enters a brood cell produces offspring, and some produce only males. The process the female goes through in the capped cell leading to mating is complex, and still not completely understood. However, it appears that some type of chemical 'trigger' obtained from the pupa is required for her to begin egg laying, and for her offspring to mate.

The number of female mites not producing offspring (called the 'infertility rate') is generally between 10 and 20% in *A. mellifera* colonies. There are also seasonal effects, with infertility lower in late winter/early spring, increasing as the brood rearing increases, and then going back down in autumn. However, mite infertility rates as high as 40% have been found in some bee stocks, and researchers have determined that it is a genetically based factor in the bees (suggesting lack of sufficient chemical 'trigger') that can be selected for and bred.

Identifying high-infertility stocks can be time-consuming, but results from bee geneticists in the US suggest high varroa infertility can result in slow (or even negative) mite population growth, so it may be worth considering for dedicated queen breeders. To survey for infertility, at least 20 mite-infested worker cells at the purple-eye pupae stage have to be dissected. This stage is chosen because it is too late for the female mite to begin producing viable offspring, and the young mites are easily distinguished from the dark brown-coloured original female that entered the cell. Mite infertility is judged as either a single dead female mite in the cell, or a single live female, but no offspring. The percentage of infertile cells can be compared between breeder queens.

Differences in mite infertility rates offer real hope of breeding varroa tolerant honey bee stocks.

9.2.5 Attraction of mites to brood

Bee larvae produce chemicals attractive to varroa that help the mites enter cells at the right time (just before capping). A German researcher put sections of the same age brood from seven different strains of bees into the same varroa-infested colony and found there were significant differences in the number of mites entering the cells for the different strains. This brood attractiveness also correlated with varroa population development in hives. The obvious suggestion is that mites staying out of brood cells longer slows down the mite reproduction rate.

Bee geneticists have found that this attractiveness is genetically based and can be selected for in bee stocks. The problem is in determining the relative number of mites in

cells, since different hives will have different mite numbers. A test similar to the one performed by the German researcher can be carried out, though it would be fairly painstaking.

9.2.6 Grooming

Grooming behaviour has been discussed above in relation to both *Apis cerana* and *A. mellifera*. There are considerable differences between the amount of grooming behaviour carried out in different stocks of *A. mellifera*. For instance, Africanised bees groom 38% of mites, versus 5% for Italians. This was originally suggested as a reason Africanised bee colonies in South America did not suffer significant damage from varroa infestation. However, it has since been revealed that a more important difference is the infertility rate, which is 50% for Africanised bee worker brood, compared with an average of 15% for European bees.

Bee geneticists have determined that grooming behaviour is genetically based and can be selected for in bee stocks. However, it is not considered to be an important trait to select for when breeding for varroa tolerance.

Grooming is not considered an important trait to select for when breeding for varroa tolerance.

9.3 Examples of breeding programmes for varroa tolerance

9.3.1 Russian stocks

Probably the best known breeding programme for varroa tolerance is the importation and controlled release into the US of bee stock from eastern Russia. The Russian stock is descended from *Apis mellifera* bees taken to that part of Russia at the end of the 1800s with the completion of the trans-Siberian railway. *A. mellifera* was not native to the area, but the original host of varroa (*A. cerana*) was. The Russian bees are therefore likely to be the stock of *A. mellifera* with the longest exposure to varroa anywhere in the world.

Honey bees from eastern Russia are likely to be the stock of Apis mellifera *with the longest exposure to varroa anywhere in the world.*

Tests carried out by the US Department of Agriculture showed the Russian stock had an average infestation of only 7% of worker brood 15 months after having been treated with Apistan, whereas similar US stock had 33% infestation within 12 months. A significant difference between the two stocks was the percentage of mites found to be on brood at any given time. For the Russian bees, this was 48%, compared to 65-75% in non-tolerant stock. It would appear that lack of brood attractiveness slowed down the population development of varroa in the colonies.

Breeder queens of the Russian stock were imported and kept under quarantine in Louisiana. Queens were reared from these breeders and then tested for varroa tolerance. The stock has now been released to commercial queen producers in the US who will make it available to beekeepers throughout the country.

9.3.2 Arizona practical breeding programme

This programme is described in more detail in chapter 12. The programme does not use detailed selection methods for varroa tolerance. It instead focuses on the ability of honey

bee colonies to survive varroa infestation without treatments, and then maintains the population of remaining colonies by isolated mating. The varroa tolerant population is reported to have been managed since 1994 without any other mite control being used, and with levels of varroa infestation of between 6 and 7 mites/100 bees. Queens from the programme have been used to requeen a 600 colony enterprise, with only about 1 in 15 hives showing significant varroa damage after one season.

Varroa tolerance can be developed in honey bee stocks using simple bee breeding techniques.

9.3.3 Selecting for shorter capped period

As discussed above, the duration of the capped period can reduce mite populations significantly (1 hour less results in an 8.7% mite population reduction). Bee geneticists have also shown that selecting for rapid development can result in a 5.4 hour change in worker development in the top 10% of colonies after the first generation of selection.

Canadian researchers found significant differences in the development periods of all three castes of honey bees (worker: 19.1-24.1 days, average 20.1 days; queen: 14.7-17.2 days, average 15.6 days; drone: 22.0-25.5 days, average 23.1 days). They used a queen isolation cage to confine the queen to a frame for a short period of time, and then followed the development of the eggs that were laid. They recommend that selection for rapid development is done with worker bees because this gives a reliable estimate with fairly small effort.

Significant differences exist in the development periods of all three castes of honey bees.

Their results have now been put into practice by a US queen producer, who selects queens based on rapid development. Queen cells are put in an incubator on the 14th day after the egg is laid, and then only those queens that have emerged at the very beginning of the next day are used for breeding stock. Breeder queens are also isolated on drone comb, with the queen only allowed to lay for a short time. The resulting drones are emerged in an incubator. Drones emerging on the 22nd day are marked, and then allowed to mature in an excluded queenless colony. The drones are used to inseminate selected breeder queens.

9.3.4 Selection for low varroa infestation levels

Projects in both Canada and Germany have involved selecting colonies for low varroa infestation levels (e.g., 24-hour mite fall), then using these as breeders for the next generation. In both programmes, the overall varroa infestation levels have gone down in all colonies over time. For instance, in the German breeding programme with Carniolan stock, 164 colonies with queens from the breeding programme were compared to 232 non-programme colonies. The mite levels in the selected stock were on average 36% less than in the non-programme stock. Correlations were found between mite infestation and a number of tolerance factors such as hygienic behaviour, grooming, brood attractiveness and infertility rate.

Correlations exist between varroa infestation and a number of tolerance factors in honey bees.

10. INTEGRATED PEST MANAGEMENT

This chapter explains the concept of integrated pest management, and shows how it applies to varroa control.

10.1 History of pesticide use in New Zealand

Pesticide use in New Zealand has gone through, and is continuing to go through, a revolution. The revolution started in the 1940s, when it was thought that all our agricultural pest problems could be solved with a 'silver bullet', or at least a collection of them.

Foremost among these silver bullets was the insecticide DDT. It was inexpensive, easy to use and very effective. We thought we had won the war against insects that were damaging our crops, and in other countries adversely affecting human health. DDT was used everywhere. Thousands of tonnes were applied to pasture to kill grass grub and other pests, used in home gardens, put into water to kill mosquitoes, and even dusted on human beings to control lice and fleas.

However, by the late 1950s, our silver bullets were starting to cause disquiet in some quarters. Increasingly, more insects were building up resistance to DDT. Residues of the chemical were turning up in foods such as milk and meat, and in humans, fish and other animals. Some bird species were becoming scarce because the chemical was making their eggshells too thin.

Rachel Carson's book *Silent spring*, published in 1963, highlighted what the world would look like if we carried on with the extensive use of pesticides. The public began to develop an understanding of the risks of pesticides, and in the last several decades there has been an ever-increasing pressure to reduce pesticide use, especially for chemicals that persist in the environment, kill a wide range of insects and have adverse environmental effects.

Domestic consumers and overseas markets are demanding reductions in pesticide use.

All areas of agriculture in New Zealand have been affected by these pressures, but most especially those relying on export markets. We have seen the growth of a number of organic and low-pesticide-use movements, both here and overseas. Some of our important markets are also not only demanding product without pesticide residues, they are requiring proof that the food was produced in a sustainable way that didn't cause ecological damage to the countryside. Now that the beekeeping industry has to rely on pesticides to control varroa, it will be under the same pressures regarding pesticide use faced by the rest of agriculture in New Zealand.

10.2 What is integrated pest management?

One of the ways New Zealand and other countries have been able to reduce pesticide use is through a technique called 'integrated pest management' (IPM). Traditional pest control involved applying chemicals at a prescribed time, regardless of whether the pest was actually present. IPM is different because it applies controls only when the pests are present, and uses a variety of suitable techniques to keep pest populations below the level where they cause economic damage. For a technique to be considered suitable, it

should be inexpensive, cause few or no chemical residues, not result in pest resistance, and not cause environmental damage.

Integrated pest management (IPM) uses a variety of techniques to keep pest populations below a level where they cause economic damage.

IPM is already in use in New Zealand beekeeping for American foulbrood (AFB) control, although it is usually not referred to as an IPM programme. The programme consists of monitoring hives for the presence of AFB, destroying affected material, sterilising equipment, and managing colonies to avoid the spread of AFB.

10.3 Economic threshold

A basic concept used in IPM is the 'economic threshold'. The economic threshold of a pest is the population level where the pest begins to cause a level of economic damage that is greater than the cost of controlling the pest.

The economic threshold for a pest is the population level where the pest causes significant economic damage.

The threshold can vary according to the pest or disease, or the tolerance an export market has for the presence of the pest. For example, one cell of AFB means the hive must be destroyed, but the presence of a single varroa mite in a hive is actually of very little significance, unless of course it has never been reported in the area before. A mite's presence is not a reason to treat a colony, as by itself it will not cause any detectable damage.

In an IPM programme, the time to treat a colony is when the population of varroa reaches a level where it is causing economic levels of damage, or more correctly where the population will have reached this level before the beekeeper visits the colony again.

Unfortunately, we do not have good information about the population development of varroa in honey bee colonies under New Zealand conditions (especially in relation to climate and length of brood rearing season), or the mite population level at which our colonies begin to experience economic levels of damage.

Until such figures are determined through experience and research, beekeepers in New Zealand should use the threshold figures that have been developed overseas. These thresholds are discussed in detail in chapter 5 for each detection method. There is some dispute about the mite population level that causes significant damage, however. Some researchers say 2500 mites, while a US study in a climate similar to the north half of the North Island suggests 3200. Nevertheless, until we have better information, 2500 mites in a colony should probably be taken as the threshold level under New Zealand conditions. Remember that when using a method that surveys a sub-sample of bees or brood in the hive, the number of mites in the sample has to be multiplied by a conversion factor to determine the total number of mites in the hive (see appendix 1).

Economic threshold levels for varroa are discussed in detail in chapter 5.

10.4 Monitoring

While the goal of any IPM programme is to reduce pesticide use, there is always a trade-off, since more labour needs to be invested in monitoring to determine when the pest

reaches an economic threshold. The way to make good IPM varroa control decisions in a beekeeping outfit is to routinely sample at least a portion of the hives in each apiary for mites.

In order to make good IPM varroa control decisions, it is important to routinely sample at least a portion of your hives in every apiary for mites.

The various types of detection methods suitable for IPM monitoring are discussed in detail in chapter 5. Important points to remember are to use a method that fits with other beekeeping work, and provides accurate information. Some detection methods are very accurate (e.g., soapy water wash), but also take a lot of time. Other detection methods are very quick (e.g., the ether roll), but aren't very good at determining mite levels. Use the various conversion factors in order to work out the likely total number of mites in the hive.

Chapter 5 also gives good information on using mite numbers obtained from monitoring to make predictions about when the mite population will reach the economic threshold level. As time goes on, there is no doubt that New Zealand beekeepers will become quite skilled at carrying out IPM survey work, calculating likely mite numbers, and making predictions about when mite populations will reach the economic threshold level.

The following recommendations for varroa monitoring come from British Columbia, Canada:

- **Acute stage** – Where varroa has just come to an area, survey before applying spring treatment to see if treatment is required. Survey after treatment to see if treatment has been successful. Survey towards the end of summer to determine if a second treatment is necessary, and survey after the treatment to determine if it has been successful. If a spring treatment was not necessary, survey in mid-summer to avoid colony damage before autumn treatment.
- **Chronic stage** – After the acute stage has passed (about 3 years) and mite population growth is more stable (i.e., there is infrequent invasion), survey twice per year (spring and autumn). Be prepared for years of severe infestation, followed by lulls where varroa is easy to control, followed once again by a difficulty of control. Varroa infestation comes in 'waves'.
- **Number of hives to survey** – For hobbyists, every hive; for commercial beekeepers, 10% of hives in each apiary.

Be prepared for years of severe mite infestation, followed by lulls where varroa is easy to control, followed once again by a difficulty to control. Varroa infestation comes in 'waves'.

10.5 Decision-making and control

When assessing mite numbers, the decision a beekeeper using IPM has to make is whether the population of varroa is high enough to cause a greater economic loss than the cost of treatment. To be able to do this, beekeepers need to accurately assess the cost of treating colonies. This should include the cost of materials, labour and travel. In any IPM programme, preventative (also called 'prophylactic') treatments are generally not considered to be cost-effective (with the possible exception of slowing down the spread of a pest into a new area).

In an IPM programme, only treat colonies when varroa numbers are high enough to cause more economic damage than the cost of the treatment.

The goal of any IPM programme should be to limit the use of controls to an economic minimum. However, in the early stages of varroa infestation in an area (the acute stage), caution needs to be used when making assessments of mite numbers and predicting how populations will develop, since mite invasion from feral and untreated colonies is likely to result in quick mite population increases. Under such circumstances, there is a role for prophylactic treatment until invasion pressure from outside sources reduces.

In the acute stage, chemical control should be used on a routine basis until mite invasion pressure from outside sources reduces.

Once the acute stage has passed, and mite population growth in colonies is more predictable, beekeepers ideally should try to reduce chemical control treatments to no more than two (and hopefully one) per year.

There are also a number of factors influencing the choice of varroa control method:

- **Availability** – Not all of the methods used overseas are likely to be available in New Zealand. To be able to use a pesticide legally to control varroa, it must be registered by going through the same process as all other agricultural chemicals. The registration process is relatively expensive. There are direct costs in having a pesticide assessed, and an even larger cost in supplying the information necessary for the assessment. Because of the relatively small size of our industry and the cost of registration, some companies may decide not to register their varroa control products in New Zealand.
- **Cost** – The cost of some control methods (e.g., drone trapping) may limit their usefulness to commercial beekeepers. Because economics is usually of lesser importance to hobbyist beekeepers, they are likely to use a wider range of techniques.
- **Residues** – The need to limit pesticide residues in honey and wax will restrict the range of pesticides that can be used and when they can be applied.
- **Resistance** – The need to prevent or delay resistance will influence both the pesticides used, and how often a particular compound is applied.
- **Toxicity** – The toxicity of the products to the beekeeper and bees is very important, and some beekeepers may decide not to use a chemical such as formic acid because of the potential dangers involved.
- **Environmental concerns** – Most beekeepers take these concerns very seriously, especially since environmental problems that are often out of their control can have big impacts on their beekeeping. Beekeepers need to assess the effect of the varroa control products used (and their disposal) on the environment.

11. TIMING OF VARROA CONTROL

This chapter discusses in detail the various options that exist for deciding when to apply varroa controls.

11.1 Factors affecting timing of varroa control

The timing of pest control methods is a major component in any IPM programme. In the past, the horticulture industry relied on calendar spray programmes for pest control, where a particular spray was applied on a certain date regardless of the size of the pest population.

Now that more has been learned about the biology of many pests, much of commercial horticulture has moved away from calendar spray programmes. Instead, the timing of pesticide application is often targeted to particular stages of the pest's life cycle, or to when a pest has reached a certain population size. By doing this, horticulturalists have been able to reduce both their reliance on chemical control and total pest control costs.

Timing is also important in varroa control programmes. There are a number of factors that need to be taken into account when deciding when to treat hives for varroa. These include:

- Number of varroa present in each hive and the surrounding bee population (ferals and other beekeepers' hives).
- Type of control being used.
- The need to limit residues in bee products.
- Management of the colonies.
- Timing of treatments by neighbouring beekeepers.
- Length of time before the hives can be treated again.
- Rate of varroa population growth.
- How the hives are going to be used.

11.2 Treatment programme types

There are three types of treatment programmes for varroa control. They all have their advantages and disadvantages.

11.2.1 Prophylactic treatment

Description: Colonies that don't have varroa, or have low varroa levels, are treated as a preventative to reduce the effects of invasion from other colonies in the neighbourhood. A good example of where prophylactic treatment might be used is when hives are put into kiwifruit pollination. The beekeeper may have finished varroa control while preparing colonies for pollination. By the time the hives are moved into orchards, they have very low mite numbers and should not need to be treated until the following season. However, in some kiwifruit areas colonies are placed at very high densities (up to 600 colonies per km^2). Thus, there is a significant risk of these colonies being invaded by a large number of mites from colonies (managed or feral) where varroa has not been controlled.

Prophylactic treatments were used in the spring of 2000 in New Zealand. Colonies moved into the Te Puke area for kiwifruit pollination that were placed within 5 km of a known apiary infested with varroa were treated with Apistan strips paid for by the government.

This was done to reduce the chance of varroa migrating to the pollination hives and then being taken to new, non-infested areas when the hives were removed following pollination.

Advantages: Prophylactic treatment reduces the risk of losing colonies because of invasion of varroa from neighbouring colonies.

Disadvantages: Prophylactic treatment increases the amount of pesticide that is used, with consequent increased control costs and the chance of residues and chemical resistance. Many of the colonies that are treated are probably not in danger of invasion, so much of the treatment may actually be unnecessary.

Prophylactic treatment increases control costs and the chance of residues and chemical resistance.

11.2.2 Calendar treatment

Description: All mite-infested colonies are treated at a particular time, irrespective of whether they have potentially damaging levels of varroa. Before treating the colonies, no attempt is made to survey them to determine whether economic threshold levels have been reached. Calendar treatment differs from prophylactic treatment only to the extent that in prophylactic treatment colonies not even known to be infected with varroa are treated.

Advantages: The method avoids the cost of surveying hives for varroa. It is the method most likely to be successful in avoiding damage caused by varroa, since all colonies are treated. If timed properly, calendar treatment also has a good chance of protecting colonies during autumn mite invasion in the acute phase.

Disadvantages: The method uses large amounts of pesticides, with increased cost and increased risks of residues and chemical resistance.

If timed properly, calendar treatment will protect colonies during autumn mite invasion in the acute phase.

11.2.3 Treatment based on monitoring and economic thresholds (IPM)

Description: Colonies are tested for the presence of varroa, and are treated only if varroa is present in high enough numbers that economic damage will likely be caused. This method is similar in concept to the IPM programmes used by the apple and kiwifruit industries.

Advantages: Only colonies that need it are treated, reducing the amount of pesticide used and the attendant costs. The reduced chemical usage reduces residue problems and the risk of chemical resistance developing.

Disadvantages: Colony monitoring is labour-intensive and exacting. It requires higher skill levels than the other two methods, so there is a greater chance that mistakes will be made. At present we also do not have economic thresholds established for varroa in New Zealand. Finally, colony monitoring may not be able to predict rapid increases in mite populations during autumn invasion in the acute phase.

IPM treatment reduces costs, as well as chances of residues and chemical resistance. It is more labour-intensive, however, and costly mistakes can sometimes result.

11.3 Reducing residues

The careful timing of treatments is an important way of reducing residues in bee products. Not using chemical control measures while the honey supers are on hives is obviously important for some of the products. It does, however, require a higher degree of planning, especially in the spring. It is very important to carefully follow label directions for whatever control product is being used, since this information is based on research regarding the best way to limit residues.

To avoid residues in bee products, always follow the label directions on varroa control chemicals.

11.4 Changes to management

A significant issue for some beekeepers will be adjusting their beekeeping management programmes to the required timing of varroa control treatments. Overseas experience has shown the necessity to carry out treatment in the late summer/early autumn to protect over-wintering bees. This has required a change in beekeeper practice so that the honey crop is removed earlier.

If label directions are followed and varroa control is not applied until after the honey is removed, but there is some laxness in taking off the crop, beekeepers may find their colonies collapsing in the autumn even though the presence of well-filled boxes made it seem as if there was no varroa problem in the hives. It is far more important to treat on time and use proper detection techniques to determine the varroa status of hives than it is to delay treatment because it doesn't fit in with time-honoured beekeeping management practices.

Beekeepers should remove their honey crop as soon as possible so they can begin varroa treatment before autumn invasion pressure causes colony damage.

11.5 Co-ordinated treatments

In the past, it was possible to keep honey bees in New Zealand without too much interference caused by the management practices of other beekeepers. Occasionally there was competition for apiary sites and the problem of a robbed-out AFB hive.

More recently, intense competition for honey production sites (especially manuka) and kiwifruit pollination has meant that in many areas of the North Island, at least, beekeepers need to co-operate with each other to increase income and reduce disease risks. The advent of varroa greatly increases the need for beekeepers to work well together, since overseas experience shows that the most efficient varroa control is achieved by beekeepers co-ordinating their mite treatments.

After treatment with some of the most effective varroa control substances, the level of varroa in a colony is usually very low. Because population growth of varroa in a colony is exponential, varroa populations build up very slowly at first, and may take considerable time to reach damaging levels.

However, varroa can easily be transported between hives, either by the bees themselves or by beekeepers. When this occurs, varroa levels can build up to damaging levels much more quickly. In some cases, numbers can even increase fast enough to defeat the most effective control measures that are put in place.

Invading mites may come from feral colonies, or managed colonies not in a varroa treatment programme. However, another important source of these mites is managed colonies that are in a treatment programme where the treatments do not coincide.

One beekeeper may treat hives early in the spring and have completed the work several weeks before a neighbouring beekeeper starts treatments. This leaves time for the hives that were treated early to become re-infected by the hives that were treated late.

Because of the high probability of cross-infestation between hives in different apiaries, it is very worthwhile for neighbouring beekeepers to co-ordinate their treatments. To facilitate this, it is a good practice to contact all the beekeepers in the area in order to come to an agreement on treatment times. In countries such as Denmark, this contact is made through the beekeepers' association, and in New Zealand local NBA branches could provide a similar forum for varroa control co-ordination.

Co-ordinate your varroa control treatments with those of neighbouring beekeepers.

A co-ordinated treatment programme is much easier when hives are not moved frequently. Obviously moving hives for pollination or to collect honey makes the job more difficult. The best approach may be for all beekeepers in an area to treat their hives early in the spring before the hives are moved. It is also useful to talk to beekeepers in an area before hives are moved in to ensure they have completed their treatment programmes.

11.6 Spring and autumn treatments

Varroa control in most countries depends on both spring and autumn varroa treatments. It is important to have very good control in spring because the large amounts of worker and drone brood in the hive will provide ideal breeding conditions for the mites. Not providing a high level of control at this time can result in colonies collapsing before the autumn treatment. At the same time, good varroa control is essential throughout the autumn period to protect hives from invasion, especially during the acute stage.

Many beekeepers in Europe use organic products such as formic or oxalic acid as an autumn treatment, whereas in Canada formic acid treatment is preferred in spring. The use of organic control compounds is likely to work best in the colder parts of New Zealand, where there is no brood rearing throughout the winter. Even if the varroa kill rate is not high, the absence of brood throughout the winter in these areas will mean that they cannot reproduce until the spring, immediately before the spring treatment.

Much higher varroa kill rates will be required in the autumn in warmer parts of New Zealand, where bees rear brood throughout the winter. This may limit the use of organic compounds in these areas, entail more treatments, or at least make it critical that the compounds are used very effectively.

12. CONTROL METHODS USED OVERSEAS

This chapter briefly describes varroa control methods used by beekeepers in various places around the globe. The list isn't exhaustive, and varroa control is evolving rapidly because the mite is of such economic significance. However, what we have tried to do is identify several approaches from overseas that may be of interest to New Zealand beekeepers.

12.1 British Columbia, Canada

Varroa mite was found in British Columbia (BC) in 1990, and since then it has spread to most areas of the province. Beekeepers there suffered some serious hive losses in the early years mostly because they were unfamiliar with varroa control. Some of the main reasons for the losses were:

- mite invasion of colonies after treatment;
- improper timing and use of treatments; and
- not treating hives until visual symptoms were apparent.

Varroa caused heavy hive losses in British Columbia because beekeepers were unfamiliar with varroa control and delayed treatments until they noticed visual symptoms of mite damage.

Beekeepers in BC now treat their hives for varroa by alternating Apistan and formic acid. They do this to help avoid mites building up resistance to a single chemical.

Formic acid is generally used in the spring as soon as temperatures reach a minimum of 10ºC. The ability of formic acid to kill varroa is very much dependent on how well the chemical can vaporise and transfer throughout the hive. Apistan may also be used in the spring, particularly if bees are being moved to other Canadian provinces that legally require Apistan treatment. Spring formic acid application also works well to control tracheal mites.

Apistan is generally used in late summer after the crop has been harvested. Beekeepers are encouraged to remove honey as early as possible and then treat in order to prevent serious mite damage to over-wintering bees that are being reared by the colonies at that time.

Apistan is used according to label directions (one strip for each 5 frames of bees in each brood chamber). Strips are left in the hives for 6 weeks and removed.

Formic acid is applied in a variety of ways, including:

- Absorbent pads.
- Bottom boards.
- Mite wipes.
- Plastic pouches.

See appendix 2 for detailed descriptions of formic acid application methods. Canada has led the way in developing formic acid treatments for both varroa and tracheal mites, and so we have copied their recommendations for formic acid varroa control in this book.

Monitoring of mite levels is now also used in BC in an integrated pest management (IPM) programme designed to reduce chemical use and mite control costs. Hobby beekeepers are recommended to survey all of their colonies, while commercial beekeepers should sample 10% of hives in each apiary (especially very large and very small colonies, and colonies at the ends of rows that pick up drifting bees carrying mites).

For IPM purposes, hobby beekeepers survey all colonies, while commercial beekeepers sample 10% of hives in each apiary.

In areas where the mites are not thought to have established, it is recommended that colonies are surveyed twice annually (spring and autumn).

When mites are first found in an area, beekeepers survey before applying spring treatment to see if treatment is required, and survey after treatment to see if treatment has been successful. They also survey towards the end of summer to determine if a second treatment is necessary, and after the treatment to determine if it has been successful. If a spring treatment was not necessary, they survey in mid-summer to avoid colony damage before autumn treatment.

Once feral and untreated colonies are no longer present to act as mite reservoirs for invasion, surveying can go back to twice per year.

Sticky boards with screens are preferred as a mite survey method. Formic acid, Apistan and the ether roll are also used in survey work. In each case, multiplication factors must be used to determine the total number of mites in the hive.

Economic thresholds have not been determined for varroa in BC. At one time recommendations from California were followed. Most BC beekeepers now decide when to treat based on the data they have gathered over years of sampling their own operations, since climatic conditions vary considerably throughout the province.

12.2 Georgia, USA

Varroa was first discovered in the United States in 1987, and since that time it has spread throughout the country, especially as the result of migratory commercial beekeeping activity. Varroa control in the US was for many years confined to Apistan, but more recently (and as a result of fluvalinate-resistant varroa developing) both formic acid and coumaphos (Check-Mite+) have been approved for use by some government authorities.

A significant study on economic thresholds of varroa mite populations was carried out in Georgia, in a climate somewhat similar to the northern part of our North Island. The goal of the research was to establish mite levels using various survey techniques so that sound decisions could be made about the use of miticides.

To reduce bias caused by differing colony strengths, the study used standard 1 kg broodless packages of bees with small populations of mites. Hives were divided into apiaries and one apiary was treated with Apistan in June, another in August, another in October, and a last acting as a control (no treatment). Mite populations were surveyed at the treatment times, using both sticky boards (natural mite drop) and ether roll. Hives were dismantled in December (winter), and total mite populations assessed.

The results suggest that for first-year colonies in this climate (with prolonged brood rearing), a single miticide treatment in the summer (making sure not to contaminate

honey) is possibly not enough to reduce mite levels sufficiently to prevent damage to the colonies. However, a second (autumn) treatment is required only if mites have reached the economic threshold.

In warm climates with prolonged brood rearing, a single treatment may not be enough to reduce mite levels below damaging levels.

The economic threshold at the end of summer (August) was determined to be about 3200 mites (total mite population in the hive), higher than the threshold level set in the UK (2500). The Georgia total hive threshold equates to 15 mites on a 300 bee sample using the ether roll, and 117 mites overnight (18 hours) for natural mite fall on sticky boards. Sticky boards were found to be a more reliable predictor of total mite populations than the ether roll.

Interestingly, continuous miticide treatment of colonies did not result in greater bee or brood amounts than colonies treated two times per year.

12.3 Arizona, USA

Since 1994, researchers and beekeepers in Arizona have been involved in a co-operative programme to see whether it is possible to develop a local population of varroa-tolerant honey bees, using selective breeding and normal beekeeping practice but without the use of any other mite control techniques.

Their work suggests that it is fairly easy to create a varroa-tolerant strain, with selected stock having survived for 6 years with low annual infestation rates remaining constant at 6 to 7 mites per 100 bees. Colonies in the area originally had 120 mites per 100 bees.

Varroa tolerance can be developed in honey bee stocks using simple bee breeding techniques.

The mechanisms of varroa tolerance were not studied in the Arizona project. They concentrated instead on beekeeping outcomes – a honey bee stock that can live with a low level of varroa infestation.

The following step-by-step programme has been offered to beekeepers in other parts of the world as a recipe that can be used to develop a varroa tolerant strain. Under Arizona (hot, dry) conditions, the programme developed varroa tolerance in two years.

Step 1 – Identify varroa-tolerant colonies.

This can be done in several ways, including:

- Leaving colonies or whole apiaries untreated (a risk, but may be worth doing as a beekeeper group project).
- Selecting hives in the autumn before miticide treatment that have good brood patterns, few worker cells with mite faeces, few drone brood with mites, few bees with deformed wings, or few dead mites on the bottom board.
- Accepting untreated hives that may be abandoned or are given away and haven't been treated for 12 months.
- Finding hives or sites that have unintentionally been missed at treatment time the previous year.

The Arizona work suggests that 3-10% of hives in an apiary may show some varroa tolerance. To begin the programme, at least 10 good survivor hives are required.

In an apiary of commercial size, 3-10% of hives may show some varroa tolerance.

Step 2 – Put the varroa-tolerant colonies in a test apiary.

This apiary needs to be isolated (about 5 km away) from other managed hives that are being treated to control varroa. This is done to keep drones produced by possibly varroa-susceptible colonies from mating with varroa-tolerant virgin queens, although the researchers say they are unsure that such mating actually reduces varroa-tolerance. Don't worry about drones from feral colonies, since there is a natural selection process at work with feral colonies for varroa tolerance.

Step 3 – Monitor varroa levels.

Use the soapy water/alcohol wash technique (see section 5.3.5) to sample 100 bees from every hive every 3 months. Wash the bees with a spray attachment to ensure all mites are removed from the bees.

Step 4 – Produce queens from colonies with low mite levels.

Remove any colonies from the apiary with more than 15 mites per 100 bees by requeening them with queens raised from colonies with less than that number. As the years progress, reduce this down to 10 mites per 100 bees or less. Also make sure not to use poor producing colonies, or ones that show high aggression. Mate all the queens in the isolated apiary. Mark the queens to ensure that the colonies on test aren't headed by supersedure queens. It is also worthwhile putting drone comb in selected colonies so there are good populations of selected drones available for mating.

Requeen hives that have more than 15 mites per 100 bees with queens raised from colonies with less than that number.

Step 5 – Re-queen other hives from queens produced in this apiary

Use the isolated apiary to produce further queens for requeening other apiaries. Re-queen all the colonies in an apiary at the same time, and then evaluate these colonies (as above) to increase the number of colonies to select from in further generations. Mark the queens. Move selected colonies back to the isolated apiary.

Using this system, a 600 hive outfit was totally requeened in a two-year period with selected queen stocks. In the first year, 25% of the outfit didn't need to be treated with miticides, based on a mite population survey in the autumn. In the next autumn, only about 6% of the outfit showed signs of significant varroa damage (deformed wings, parasitic mite syndrome, and rapid bee population decline).

12.4 United Kingdom

Varroa was first discovered in the UK in 1992. Movement controls were imposed on a county by county basis, with free movement within the infected area, but no colonies moved into non-infected areas. According to government authorities, the idea was to slow the inevitable spread of the mite northwards through the country. By 1999 the mite had spread throughout England and Wales, and it has now also been found in Scotland.

Beekeeping in the UK is almost entirely hobbyist in orientation, but the finding of varroa there has energised both beekeeping and government beekeeping services. Excellent

pamphlets have been produced on managing varroa and monitoring and forecasting mite populations. The National Bee Unit is part of the Ministry of Agriculture, Fisheries and Food's Central Science Laboratory, and the Unit maintains a network of regional and seasonal bee inspectors to provide advice and assistance on mite control and other matters. The Unit also works with a Bee Health Advisory Panel of independent beekeeping and science experts, including representatives of the national beekeeping organisations, to review bee disease programmes.

The finding of varroa in the UK has energised both beekeeping and government beekeeping services.

Two varroa control products are registered for use in the UK – Apistan and Bayvarol. Both products are allowed to be applied during honey flows, although this is not recommended unless there is a significant mite problem in the hive. Currently none of the essential oils or organic miticides such as formic acid are registered, but veterinary authorities acknowledge the lack of suitable registered miticides and the 'duty of care' beekeepers have to treat their bees. So unregistered products are used, but they cannot be provided to others for mite control and cannot be used if they are likely to be harmful to human health when present in bee products.

The UK has developed a sophisticated integrated pest management (IPM) programme for varroa control, based on mite monitoring (natural mite fall and inspecting capped brood are the preferred methods), a series of calculations and correction factors (including estimations of colony brood amount and bee population), and a prediction table that estimates the number of days before mite populations reach 2500 and the colony therefore requires treatment. Details of the UK thresholds are given in chapter 5. The IPM programme relies on a varroa population computer model developed by the Central Science Laboratory. The model is being refined as a result of new data, and is being used to predict the results of various approaches to varroa control.

Biotechnical methods are also suggested as an alternative to miticide controls, and extension pamphlets provide descriptions of different methods and explain the pros and cons of each approach.

Workers in the UK have developed a sophisticated integrated pest management programme for varroa control.

Finally, as a recipe for beekeepers who don't want to carry out monitoring activities or use biotechnical methods, the recommendation is to treat all colonies on a preventative basis early in the spring and then in summer after the honey is removed. Once local losses have stabilised (the acute phase is over), a single autumn treatment may be enough. UK experience suggests that during the acute phase it is essential to treat hives quickly at the end of summer, even if honey supers have to be removed earlier than in the past. Beekeepers who waited to treat until after the traditional time they took honey supers off often saw their colonies collapse due to invasion pressure.

During the acute phase, beekeepers in the UK found that it was essential to treat hives for varroa at the end of the summer, even if honey supers had to be removed earlier than in the past.

12.5 Denmark

Denmark is often given as an example of a successful varroa control programme that doesn't use synthetic chemicals (such as fluvalinate, flumethrin, amitraz, coumpahos) that are prevalent elsewhere in Europe. Bayvarol (flumethrin) is available for mite control in Denmark on veterinary prescription, but according to a survey conducted in the country in 2000, 86% of the beekeepers (who keep 78% of the country's total hives) use 'biological' methods (organic chemicals and biotechnical controls).

Denmark has 4,600 beekeepers and 155,000 hives. Average production is similar to New Zealand's, at about 35 kg per hive. Varroa was first discovered in Denmark in 1984 and is now spread throughout the country, including on most off-shore islands.

In 1984, the Danish Institute of Agricultural Sciences (Ministry of Food) proposed a varroa control strategy that did not rely on veterinary drugs. The proposal was later approved by the Danish Beekeepers' Association (DBF). Both organisations have spent considerable time and money since developing the use of organic miticides (such as formic acid, lactic acid and oxalic acid), as well as biotechnical controls (mostly drone brood removal, comb trapping and heat treatment). Their objective is to maintain pesticide use at a minimum and keep chemical residues out of honey and beeswax. The approach follows on from their commitment not to use antibiotics to control American foulbrood, a similarity they have with New Zealand beekeepers.

Denmark is an example of successful varroa control using organic chemicals and biotechnical methods.

The Danish system can be summarised as follows:

- Drone brood removal/trapping during the late spring/early summer build-up period.
- Short and/or long-term formic acid treatment immediately following the honey harvest.
- A late treatment once brood rearing has ceased, using either lactic acid or oxalic acid.
- Monitoring natural mite fall, and mite fall after treatment, especially in the summer and after lactic acid treatment in autumn.

The system also includes variations for early and late honey production, since some beekeepers produce ling heather honey at the end of summer or beginning of autumn.

Monitoring is usually done with mesh screens on the bottom board of each hive. Daily natural mite fall (for colonies with the equivalent of at least one frame of brood) is multiplied by 120 to give the total number of varroa in the colony. If total mite numbers rise above 1000, control is carried out as soon as possible.

An interesting drone brood trap used in Denmark consists of a frame divided vertically into three sections. The frame (without foundation) is inserted into the centre of the brood nest once the colony and conditions are good enough for comb drawing. When the bees finish drawing out the frame with drone comb, two sections are removed, and then a week later one of the rebuilt sections is removed again. This provides by the third week a single comb with three different stages of drone brood development. Once a section of brood is capped, it is removed and destroyed (usually up to the beginning of the honey flow).

Nucleus colonies are made to increase numbers and for swarm control, and drone brood trapping is used in these circumstances to take advantage of broodless situations and the attraction that a frame of larvae has to mites looking to reproduce.

When the honey flow is over, the honey is removed and hives are treated with formic acid in a fibre-board square sealed into a heavy-duty plastic bag. A 16 mm hole is cut in each side of the bag. The board is left in the hive for either one or two weeks.

The colony is then given a feed of sugar syrup for over-wintering, and a second formic acid treatment is applied for another week (provided mite fall during the previous treatment was more than 50-100 mites). Mite fall is assessed during both treatments to ensure temperature conditions are sufficient for the formic acid to evaporate properly and kill mites in the hive. In some areas, beekeepers also try to co-ordinate their formic acid applications to improve reduction of mite populations in all colonies in the vicinity.

However, re-invasion of mites is sometimes noticed, and so once the hives have become broodless in late autumn colonies are often treated with a 15% dilution of lactic acid sprayed on to each frame side with a garden sprayer. Each side receives 5 ml, and treatments are repeated until fewer than 50-100 mites fall from the last treatment. If mite numbers are low, sometimes the late lactic acid treatment is not carried out.

Oxalic acid has so far not been approved for use in the European Union, but is nevertheless in use in countries such as Denmark. The best recommendation is to use the substance mixed in sugar syrup. This is trickled on the bees between the combs. Temperatures at the time of application need to be above 0°C. Rubber gloves and goggles should be worn. Repeated treatments can cause damage to the bees, and the presence of sealed brood will reduce effectiveness (since the material does not kill mites in the cells).

Oxalic acid in sugar syrup trickled over the top bars is now being used in Europe as a varroa control in the autumn.

For late honey flows, the formic acid treatment is either not done or is done later in the autumn. One treatment of lactic acid or oxalic acid is sometimes substituted for this formic acid treatment. A repeat with lactic acid only is carried out if more than 50-100 mites fall as a result of the previous treatment.

A survey of Danish honey and beeswax showed the organic chemical treatment programme was effective in keeping miticide residues out of bee products. No miticide residues were present in 43 samples of Danish honey. One sample was found with a residue of a miticide that had not been in use in Denmark for 10 years. The suggestion was that the residue, like several wax samples showing fluvalinate contamination, came from imported beeswax.

12.6 Vietnam

Vietnam provides an interesting example of long-term success in controlling varroa without the use of chemicals. Varroa is indigenous in Vietnam, and is a natural parasite of *Apis cerana* there. It is also, however, a major pest of *A. mellifera*, which has been kept in the country since the early 1960s. There are currently over 100,000 *A. mellifera* hives in Vietnam, and most are kept by commercial beekeepers (the average hive holding is about 500 hives).

It is actually difficult to give a total number of *A. mellifera* hives for either Vietnam as a whole or for individual beekeepers, because their strategy for mite control involves reducing colony numbers at the end of the beekeeping season (the beginning of the rainy season), and then increasing them again at the beginning of the season (the beginning of the dry season). Their system controls both varroa and *Tropilaelaps clareae*, another mite that has crossed over to *A. mellifera* from its original host (*A. dorsata*).

Once the dry season begins, beekeepers move their hives from crop to crop for a series of pollen and honey flows (there is very little honey produced from wild plant species), and the first of these flows is used to make splits. Beekeepers often carry over only 50-100 colonies through the rainy season, but then split ultimately to 500 hives during the active beekeeping year. Interestingly, annual honey yields are quite similar to New Zealand's, at about 30 kg per hive, based on the total number of splits finally made.

The splitting and rapid build-up means that honey bee colonies literally 'out-breed' the varroa in the hives, so that varroa populations don't have a chance to cause economic damage until the beekeeping season has ended. The beekeepers then reduce their hive numbers back down to a 'foundation' stock of 50-100 hives, making sure to select only the best colonies to bring through the rainy season.

Vietnam is a pioneer in developing biotechnical methods for control of parasitic bee mites.

During the rainy season, the beekeepers also practice biotechnical control. Frames of worker comb often have the bottom corners cut out in a triangle shape, and these are rebuilt as drone comb. When the drone brood has been capped, the triangles are removed and destroyed at intervals of about 15 days.

The Vietnamese also use whole drone combs that they encourage the bees to produce by putting an empty frame into a strong, well-fed colony. Sometimes a group of colonies are maintained for this purpose, and once the frames are drawn and contain young larvae, the frames are distributed to other colonies to act as drone traps. When the brood is capped, the frame is taken out of the hive and the pupae are removed in a hand extractor. The pupae are sold in markets as a food delicacy.

A third technique allows beekeepers to control varroa and *Tropilaelaps* (which is easier to control, since it can only survive away from brood for several days). This technique is used during the build-up phase of new colonies once the rainy season has ended. In one colony, all of the brood is removed, leaving only the queen, empty combs and bees. The first two frames of capped brood that are produced are taken from the hive, uncapped and the pupae removed. In a second colony, the queen is replaced with a cell, and given all the brood from the first colony. Once the new queen begins to lay, again the pupae in the first two capped frames of brood are removed. In both cases, *Tropilaelaps* is killed during the broodless period, and varroa is killed during the brood trapping.

Obviously the climate and honey flows in Vietnam are very different to those found in New Zealand, so the Vietnamese system of increase and decrease of hive numbers probably isn't applicable here. However, the biotechnical control methods, including drone trapping and hive splitting, may have a use in New Zealand conditions.

MANAGEMENT PLANS TO CONTROL VARROA

This section provides detailed varroa control recommendations for beekeepers of different sizes and types of production. The recommendations depend on how long varroa has been present in an area.

Hobbyist beekeeper – varroa not present in area

- Survey all colonies twice annually (spring and autumn) using one of the methods described in chapter 5.
- Seek a second opinion from an Apiculture Officer or local NBA Authorised Person on any unusual findings, either as a result of the survey or when carrying out brood examinations.

Hobbyist beekeeper – acute stage (varroa present for 1-3 years)

General production

- Survey all colonies, using one of the methods described in chapter 5:
  - before applying spring treatment;
  - after the treatment to see if treatment has been successful;
  - in mid-summer to avoid colony damage before autumn treatment;
  - before applying autumn treatment; and
  - after the treatment to determine if it has been successful.
- Treat all colonies in the early spring at the beginning of brood rearing (August-September), and in the autumn after all surplus honey has been removed.
- To ensure treatment begins early enough to avoid colony collapse from invasion, take honey off as soon as possible, even if the last of the crop is still coming in.
- Use registered varroa control substances (see chapter 6), and follow the label directions exactly.
- Use a control substance in the autumn that is different from the one used in the spring to help avoid creating chemical resistant mites (e.g., Apistan in the autumn and formic acid in the spring).
- Carry out a treatment (remove surplus honey first) using a registered control substance whenever the survey shows a total mite population in the hive equivalent to 2500 mites (see table 5.2 for threshold levels for different survey methods).
- Check mite numbers in some hives after treatment to determine if the treatment was effective.

Organic production

- Survey all colonies, using one of the methods described in chapter 5:
  - before applying spring treatment;
  - after the treatment to see if treatment has been successful;
  - in mid-summer to avoid colony damage before autumn treatment;
  - before applying autumn treatment; and
  - after the treatment to determine if it has been successful.
- Treat all colonies in the early spring at the beginning of brood rearing (August-September), and in the autumn after all surplus honey has been removed.

- To ensure treatment begins early enough to avoid colony collapse from invasion, take honey off as soon as possible, even if the last of the crop is still coming in.
- Use organic varroa control substances such as formic acid in the spring and oxalic acid in the autumn (see appendices 2 and 3), and follow directions exactly.
- Use drone trapping and other biotechnical methods described in chapter 8 during the beekeeping season.
- Carry out a treatment (remove surplus honey first) using a registered control substance whenever the survey shows a total mite population in the hive equivalent to 2500 mites (see table 5.2 for threshold levels for different survey methods).
- Check mite numbers in some hives after treatment to determine if the treatment was effective.

Hobbyist beekeeper – chronic stage (after 3 years)

General production

- Follow the same regime as for the acute stage, except survey all colonies twice annually (early spring and early autumn).
- If the autumn survey reveals mite populations well below the equivalent of 2500 mites in a hive, an autumn treatment may not be necessary.

Organic production

- Follow the same regime as for the acute stage, except survey all colonies twice annually (early spring and early autumn).
- If the autumn survey reveals mite populations well below the equivalent of 2500 mites in a hive, an autumn treatment may not be necessary.

Commercial beekeeper – varroa not present in area

- Survey 10% of hives in each apiary (especially very large and very small colonies, and colonies at ends of rows).
- Survey twice annually (spring and autumn) using one of the methods described in chapter 5.
- Seek a second opinion from an Apiculture Officer or local NBA Authorised Person on any unusual findings, either as a result of the survey, or when carrying out brood examinations.

Commercial beekeeper – acute stage (varroa present for 1-3 years)

General production

- Survey 10% of hives in every apiary, using one of the methods described in chapter 5:
  - before applying spring treatment;
  - after the treatment to see if treatment has been successful;
  - in mid-summer to avoid colony damage before autumn treatment;
  - before applying autumn treatment; and
  - after the treatment to determine if it has been successful.
- Treat all colonies in the early spring at the beginning of brood rearing (August-September), and in the autumn after all surplus honey has been removed.

- To ensure treatment begins early enough to avoid colony collapse from invasion, take honey off as soon as possible, even if the last of the crop is still coming in.
- Use registered varroa control substances (see chapter 6), and follow the label directions exactly.
- Use a control substance in the autumn that is different from the one used in the spring to help avoid creating chemical resistant mites (e.g., Apistan in the autumn and formic acid in the spring).
- Carry out a treatment (remove surplus honey first) using a registered control substance whenever the survey shows a total mite population in the hive equivalent to 2500 mites (see table 5.2 for threshold levels for different survey methods).
- Check mite numbers in some hives after treatment to determine if the treatment was effective.

Organic production

- Survey 10% of hives in every apiary, using one of the methods described in chapter 5:
  - before applying spring treatment;
  - after the treatment to see if treatment has been successful;
  - in mid-summer to avoid colony damage before autumn treatment;
  - before applying autumn treatment; and
  - after the treatment to determine if it has been successful.
- Treat all colonies in the early spring at the beginning of brood rearing (August-September), and in the autumn after all surplus honey has been removed.
- To ensure treatment begins early enough to avoid colony collapse from invasion, take honey off as soon as possible, even if the last of the crop is still coming in.
- Use organic varroa control substances such as formic acid in the spring and oxalic acid in the autumn (see appendices 2 and 3), and follow directions exactly.
- Use the hive-splitting varroa control method and other biotechnical methods described in chapter 8 during the beekeeping season.
- Carry out a treatment (remove surplus honey first) using an organic control substance on every hive in an apiary whenever the survey shows a total mite population in a hive equivalent to 2500 mites (see table 5.2 for threshold levels for different survey methods).
- Check mite numbers in some hives after treatment to determine if the treatment was effective.

Commercial beekeeper – chronic stage (after 3 years)

General production

- Follow the same regime as for the acute stage, except survey all colonies twice annually (early spring and early autumn).
- If the autumn survey reveals mite populations well below 2500 mites, an autumn treatment may not be necessary.

Organic production

- Follow the same regime as for the acute stage, except survey all colonies twice annually (early spring and early autumn).
- If the autumn survey reveals mite populations well below 2500 mites, an autumn treatment may not be necessary.

Queen producer – varroa not present in area

- Survey 10% of support colonies (especially colonies at ends of rows).
- Be especially vigilant in seeking a second opinion from an Apiculture Officer or a local NBA Authorised Person for anything unusual found during surveying or brood examination, since queen shipments can easily transfer varroa to areas currently free of the mite.

Queen producer – acute stage (varroa present for 1-3 years)

General production

- Treat all support colonies and nuc-provisioning colonies in the early spring prior to making up nucs, and in the autumn once the nucs have been reunited.
- Use registered varroa control substances (see chapter 6), and follow the label directions exactly.
- Use a control substance in the autumn that is different from the one used in the spring to help avoid creating chemical resistant mites (e.g., Apistan in the autumn and formic acid in the spring).
- Ensure substantial numbers of drone production colonies are available for queen mating purposes, since varroa depletes drone numbers.
- Treat drone production colonies at least 40 days in advance of their use to supply drones for queen mating (further treated colonies may need to be introduced during the season).
- Survey drone brood for mite populations using the cappings scratcher technique (see 5.3.3).
- Survey 10% of support colonies, using one of the methods described in chapter 5, every other month of the active beekeeping season.
- Carry out a treatment (remove surplus honey first) using a registered control substance on every support hive whenever the survey shows a total mite population equivalent to 2500 mites in any hive (see table 5.2 for threshold levels for different survey methods).
- Check mite numbers in some hives after treatment to determine if the treatment was effective.
- Select breeder queens for hygienic behaviour and suppression of mite reproduction (see chapter 9).
- Enter into a co-operative mite tolerance breeding programme with other beekeepers (see chapter 12).

Organic production

- Treat all support colonies and nuc-provisioning colonies in the early spring prior to making up nucs, and in the autumn once the nucs have been reunited.
- Use organic varroa control substances such as formic acid in the spring and oxalic acid in the autumn (see appendices 2 and 3), and follow directions exactly.
- Avoid using formic acid on drone production colonies, since the chemical has been shown to affect drone production.
- Ensure substantial numbers of drone production colonies are available for queen mating purposes, since varroa depletes drone numbers.
- Treat drone production colonies at least 40 days in advance of their use to supply drones for queen mating (further treated colonies may need to be introduced during the season).

- Survey drone brood for mite populations using the cappings scratcher technique (see 5.3.3).
- Use the hive-splitting varroa control method and other biotechnical methods described in chapter 8 during the beekeeping season.
- Survey 10% of support hives, using one of the methods described in chapter 5, every other month of the active beekeeping season.
- Carry out a treatment (remove surplus honey first) using an organic control substance on every support hive whenever the survey shows a total mite population in a hive equivalent to 2500 mites (see table 5.2 for threshold levels for different survey methods).
- Check mite numbers in some hives after treatment to determine if the treatment was effective.
- Select breeder queens for hygienic behaviour and suppression of mite reproduction (see chapter 9).
- Enter into a co-operative mite tolerance breeding programme with other beekeepers (see chapter 12).

Queen producer – chronic stage (after 3 years)

General production

- Follow the same regime as for the acute stage, except survey all support colonies twice annually (early spring and early autumn).
- If the autumn survey reveals mite populations well below 2500 mites, an autumn treatment may not be necessary.

Organic production

- Follow the same regime as for the acute stage, except survey all support colonies twice annually (early spring and early autumn).
- If the autumn survey reveals mite populations well below 2500 mites, an autumn treatment may not be necessary.

Appendix 1. Estimating mite populations in hives

A. Mites in brood

All the methods except the visual inspection of brood only provide information about the number of mites on adult bees. When a hive is in full brood production, it is estimated that only about 15% of mites are on adult bees. Thus, the number of mites on adult bees in the sample has to be multiplied by a correction factor of 6 to estimate the likely total number of mites in the hive. At other times during the production season when brood is present, use a correction factor of three. When no brood is present, no correction factor is needed.

B. Jars of bees

When using an adult bee survey technique that doesn't involve a miticide and samples only a portion of the bees (i.e., ether roll, sugar shake, soapy water wash), a rule of thumb would be to divide the number of bees in the hive (15,000 in a full Langstroth super) by an estimate of the number of bees in the sample.

This will give a figure that can be multiplied by the number of mites in the sample and a mites-in-brood multiplier to determine the likely number of mites in the hive.

$$\frac{\text{estimated bees in hive}}{\text{bees in sample}} \times \text{mites in sample} \times \text{brood multiplier} = \text{mites in hive}$$

As an example, if the hive has one full box of bees (15,000) and the sample has 300 bees:

15,000/300 = 50

If the number of mites in the sample is 2 and the hive is in full brood production (see A. above), then the total number of mites in the hive is:

50 x 2 x 6 = 600

C. Brood sampling

To estimate the number of mites in a colony from a sample of brood, British researchers recommend different multipliers for drone brood (10) and worker brood (1.8). To begin, a percentage of infestation is determined by dividing the number of cells found to be infested by the total number of cells examined. Then an estimate is made of the total amount of sealed brood. Use a figure of about 1000 cells for one side of a good (60% covered) frame of capped brood. This is then multiplied by the correction factor to determine the total mite population in the hive. The estimate should only be made in the summer.

D. Natural mite fall

According to British researchers, the daily natural mite fall on a screened bottom board with a sticky board in winter can be multiplied by 400 to get the total number of mites in the hive, while in the summer the multiplication number is 30. In the early spring when brood is expanding rapidly, and in the autumn when brood amount decreases, they say mite fall is unreliable but estimate a multiplication factor of 100. All of these multiplication factors include mites on brood.

Danish researchers, on the other hand, suggest multiplying daily mite fall by 120 to give total varroa in a colony during the production season.

E. Whole hive sampling

If Apistan, Bayvarol or formic acid is used, assume 85% of the mites on adult bees were killed during a 24 hour survey. So divide the total number of mites on the board by 0.85 to get the total number of mites on adult bees in the hive. Also multiply the total number by 6 if there is substantial brood in order to determine the total number of mites in the hive (see A. above).

F. Counting mites on sticky boards

Since varroa mites are small, a magnifying glass is recommended for mite counting. Before beginning to count boards, it is also important to do a quick refresher on the size and shape of varroa, and how it compares with the melittiphis mite. Retaining a sample of both mites (e.g., laminated on a card) can be especially useful.

The method used to count mite numbers on sticky boards depends on the reason the mites are being counted and the number of mites on the board. In most cases all that is necessary is to estimate the number of mites. This can be done by just making a quick count of a measured area and then multiplying it by the total area of the board.

However, if a more accurate count is needed, two different methods can be used:

- **Low mite numbers** – When mite numbers are low, it can be difficult to scan a board to determine if there is a varroa on it without missing some areas. To make the count more uniform, draw parallel lines 2.5 cm apart over a sheet of clear Perspex that has been cut to the same size as the sticky board. The Perspex can then be placed over the board with each pair of lines used as a guide to ensure the whole board is assessed.
- **High mite numbers** – High mite numbers can also be difficult to count. The best way to proceed is to also use a sheet of Perspex. Draw a 2.5 cm x 2.5 cm grid over the sheet. Randomly select 25% of the squares and mark their boundaries with another colour, or erase the lines marking the squares that are not selected. The number of mites in the selected squares is then counted and multiplied by 4 to estimate the total number of mites on the board. If the distribution of mites does not appear to be reasonably even over most of the board, use the method for low mite numbers above and count all the mites.

Appendix 2. How to use formic acid

Formic acid can be purchased as an 85% concentrate. To reduce the product down to the recommended 65%, 3 parts of the concentrate should be mixed with 1 part water.

A. Precautions

Read the formic acid label before using and take all recommended precautions. Formic acid is strongly corrosive.

Avoid:

- **Skin contact** – Formic acid can cause skin burns.
- **Eye contact** – Formic acid can cause blindness.
- **Ingestion** – Formic acid can cause burns to the stomach and oesophagus and damage to the kidneys.
- **Breathing it in** – Formic acid can cause potential harmful effects.

Read the formic acid label before using and take all recommended precautions.

B. Operator safety

- Acid-resistant gloves must be worn.
- Goggles should be used.
- Acid-resistant apron, sleeves and boots should also be used, especially when large quantities of formic acid are being handled.
- An air-purifying cartridge-type respirator equipped for organic vapours is recommended when using formic acid, especially in situations where there isn't good ventilation.
- Have ample water and rags available in case of an accident or spill.
- Avoid using warm formic acid in hot weather. Less of the harmful vapours will be given off when the acid is cold. It may be necessary to cool the formic acid.
- Be careful when disposing of containers. Wash thoroughly with water.

C. Avoiding residues

- Do not apply formic acid when honey supers are on hives, or during nectar flows, if honey is to be extracted for human use.

Do not apply formic acid when honey supers are on hives.

D. Application methods

Formic acid works by producing a vapour that penetrates the hive. It is important that there is enough space between the top bars of the top super and the lid to allow the formic acid vapour to reach all parts of the colony. Manufacturers of the Canadian product Mite Away recommend placing the bags on thin wooden strips to elevate them slightly above the top bars. It is also important that the formic acid is not applied directly to the bees or brood, since it will kill them.

Do not apply formic acid directly on bees or brood.

A variety of application methods have been found to be effective. The methods use formic acid in a manner that extends the time the fumes are in the hive, although some methods require repeat applications at 1-3 day intervals. The four most common application methods are:

- Absorbent pads.
- Application directly to bottom boards.
- Mite wipes.
- Plastic pouches.

Table 1 at the end of this appendix provides a summary of the four methods.

1) Absorbent pads (figure 1)

- The absorbent pads can be made up of any material that will absorb formic acid (e.g., three cloth serviettes, several paper towels, a potholder or disposable nappies).
- The material must be able to absorb 30 ml of 65% formic acid without letting any drip through.
- Prospective material can be tested for absorbency by using water.
- Smoke bees off an area of the top bars of the top brood box of a colony where the pad is going to be placed.
- Lay the absorbent pad on the top bars and dispense 30 ml of 65% acid onto the pad.

Figure 1 Applying formic acid using an absorbent pad.

The material must be able to absorb 30 ml of formic acid without letting any drip through.

- If temperatures are above 25ºC, or if the cluster is close to the bottom board, pads may be placed on the bottom board instead of the top bars.
- In warm temperatures, formic acid evaporates from pads in less than 24 hours.
- The treatment needs to be reapplied at 1-4 day intervals (depending on evaporation rate), for a total of five or six applications.

The treatment needs to be reapplied at 1-4 day intervals, for a total of five or six applications.

Figure 2 Applying formic acid directly to a bottom board.

2) Application directly on bottom boards (figure 2)

Formic acid can be applied directly on bottom boards:

- To avoid killing bees, smoke the entrance to ensure the cluster is above the bottom board.
- Using a measuring syringe or a drench gun, squirt 15 ml of 65% acid along each side rail towards the back of the bottom board.
- The treatment needs to be reapplied at 1-4 day intervals (depending on evaporation rate), for a total of five or six applications.

3) Mite wipes

These are a type of absorbent pad similar to padding found in the bottom of styrofoam meat trays. Mite wipes prolong the evaporation period of formic acid up to 3 days.

- Work in a well-ventilated area, preferably outdoors.
- Prepare only enough pads to use in one day.
- Place the pads to be soaked in formic acid in a plastic storage container that has an airtight cover.
- Pour 40 ml of 65% formic acid per pad onto the pads in the container. As an example, if the container contains 10 pads, pour on 400 ml. Let the pads soak up the acid. Place the cover on the container.
- Use as soon as possible. Storage of pads in acid for more than 2 days can damage the pads.
- Use the pads on hives only when the outside temperature is between 10 and 30°C.
- Before going to an apiary, remove soaked pads from the soaking container. Use gloves or tongs. Place soaked pads in a plastic pail with a lid.
- Smoke the bees off the top bars and place a pad on the top bars of the hive.
- Position the pad close to the edge of the bee cluster at the opposite end to the hive entrance.
- Reapply five times at 4-10 day intervals (depending on evaporation rate).
- Take out used pads from hives before new ones are applied, or after 5-10 days use.
- Do not re-use the pads.

4) Plastic pouches (figure 3)

Figure 3 Cutting a window in a formic acid plastic pouch.

These consist of zip-lock freezer or vegetable bags filled with absorbent material. Pouches are a convenient treatment method for beekeepers with outlying apiaries because only two trips are necessary for a full treatment. The pouch method extends formic acid release over a 3-4 week period.

- Put 20-30 layers of newspaper in each 27 cm x 28 cm zip-lock bag. There needs to be sufficient newspaper to absorb all of the formic acid. This can be tested first by using water.
- Add 250 ml of 65% formic acid per bag.
- Seal the bags, excluding most of the air, and stack them flat in a plastic box with an airtight lid. It is a good idea to place the plastic box in another plastic bag to ensure it is airtight.
- Place the plastic box in a freezer for 1 or 2 days before application to any hives.
- Take the box of pouches to the apiary. Remove a pouch and cut openings (windows) in the plastic on one side of the bag exposing the absorbent material with formic acid (figure 3). Each window should measure 1cm x 24 cm.
  - For a colony in two supers, cut out two windows at either side of the pouch. After 10 days cut out a middle window as well.
  - For a colony in one super, cut out a window in the middle of the pouch. After 10 days remove one of the side windows.
  - For 4 frame nucleus colonies, use smaller zip-lock bags with half of the amount of formic acid used for bigger hives.
- Place one pouch on the top bars or bottom board of a hive with the window facing the bees.
- If used on the top bars, use a wooden rim or inner cover to provide enough room for the bag without crushing and to provide evaporation space for the formic acid.
- If used on the top bars, the window openings should be oriented at right angles to the top bars.
- In cool weather, if the clusters are mainly in the top brood box away from the bottom board, place the bags on the top bars.
- If the bees are close to the bottom board and the temperature is reasonably warm, the pouches can be placed on the bottom board.

As an alternative to zip-lock freezer bags, zip-lock perforated vegetable bags can be used. To charge them with formic acid, put 250 ml of acid for every bag to be filled in a large plastic airtight container and immerse the absorbent-filled bags in the liquid. Turn the bags several times so that they all absorb an equal amount of acid.

E. When to use formic acid

- Use formic acid only when outside temperatures are between 10° and 30°C.
- Spring treatment – September and October.
- Late summer treatment – February and March.

Table 1 Summary of formic acid application methods

Method	Amount used (65%)	Treatments	Days apart
Absorbent pads	30 ml	5-6	1-4 (based on evaporation rate)
Bottom boards	15 ml	5-6	1-4 (based on evaporation rate)
Mite wipes	40 ml	5	4-10 (based on evaporation rate)
Plastic pouches	250 ml	1	3-4 weeks duration

Appendix 3. How to use oxalic acid

Oxalic acid can be purchased in crystal form as oxalic acid dihydrate. While this form is a powder, it actually only contains 71.4% oxalic acid, so it is important to use this correction factor when preparing solutions. To work out the percentage (weight/volume) of oxalic acid in a syrup solution, divide the actual amount of oxalic acid (weight of oxalic acid dihydrate x 0.714) by the total volume of the sugar solution. One kilogram of sugar mixed with 1 litre of water produces a syrup solution of about 1.67 litres.

A. Precautions

Read the oxalic acid label before using and take all recommended precautions. Oxalic acid is strongly corrosive.

Avoid:

- **Skin contact** – Oxalic acid can cause skin burns.
- **Eye contact** – Oxalic acid can burn the eyes.
- **Ingestion** – Oxalic acid can cause cramps, vomiting and convulsions.
- **Breathing it in** – Oxalic acid can cause harmful effects.

Read the oxalic acid label before using and take all recommended precautions.

B. Operator safety

- Acid-resistant gloves must be worn.
- Goggles must be used.
- A dust mask is required when handling the pure chemical to prevent the dust from being inhaled.
- Have ample water and rags available in case of an accident or spill.
- Be careful when disposing of containers. Wash thoroughly with water.

C. Avoiding residues

- Do not apply oxalic acid when honey supers are on hives, or during nectar flows, if honey is to be extracted for human use.

Do not apply oxalic acid when honey supers are on hives.

D. Mixing with sugar syrup

- To produce a sugar syrup with 3.2% oxalic acid (w/v), mix 1 litre of water with 1kg of sugar. Add 75 g of oxalic acid dihydrate. Mix thoroughly.

E. Amount to use

- Use 5 ml of the sugar syrup mixture per frame of bees (bees filling the inter-space between two frames from end to end).

F. Application method

- Use a large volume syringe (150 ml).
- Take up the proper dose for the population of bees in the hive and trickle the syrup over the bees along the top bars (figure 1).

G. When to use oxalic acid

- Use oxalic acid in the winter when there is little or no brood in the hive.
- Outside temperature is not important, although the syrup can chill the bees at very low temperatures (below 0°C).
- Oxalic acid may not have much extended mite-killing effect, so it is not recommended during autumn when mite invasion pressure is high (acute stage).

Figure 1 Applying oxalic acid in sugar syrup directly to a colony.

Appendix 4. How to use thymol

Thymol can be purchased in crystal form, and then either dissolved in alcohol or used directly as crystals.

A. Precautions

Read the thymol label before using and take all recommended precautions. Thymol is a hazardous substance.

Avoid:

- **Skin contact** – Thymol can cause skin burns.
- **Eye contact** – Thymol can cause serious damage to eyes.
- **Ingestion** – Thymol is harmful if swallowed.
- **Breathing it in** – Thymol can cause harmful effects.

Read the thymol label before using and take all recommended precautions.

B. Operator safety

- Wear acid-resistant gloves.
- Use goggles.
- A dust mask is required when handling the pure chemical to prevent the dust from being inhaled.
- Have ample water and rags available in case of an accident or spill.
- Be careful when disposing of containers. Wash thoroughly with water.

C. Avoiding residues

- Do not apply thymol when honey supers are on hives, or during nectar flows, if honey is to be extracted for human use.

Do not apply thymol when honey supers are on hives.

D. Amount to use

- The amount of thymol used per treatment depends on the treatment method.

E. Application methods

Thymol works by producing a vapour that penetrates the hive. It is important that there is enough space between the top bars of the top super and the lid to allow the thymol vapour to reach all parts of the colony. Use a wooden rim above the top super of the brood nest.

Thymol can be applied as:

- Liquid soaked into absorbent pads.
- Crystals.

1) Absorbent pads (figure 1)

- The absorbent pads are made from vermiculite, the green foam used by florists.
- Cut the foam into 6 cm x 4 cm rectangles with a thickness of 0.5 cm.
- For each hive to be treated, dissolve 4 g of thymol in 4 ml of alcohol (75%).
- Stir the solution thoroughly to dissolve the thymol crystals.
- Use a large syringe to take up 8 ml of the thymol solution and deposit on the piece of foam.
- Place two pieces of foam on the top bars at opposite corners of the brood box.
- Place the rim on the box before putting on the lid.
- Apply another 8 ml of solution to each piece of foam 2-3 times at 8 day intervals.

2) Crystals

- Use lids from plastic jars about 5-7 cm in diameter.
- For each hive to be treated put two lids on the top bars at opposite corners of the brood box.
- Put 4 g of thymol crystal in each lid.
- Place the rim on the box before putting on the lid.
- Apply another 4 g of thymol to each lid 2-3 times at 8-day intervals.

Figure 1 Applying thymol acid using an absorbent pad.

Appendix 5. Varroa chemical resistance test

This test can be used to determine mite resistance when a beehive doesn't appear to respond to chemical mite control. The instructions that follow refer to Apistan, but by substituting, resistance can be tested for chemical strip products such as Bayvarol, Check-Mite+ or Apivar.

The following materials are required to carry out the test:

- 500 ml jar with lid.
- Light metal mesh cover for the jar.
- 75 x 125 mm index card or similar.
- 9 x 125 mm piece of a new Apistan strip.
- Cup to scoop up bees.
- Freezer.
- Large funnel.
- Methylated spirits.
- Paper towel.
- Plastic or rubber gloves.
- Plastic bucket.
- Sheet of white paper.
- Stapler.
- Sugar cube.

Step 1

Staple the section of an Apistan strip to the centre of the index card. Make sure to handle the Apistan with gloves. Place the card in the jar with the section of Apistan strip facing inwards. Place a sugar cube in the jar.

Step 2

Shake the bees from one or two combs into an up-turned hive lid or a bucket. Scoop up 1/4 of a cup (about 150 bees) and put them in the jar, being careful not to damage the bees.

Step 3

Place a wire mesh lid over the jar to stop the bees from escaping. The holes in the mesh should be large enough to easily let varroa through. Place the jar in a warm room in the dark for 24 hours. Make sure the lid isn't covered so air gets to the bees.

Step 4

After 24 hours, hold the jar about 10 cm above a piece of white paper and turn it so the mesh lid is facing downwards. Hit the jar with the palm of the hand three times. Count the number of mites that fall on the paper. This is the 'initial kill' figure used in step 8.

Step 5

Place the jar of bees in the freezer to kill them. Remove the cardboard and fill the jar half-way with methylated spirits. This should be done outside using gloves. Remove the mesh lid and replace with the original lid for the jar. Shake the jar vigorously for 5 minutes.

Step 6

Replace the mesh lid to keep the bees in the jar. Pour the methylated spirits into a bucket using a funnel lined with a paper towel. Refill the jar with methylated spirits, swirl the bees around and tip the spirits into the paper towel again.

Step 7

Remove the paper towel and count the number of mites recovered. Use this number as the 'final kill' figure in step 8.

Step 8

Before attempting to calculate the percentage of mites killed, add together the initial kill and the final kill. If the sum is less than 10, there were too few mites on the bees and you will need to carry out the test again.

To calculate the percentage of mites killed, divide the number of mites that fell on the white paper before the bees were placed in the freezer (initial kill) by the total number of mites recovered (both on the white paper and the paper towel). Multiply this number by 100 to get the % of mites killed by the Apistan.

$$\% \text{ kill by Apistan} = \frac{\text{initial kill}}{(\text{initial} + \text{final kill})} \times 100$$

If less that 50% of the mites were killed by the Apistan, the mites may be resistant and should be tested with a more sensitive laboratory test.

If less than 50% of the mites are killed in the jar by Apistan, the mites may be resistant to Apistan and should be tested by a laboratory.

Appendix 6. Regulatory and legal issues related to movement controls

The Biosecurity Act 1993 provides for *controlled areas* to be declared for the purpose of instituting movement and other controls to, amongst other things, aid in limiting the spread, minimise the damage caused, and protect an area from, an incursion of a pest or unwanted organism.

While a controlled area notice is in force, notice may be given by a *chief technical officer* or *management agency* that the movement into, within, or from the controlled area of certain organisms, organic material, risk goods or other goods specified in the notice is restricted, regulated, or prohibited. Notice may also be given that the organisms, organic material, risk goods or other goods specified in the notice must be subject to such treatment and procedures as specified.

It is an offence under the Biosecurity Act 1993 to move any organism, organic material, risk good or other good specified in a controlled area notice into, within or from the controlled area, without the permission of an inspector or authorised person, or otherwise than in accordance with the conditions specified in the notice.

Movement controls are subject to change as varroa spreads. Consequently, details of current movement control conditions and zones have not been listed here. For up-to-date information on movement control and to obtain movement control permits, contact AgriQuality, free phone 0800 424 490, or look on the MAF website (www.maf.govt.nz).

Appendix 7. Regulatory and legal issues related to treatment

There are a number of legislative controls that impact on the treatment and control of varroa. Some of the provisions that affect beekeepers are listed below, but this is by no means an exhaustive list of the legislative controls that may apply.

Animal Products Act 1999

It is an offence under the Animal Products Act 1999 to use any drug, substance or mixture of substances for the prevention or treatment of varroa unless it has been approved for that purpose.

The Hazardous Substances and New Organisms Act 1996

Some treatments for varroa may fall within the definition of a *hazardous substance* for the purposes of the Hazardous Substances and New Organisms Act 1996.

It is an offence under the Hazardous Substances and New Organisms Act 1996 to knowingly, recklessly, or negligently possess or dispose of a hazardous substance that has been imported, manufactured, developed, or released in contravention of the Act.

Agricultural Compounds and Veterinary Medicines Act 1997

Some treatments for varroa may constitute agricultural compounds for the purposes of the Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM Act).

It is an offence under the Agricultural Compounds and Veterinary Medicines Act 1997 to knowingly possess any agricultural compound which has not been cleared for entry into New Zealand in accordance with the Act, or to knowingly use an agricultural compound in contravention of the Act.

It is also an offence under the ACVM Act to knowingly sell any animal, plant, or primary produce that has been treated with, or exposed to any agricultural compound that is not imported, sold or used in accordance with the provisions of the Act.

The New Zealand (Maximum Residue Limits of Agricultural Compounds) Mandatory Food Standard 1999

The New Zealand (Maximum Residue Limits of Agricultural Compounds) Mandatory Food Standard 1999 prescribes the maximum residue limits for agricultural compounds in food. No person shall sell any food containing residues of an agricultural compound unless its presence is authorised under the Standard. Where a food contains an agricultural compound for which the maximum residue limit is not prescribed in the Standard, a person may only sell that food if it contains residues not exceeding 0.1ppm. At this time, no maximum residue limits have been set for any varroa control treatments.

It is an offence under the Food Act 1981 for a person to produce, prepare for sale, or sell any food unless that food complies with all applicable food standards.

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Internet resources

Ecosur Alternative Varroa Control Site – a short-course for South and Central American conditions, but still very useful, especially for New Zealand organic producers.
[http://www.apicultura.com/articles/control_varroa/curso2.htm]

UK MAFF National Bee Unit – varroa control pamphlet and other valuable varroa reference materials.
[http://www.csl.gov.uk/prodserv/cons/bee/]

University of Florida Varroa Site – a comprehensive review of varroa.
[http://creatures.ifas.ufl.edu/misc/bees/varroa_mite.htm]

USDA Honey Bee Breeding, Genetics and Physiology Laboratory – information on breeding for varroa resistance and great photos of varroa reproduction.
[http://msa.ars.usda.gov/la/btn/hbb/]

Varroa WWW Hub – an excellent set of links to other varroa control resources.
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TERMS AND ABBREVIATIONS USED IN THIS GUIDE

Absconding – The abandonment of a nest or hive by a colony of bees. A natural occurrence brought on by outside disturbance or mite infestation. More common in some races and species of honey bee (e.g., Africanised honey bee, *Apis cerana*) than in others.

Acute stage – The initial stage of varroa mite infestation in a population of honey bee colonies. Large numbers of feral colonies act as a major source of mite invasion to managed hives. Invasion results in rapid increases in mite numbers in hives.

AFB (American foulbrood) – A brood disease of honey bees caused by the bacterium *Paenibacillus larvae larvae*. Produces symptoms (larvae light brown in colour, slumped down along the side of cell) that are similar to symptoms sometimes found in association with parasitic mite syndrome.

Apiguard – A varroa control product using the essential oil thymol formulated into a gel.

Apilife VAR – A varroa control product incorporating thymol and other essential oils in a vermiculite tablet.

Apis cerana – The Asian hive bee, the original host of varroa.

Apis dorsata – The giant honey bee, the original host of *Tropilaelaps clareae*.

Apis mellifera – The western honey bee, the honey bee species present in New Zealand.

Apistan – A varroa control product consisting of a plastic strip impregnated with fluvalinate (a pyrethroid).

Apitol – A varroa control product using cymiazole (a systemic miticide) in a granular form that is mixed with syrup and fed to bees.

Apivar – A varroa control product consisting of a plastic strip impregnated with amitraz (a contact miticide).

APV (acute paralysis virus) – A virus not normally thought to cause disease symptoms in honey bees, but which can kill adult bees in varroa infested colonies, since the mite introduces the virus into the adult bee's blood when the mite is feeding.

Bayvarol – A varroa control product consisting of a plastic strip impregnated with flumethrin (a synthetic pyrethroid).

Biotechnical control – Beekeeping management techniques specifically designed to reduce varroa levels in a colony.

Black queen cell virus – A virus causing death in queen pupae. The queen cells containing the diseased pupae take on a distinctive dark brown to black coloration. Since the virus is transmitted through food, it is not associated with varroa.

Check-Mite+ – A varroa control product consisting of a plastic strip impregnated with coumaphos (an organophosphate).

Chronic stage – The stage of varroa mite infestation in a population of honey bee colonies following the acute stage. Die-off of feral and untreated colonies results in less mite invasion and more predictable increases in mite numbers in managed hives.

Cloudy wing virus – A virus of bees that sometimes results in loss of transparency in wings. Spread appears to have an association with varroa.

CPV (chronic paralysis virus) – A virus that produces symptoms (crawling, shaking, and a 'hairless black' coloration caused by bees pulling at the hairs of the diseased bee) in bees not infested with varroa. Increased levels of CPV have been found in bees infested with varroa.

Deutonymph – The second of two juvenile stages of the varroa mite prior to it taking on the adult body shape. White in colour.

(DWV) deformed wing virus – A virus that can infect honey bee pupae and result in adults with poorly developed wings, which die soon after emergence. Appears to be associated with varroa, although bees with deformed wings may also be caused by the direct effects of varroa feeding on pupae rather than the virus itself.

(EFB) European foulbrood – A brood disease of honey bees caused by the bacterium *Melissococcus pluton*. Produces symptoms (larvae twisted in the cell, yellowish coloration) similar to those sometimes found in association with both half-moon syndrome and parasitic mite syndrome.

Essential oils – Plant-derived extracts that are highly volatile and have strong, characteristic odours. Some essential oils like thymol are varroa control compounds.

Ether roll – A technique for detecting varroa using an Agee jar and ether in the form of aerosol engine starter. The mites stick to the side of the jar.

Exponential growth – Population growth that begins slowly and then increases more and more quickly as time goes on.

Fat-soluable – Absorbed by fats (including beeswax).

Feeding sign – Varroa mite faeces that appear as white dots at the hind end of the prepupa or pupa and on cell walls.

Formic acid – An organic acid used as a varroa control substance. It is highly volatile, so must be applied in forms (bags or evaporators) that prolong evaporation.

Haemolymph – Bee blood. Distributes digested food material and receives waste products and carbon dioxide, but does not carry oxygen.

Half-moon syndrome – A disorder of honey bees with characteristics closely resembling the symptoms of European foulbrood and parasitic mite syndrome. It does not appear to be a disease of honey bees, since no organism has ever been found that produces the syndrome's effects.

Hygienic behaviour – The uncapping and removal of dead larvae and pupae by adult bees.

Inapparent – In relation to bee viruses, not producing observable symptoms in bees (e.g., Kashmir bee virus).

Integrated pest management (IPM) – A pest control programme using population surveys and other techniques to keep pest populations below a level where they cause economic damage.

Invasion (also re-invasion) – The movement of varroa mites from an infested colony into a non-infested one as the result of drifting workers or drones, robbing of a colony that is weakened, or absconding.

Isolated mating – Taking mating nucs and drone production colonies to an area where there are few or no other colonies so the queen mating that takes place is only with drones from the nucs and the drone production colonies.

KBV (Kashmir bee virus) – A virus that does not normally cause symptoms in adult bees, but which exists as an inapparent infection. This virus, which is closely related to APV, might be spread by varroa.

Lactic acid – An organic acid found naturally in various food products that is used as a varroa control substance when sprayed directly onto bees.

Mavrik – A horticultural spray containing fluvalinate (a pyrethroid).

Melittiphis (*Melittiphis alvearius*) – A scavenger mite often found in beehives that is the same colour as varroa, but is different in shape and smaller than varroa.

Mesh bottom board – An insert that goes on top of a normal bottom board; varroa mites fall through the mesh and cannot get back into the hive. The board is a useful mite survey method and a possible partial mite control technique.

Mite Away – A slow-release formic acid control product that consists of a plastic bag and formic acid-soaked fibreboard.

Mite wipes – Absorbent pads similar to the padding found in the bottom of stryofoam meat trays that are used to prolong the evaporation of formic acid for varroa control.

Miticide – A chemical that kills mites.

Nuc (nucleus colony) – A small beehive, generally consisting of four frames in a purpose-built box (called a 'nuc box'). Nucs are often used in queen rearing (called 'mating nucs').

Nuc provisioning colonies – Colonies that are split up to make nucs.

Organic – In relation to mite control substances, chemicals found in nature.

Oxalic acid – An organic acid that is used as a varroa control substance when applied in sugar syrup directly to colonies (usually in late autumn or early winter).

Parasitic mite syndrome – The name given to a range of abnormal brood symptoms found in association with infections of both varroa and tracheal mite. No specific causative organism has so far been found, although viruses may be one of the causes.

Perizin – A varroa control product using the organophosphate coumaphos that is poured into a hive in sugar syrup to control varroa.

ppm – Parts per million.

Prepupa – A larva laying out along the bottom wall of a cell in the 24 hours prior to pupation.

Prophylactic – Use of a disease or pest treatment for prevention, rather than control.

Protonymph – The first of two juvenile stages of the varroa mite prior to it taking on the adult body shape. White in colour.

Pupa – (plural: pupae) – The final stage of development of the honey bee; the stage when brood take on the adult form prior to emerging as an adult bee.

Re-invasion – see **Invasion.**

Resistance – Where a pest such as varroa becomes more and more able to withstand a pesticide that is being used, so that the chemical no longer kills most of the pest population. Varroa has developed resistance to a range of chemical control substances.

Sticky board – A board coated with a sticky substance (e.g., vegetable oil or an adhesive) used to survey for varroa mites. The mites stick to the board and cannot return to the hive.

Sugar shake – A method for detecting varroa that uses icing sugar and an Agee jar. The sugar coats the mites and makes them fall off the bees.

Synthetic – In relation to varroa control substances, chemicals not found in nature.

Systemic – In relation to miticides, working through the bee's body rather than through direct contact.

Threshold – In relation to a pest, the population level where the pest causes significant economic damage.

Tolerance – In association with varroa, the ability of a honey bee colony to co-exist with an infestation of the mite without perishing, or at least harbour a higher population of mites without damage.

Trapping – The use of combs containing drone brood to attract varroa mites so they can then be removed from the colony. Drone brood is 8 to 10 times more attractive to varroa than worker brood.

Tropilaelaps clareae – An external mite, originally a parasite of *Apis dorsata*, that has crossed species and become a parasite of *Apis mellifera*.

Varroacide – A miticide that kills varroa.

Volatile – Able to evaporate into the air, usually at normal temperatures.

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