AMERICAN FOULBROOD CONTROL

Dr Mark Goodwin
Apicultural Research Unit
HortResearch
New Zealand

This is the first article of a series that has been written for the Management Agency on the American Foulbrood Pest Management Strategy. These monthly articles will cover a range of aspects of American foulbrood control, including how to inspect for and identify diseased colonies, the management of colonies to prevent American foulbrood and a beekeeper's legal obligation with regard to American foulbrood.

INSPECTING HONEY BEE COLONIES FOR AMERICAN FOULBROOD DISEASE

The most common reason why beekeepers have an American Foulbrood disease (AFB) problem is because they, or their staff, use incorrect techniques for carrying out disease inspections on their colonies. This article deals with how to inspect colonies.

Although not a reliable diagnostic method, be particularly suspicious of any colony that has not been performing as well as the other colonies in the apiary. Their poor performance may be due to one of a number of other causes but may be due to a large number of larvae having been killed by American foulbrood disease.

When inspecting a colony for AFB it is important that the method used is capable of detecting a single infected larva or pupa if it is present. The presence of a single diseased larva in a colony means that the colony is infected with American foulbrood disease and legally must be destroyed. The Management Agency for the AFB Pest Management Strategy must be notified within 7 days. More importantly a single diseased larva contains enough spores to infect up to 500 hundred other colonies. For this reason it is important to check each brood cell in a hive. The risk of failing to find the diseases by only inspecting a few brood cells within the hive can be estimated quite easily. Assuming a hive has 10 frames containing brood and one diseased larva, an inspection of one frame means there is a 90% probability of missing the diseased larva and not recognizing that the colony is infected. Inspecting 3 frames still means there is a 70% chance of missing a diseased larva.

When inspecting hives inspect every brood frame

Most beekeepers do not inspect all frames when carrying out a disease inspection. Some only inspect one frame and many only three brood frames. The effect of an incomplete inspection depends on when the inspection is carried out and the disease status of the hives belonging to the beekeeper. If the inspection is carried out at a time when missing an AFB hive is unlikely to result in the disease spreading i.e. when there will be another inspection before any equipment is removed from a hive, then an incomplete inspection will have few consequences. Likewise, if a

beekeeping outfit has no AFB then an incomplete inspection, even at a time when equipment is being exchanged between hives, will have few consequences. However, many beekeepers that report diseased hives each year remove frames from, and swap them between, colonies with incomplete brood checks. This is the main reason they have a continuing disease problem. Usually the reason full frame inspections are not conducted is because of the increased time required. This is however probably false economy as it is cheaper doing full frame inspections than having to burn hives due to an AFB outbreak. The change to full frame brood inspections can be painful at the start as more AFB hives are often found. However, there are many examples where beekeepers have made significant improvements in their disease status by changing to full frame inspections.

To carry out a full frame inspection, each frame containing brood needs to be removed from the hive and the bees shaken off. The comb then needs to be inspected for chewed/sunken cappings and larvae or pupae with disease symptoms. Isolated and healthy looking cells also need to be inspected as some colonies may have significant numbers of diseased larvae but no outward symptoms of AFB. I have seen several hives with brood infection rates exceeding 80%, where no diseased larvae or sunken cappings were evident but the apparently healthy cells contained diseased pupae. However, spotty brood patterns were present and the colonies were starting to become weak. For this reason it is important to always uncap some cells in healthy frames.

If less than full inspections are being carried out it is important to check frames in both brood supers. I saw one hive where the brood in the top super had no obvious AFB symptoms. However, the bees had deserted the bottom super that had an 80% brood infection.

Inspecting dead colonies for AFB is much more difficult than live colonies, especially if the colony has been dead for some time. Although a skilled observer should be able to detect AFB scale (the dried remains of diseased larvae) the condition of the comb often makes this difficult. Many beekeepers also lack the necessary experience, as they do not often come across scale. Dead colonies that have died of things other than AFB but were infected with AFB are often not diagnosed correctly. The consequences of failing to confirm that AFB was the cause of colony death are much more serious if the supers, floorboards and lids are stored in a shed and the equipment split between a numbers of colonies the following spring. There have been some disastrous incidences where the empty frames themselves have been split between a large number of colonies resulting in a major disease outbreak. The best option for beekeepers with AFB problems is to be extra diligent and make sure colonies do not die. Where colonies have died and the cause has not been confirmed as AFB, the best action is to place a strap around the hive without removing equipment even if they still have honey supers in place. The hive can then be stored until it is restocked. If the new colony develops AFB, it and the equipment can be destroyed. Only the colony itself is lost as the equipment would have had to be destroyed in any case. Loosing a single colony is preferable to what would have happened if the equipment from a dead colony was split between a number of other colonies.

Dead hives should be strapped and restocked as a whole rather than spreading the equipment between hives

The timing of inspections is also very important. Inspections should be timed to occur before hive management activities are carried out that may spread the disease.

AFB problems can also occur where inspections are carried out by a number of different people. Staff need to be well trained and supervised, an issue that that will be covered in a later article. To keep everyone motivated to perform adequate AFB checks, a good approach is to issue everybody doing inspections with a felt pen and get them to write their initials and the date on the lid of each hive they inspect.

DIAGNOSING AMERICAN FOULBROOD DISEASE

Diagnosing American foulbrood disease (AFB) in honey bee colonies correctly, can be difficult. The first step, once the bees have been shaken off a frame, is to check the cell cappings for those that are darker than the surrounding cells, sunken or have irregular shaped holes chewed in them. Some experience is required to be able to tell the difference between the holes left in cappings as they are being sealed (Figure 1), holes caused by emerging bees, and those chewed by bees trying to remove a diseased larva (Figure 2). Any suspect cell should be uncapped.

Figure 1. A cell in the process of being sealed.

Figure 2. Hole chewed in the capping of a cell where the bees are trying to remove a diseased larva.

Cells with irregular holes chewed in the cappings will, hopefully, not conceal an AFB diseased larva or pupa. Bees chew the cappings on cells containing larvae with chalk brood disease (caused by a fungus), sacbrood disease (caused by a virus infection) and parasitic mite syndrome (caused by varroa). It is important, therefore to be able to recognize these diseases as well so they can be differentiated from AFB. Every registered beekeeper in New Zealand should have received a pamphlet with colour photos describing the symptoms of all four diseases.

Unfortunately, just because one or most of the cells in a hive with chewed cappings contain larvae without AFB this does not mean that there is not one or more containing AFB infected larvae. Most beekeepers faced with a large number of cells with chewed cappings only uncap a few and if the cells do not contain AFB assume that the rest do not contain AFB larvae. The only way to be confident that there is not an AFB diseased larva lurking behind a chewed capping is to remove all chewed cappings. In some cases this may mean uncapping a large number of cells.

Just because one or most of the cells in a hive with chewed cappings contain larvae without AFB this does not mean that there is not one or more containing AFB infected larvae

Parasitic mite syndrome (PMS), which occurs with high varroa numbers, makes this even more difficult. PMS may result in more than 50% of cell cappings being chewed or sunken. It would usually be too difficult in these cases to check every cell with a chewed capping. However, beekeepers have found out the cost of not doing so the hard way. Their hives were inspected as the honey was removed and correctly diagnosed as having PMS by the beekeeper checking a few cells. The honey was removed, the hives treated for varroa, the honey extracted and the wet supers stored with the other supers. When the control strips were removed 6 weeks later the PMS had disappeared. It then became obvious that some of the chewed cappings had concealed larvae with AFB and that there was going to be more diseased colonies when the wet supers were used next.

The obvious answer to the PMS problem is to not let varroa numbers get high enough to cause PMS. If PMS is present, treat the colonies without removing the honey and only remove it after the PMS has cleared up and the hives have been checked properly. Alternatively, the honey could be removed and the PMS hives treated. Each PMS hive should be numbered along with the honey supers removed. These should not be extracted until after the PMS has disappeared and the colonies have been rechecked. Alternatively the honey could be extracted and the frames returned to their original supers. These could then be located and destroyed if the hive they came from was found to have AFB.

AFB diseased larvae or pupae may take on a range of appearances as the disease symptoms develop. A larva is initially pearly white curled around the bottom of the cell. As the disease takes hold the larva stretches itself along the lower wall of the cell (PMS larvae normally spiral up the cell). The normally plump larva then slumps in on itself as the bacteria consumes its tissues (both chalkbrood and sacbrood diseased larvae remain plump). The AFB infected larva then changes from white to a characteristic coffee (with milk) colour. From there the larva darkens as it dries out becoming a black scale that cannot be easily removed from the cell. If a larva is infected later in its development, or with fewer bacteria, it is able to develop further before dying. Early stage pupae that die can have a structure referred to as a pupal tongue stretched across the opening of the cell (Figure 3). Pupae can also die of AFB much later in their development. Fully formed pupae at the white or pink eyed stage can be found that are coffee coloured rather than the typical white colour. Other than the colour they look completely normal.

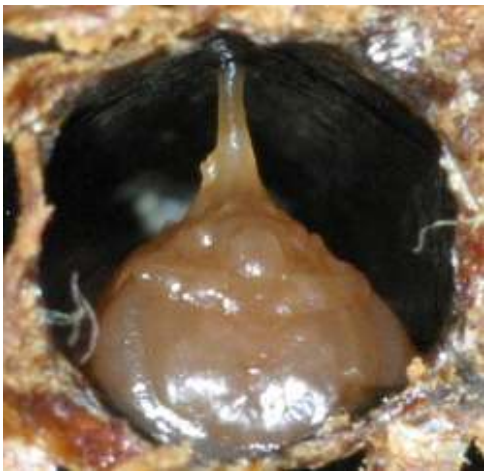

Figure 3. AFB pupa with a pupal tongue.

Figure 4. Ropiness test.

Coffee coloured larvae and pupae, and the presence of the tongue are good diagnostic tools. However, the best tool is the ropiness test. A matchstick is used to mix up the larval tissues in the cell. When the stick is withdrawn the larval material will rope out sticking to both the cell wall and matchstick. This does not occur once the larval or pupal remains start to dry out.

Even the most skilled observer will find diseased larvae where the diagnosis is unclear. The colour may not be right or the tissues do not rope out just the right way to be AFB. If this is the case then the first step should be to search

through the rest of the brood to see if a larva with more clear AFB symptoms can be found. If there is still doubt take a sample and get it tested in a laboratory. Wrap the match used for the ropiness test in plastic and place in a freezer. Then contact AgriQuality (Ph 0508001122) and they will explain how to submit a sample. This testing service is free.

The second approach is to clearly mark the lid of the hive to indicate that it is a suspect AFB hive. Nothing should be removed from the hive until it has passed a second inspection at a later date.

Not all AFB diseased larvae will be behind darkened, sunken or chewed cell cappings. Some will have cappings with a normal appearance. When these occur in a normal brood pattern they are almost impossible to identify. However, as the brood hatches, the disease cells are usually left behind. It is therefore good practice to uncap any cells that from their position the bee should have emerged, but has not.

There may also be diseased larvae in cells, which are not capped at all. Either because the diseased cell has been completely uncapped by the nurse bees or because the larva died before the cell was sealed. Unfortunately these are usually much less obvious than larvae behind chewed cappings.

AFB scale (the dried remains of an AFB infected larva on the lower wall of a cell) are probably the hardest of all to see. If present in a live hive, there should be fresh disease material that can be more easily identified. The AFB scale cannot usually be removed without breaking up the cell. If in doubt get a sample tested. To check for scale the frame should be held upside down with the top of the fame towards the observer. The light needs to shine over the shoulder and into the cells. The shape of the scale resembles the rounded end of a bullet.

FREQUENCY AND TIMING OF AMERICAN FOULBROOD INSPECTIONS

The frequency and timing of American foulbrood (AFB) inspections can have a major impact on the success, or otherwise, of a beekeepers disease control programme. Along with the number of frames inspected, timing and frequency of inspections are the most important factors.

Hives can be checked at any time for AFB as long as brood is present in a hive. Even when there is no brood present it can still be worthwhile checking frames for the remains of diseased larvae.

Some beekeepers devote a specific time, or times, to carry out inspections while others carry out a full or partial inspection every time they work on a hive. At a minimum, a full frame inspection should be conducted on all hives twice a year. One inspection in the spring and a second in the autumn.

The frequency with which beekeepers carry out inspections varies and should depend on the disease history of their hives. If little AFB has been found, the inspections can be carried out less frequently. However, where disease is a problem, inspections should be both frequent and thorough i.e. inspecting all frames in a hive.

Although badly infected colonies can be easy to identify, lightly infected colonies can be much harder. One reason for this is that adult bees in hives with AFB, especially those bees with good hygienic behavior, are continually uncapping diseased cells and removing the contents so that diseased larvae may not always be present in a diseased colony. A second inspection one week after finding AFB symptoms may result in finding no diseased larvae. Many AFB inspectors have been accused of wrongly diagnosing a hive as having a AFB when a beekeeper has checked the hive a week after the inspector had failed to find any AFB.

One hive in a group of AFB hives we were regularly checking had two cells with AFB symptoms on day one. However, none were found when the hive was inspected a week later or in any of the four inspections carried out over the following three weeks. The next inspection on day 50 revealed ten cells with AFB symptoms and on day 70 there were 30. For the disease to reappear by day 50 there was either still enough spores present in the hive to infect further larvae, or that for a month the bees were able to remove diseased cells fast enough so they were not found when the hive was inspected.

Because disease symptoms can appear and disappear, the more frequently inspections are carried out the more likely the AFB infected hives present will be detected and removed before the disease has a chance to spread.

It is best to time inspections so they are carried out immediately before hive manipulations that could spread AFB are going to be conducted e.g. before bees or equipment are removed from a hive. It is particularly important to carry out an inspection as the honey supers are removed. Failure to carry out an adequate inspection at this time is one of the major causes of the spread of AFB. During the honey removal and extraction process one or more supers are removed from each colony and then placed on completely different hives in the spring. There is usually no other beekeeping activity that redistributes more equipment between hives.

The risk of taking honey from an infected hive at this time depends on how badly the colony is infected. Failure to carry out any form of inspection while honey is harvested can result in honey being removed from badly infected colonies. These honey supers are a high risk for disease spread. During the extraction process the frames may be spread between other supers, creating an even larger potential for disease spread. Two honey supers from a badly infected colony might therefore infect three or four other colonies.

Autumn is however the hardest time to carry out inspections because the extra time spent in an apiary increases the robbing problem. An alternative to carrying out the inspection while the honey is being removed is to number each hive and put the same number on the supers that are removed. This can easily be done with a permanent marker pen. The hives can then be inspected at a later date and if an AFB hive is found the supers of honey can be located and destroyed.

In addition to the above, those beekeepers without a Disease Elimination Conformity Agreement must get a certificate of inspection signed by an approved beekeeper in the spring. This means that each colony must have a full frame inspection between 1 August and 30 November.

DESTROYING AMERICAN FOULBROOD COLONIES

Under New Zealand legislation there are very clear requirements for dealing with colonies infected with American Foulbrood (AFB). Any colony with AFB, that has one or more larvae or pupae showing AFB disease symptoms, must be destroyed along with any equipment or bee products from the hive. This must be carried out within seven days of the disease being found. Hives that have had a sample of bees or honey, which have tested positive for American Foulbrood spores, are not classed as having AFB. Only those with visual symptoms of the disease are classed as having American Foulbrood. However, any hive that tests positive for AFB spores should be treated with caution, and watched carefully as it may develop disease symptoms at a later stage. AgriQuality must also be notified of the finding of an AFB hive within seven days.

The best way of destroying a hive is to block the entrance of the diseased hive and pour half a litre (1 litre for 3 and 4 super hives) of petrol across the top bars. This should be done in the morning or evening when the bees are not flying to reduce the chance of the returning bees drifting into other hives. However, despite the legislation, many AFB hives are not destroyed for weeks and sometimes months after they have been found because the beekeeper has not been able to find the time to come back to the hive in the evening. When inspecting hives belonging to commercial beekeepers we write AFB and the date on any AFB hives we find. I can think of at least two separate occasions with different beekeepers where we recorded that the hive still had AFB when we carried out a further AFB inspection a year later. However, if you are unlikely to be able to destroy an AFB hive at night/or morning within 7 days, it is better to destroy it when found even if there are still bees flying rather than leaving it for a long period of time during which it may be robbed out. As part of a research project we placed an AFB hive next to an uninfected hive. In the middle of the day when the maximum number of bees were foraging we removed the AFB hive so all the foraging bees flew into the uninfected colony. We repeated this with 25 hives without spreading the infection. It is always best to kill hives when the bees are not flying but if there is no other option they can be killed when bees are flying with minimal risk of spreading AFB.

Once the hive has been killed it should be sealed to prevent it being robbed out by other bees before it is burnt. To burn a hive, a hole of 1m diameter and at least 300 mm deep should be dug to collect any unburnt honey. Full instructions on how to burn hives can be found in the American Foulbrood Elimination Manual, 1999.

Plate 1. Burning AFB infected equipment

As petrol is being used, a good deal of care needs to be taken when burning hives. There have been a number of cases where people have burnt more than the intended hives. In one case, some hives were placed in a pit and the fire lit. More hives were then taken off the back of the truck to put in the hole and when the beekeeper turned to take the next group of hives off the truck he found they were already burning.

In another case where a large number of hives had to be burnt, a deep hole was dug and filled with petrol soaked hives. The level of the petrol fumes had just about reached the lip of the hole when the lighted taper was thrown in. The resulting explosion rattled the windows for kilometers around. The beekeeper, minus his eyebrows, had to then pick up all the burning AFB frames that had been blasted out of the hole.

In some cases it is not possible to burn hives within the seven days specified by legislation because of fire bans. In this case permission can be sought from the Management Agency to store dead infected hives in such a way that other honey bees are prevented from gaining access to them. The material can then be burnt when the fire ban is lifted.

Care does however need to be taken when storing infected hives. One beekeeper had ten AFB hives stored in his shed when one of his workers thought they would tidy up. The worker separated the floors and lids and added these to the appropriate stacks. He then added the AFB supers to the stacks of uninfected honey supers. It took two years of burning new AFB hives to sort that mistake out.

Beekeepers with a Disease Elimination Conformity Agreement negotiated with the Management Agency can, if their agreement specifies it, salvage and sterilize some hive parts. They can only be sterilized by a method approved by the Management Agency. Currently there are only three approved methods. These are:

Paraffin wax dipping
Irradiation
Dipping in sodium hypochlorite,

The use of these will be discussed in the next article.

STERILISING EQUIPMENT CONTAMINATED WITH AMERICAN FOULBROOD SPORES

Under New Zealand legislation (National American Foulbrood Pest Management Strategy Order 1998) specifies that all bees, bee products and appliances associated with an American foulbrood (AFB) diseased colony must be burnt. The only major exception to this ruling is people sterilising equipment in accordance with their Disease Elimination Conformity Agreement (DECA). If you do not have a current DECA that specifies how you will sterilise equipment rather than burn it, you must burn all equipment associated with an AFB diseased colony.

Fortunately, relatively large numbers of spores are needed to infect a colony with AFB. Because of this any sterilising technique is not required to remove every last spore, but only to lower spore counts to levels that will not cause re-infection. High and low risk equipment, based on the likelihood of being infected with high spore levels, can be treated differently.

After handling American foulbrood (AFB) infected equipment, gloves, bee suits and the decks of trucks etc, which are all likely to be carrying low numbers of spores, are best cleaned by washing them thoroughly. Some beekeepers use disinfectants (e.g. Dettol®, Savlon®, Methylated Spirits) to try and sterilise their gloves,. however most disinfectants do not kill AFB spores. Spores can even survive being soaked in methylated spirits or alcohol. Washing gloves in soapy water is probably the best treatment as it dislodges most of the spores that may be present.

Hive tools are best cleaned in a hot flame. This can be achieved by removing the lid from a smoker and pumping the bellows until the material inside is burning vigorously. The hive tool should then be held in the flame for several minutes (Figure 1). Some beekeepers use a small gas burner to scorch their hive tool. This has the advantage that it is quicker and probably does a better job.

Figure 1 Sterilising a hive tool

There are three approved methods for salvaging infected beekeeping equipment for those beekeepers with a DECA. It is illegal to use any other methods. The economics of sterilising equipment rather than burning it needs to be considered carefully. In many cases when realistic labour costs are taken into account as well as the condition of the equipment, it is usually cheaper to burn it.

The most common method used to sterilise infected hive parts is paraffin wax dipping (Figure 2). Hive parts need to be dipped in paraffin wax at 160^{o}C for ten minutes. The time and temperature is very important so a thermometer and timer should be used. Even at this temperature there may still be the occasional AFB spore that survives. However, there will not be enough live spores to infect a colony when the equipment is used again.

A great deal of care also needs to be taken to ensure the wax doesn't get too hot or boil over if a fire is being used to heat the wax. Many beekeepers have met their local fire brigade after mishaps with their paraffin wax dippers, and a few have lost buildings when the burning wax flowed under walls. It is a good idea to have on hand a cover that can be placed over a wax dipper to put out any fires and an extinguisher to put out spilt wax that may be on fire. It is important also to wear protective clothing because of the high temperature of the wax.

Figure 2. Paraffin wax dipper.

To check that the paraffin dipping is working the boxes should be painted, immediately after dipping, with a special colour. The hives the treated boxes are put on can then be followed closely to see if they become re-infected.

Floorboards, boxes, lids, excluders and wooden or metal feeders are the most common items of equipment that are sterilised by the wax dipping method. Frames are better burnt, whist the wax is too hot to dip plastic hive components in.

Plastic hive parts and frames of foundation can instead be sterilised using sodium hypochlorite. Janola® contains 3% sodium hypochlorite while some swimming pool products contain about 35%. Sodium hypochlorite is mixed with water and so has very limited penetrating power. Anything that is to be treated needs therefore to be free of wax and propolis. Because of the air pockets that develop in cells it is not possible to sterilize drawn comb using hypochlorite.

Equipment to be treated should be immersed in at least 0.5% hypochlorite for 20 minutes. Care should be taken with dipping metal as hypochlorite can dissolve some metals as we have found out to our cost. Similarly, continually dipping leather gloves can be expensive as it causes them to rot. Sunlight breaks down sodium hypochlorite so it is important to keep it in the dark.

The third approved sterilisation method is irradiation. This is a method commonly used in Australia. We have only one irradiation plant in New Zealand situated near Wellington. If it is going to be used it is important that all the equipment is sealed in plastic so that bees do not get access to it. Irradiation has the advantage that comb can be treated as well. Brood comb should however be burnt rather than treated.

There are a number of other methods that are used overseas to attempt to sterilise AFB infected equipment e.g. scorching boxes and steam chests. These are not recommended and should not be used because they are not sufficiently effective.

THE USE OF QUARANTINES TO ELIMINATE AFB

The most powerful tool for American foulbrood disease (AFB) control, other than adequate inspections, is the use of quarantines. Quarantines restrict beekeeper movement of equipment, and consequently AFB, between hives or apiaries. The effectiveness of a quarantine is dependent on how strict it is. They do however usually require more time and a higher level of organisation

Quarantine here is defined as action taken to physically separate either hives, apiaries, or groups of apiaries. Quarantines are effective because most AFB is spread by the movement of equipment between hives rather than by the bees themselves. We know this because there are many of examples where two beekeepers have their apiaries interspersed in the same district. One of the beekeepers may have a very high level of AFB where the other beekeeper has a very low incidence.mainly spread by , rather than beekeepersn area

Hive quarantine

By far the most effective type of quarantine is a hive quarantine. This is where equipment is not moved between hives so that the only way for a colony to become infected is through robbing a diseased colony or even less likely by drifting bees. As long as care is taken to ensure colonies don't die robbing should be a reasonably rare event in most cases.

Those beekeepers with AFB problems who have initiated a hive quarantine have found it has been a great comfort to know that they will no longer spread AFB between their hives. The value of peace of mind when you are struggling with AFB cannot be over emphasised. Once a hive quarantine has been instituted, all a beekeeper usually needs to do to solve their AFB problem is to try and keep all hives alive and find the hives that are already infected with AFB and destroy them.

To be able to implement a hive quarantine it is necessary to individually number each hive. This can best be carried out by nailing a numbered sheep or cattle ear tag on the front of the floorboard (Fig 1). You can buy tags with printed numbers or blank tags that can be written on with a tag pen. It is important that the ear tag is attached to the floorboard rather than to a brood box. Even if the tag is attached to the bottom brood box, brood box positions get changed and the box may end up as a honey super. This will then be removed with the honey crop leaving the hive unnumbered.

Fig 1 A hive marked with a cattle ear tag.

For a hive quarantine nothing should be removed from a hive with the exception of honey supers. These must be numbered with a felt pen, extracted and the frames returned to the same super. The numbered supers need to be dried out on the hives they came from or be stored where they cannot be robbed and then put back on to the same hives in the spring. Feeders, excluders and other equipment should only be removed from a hive if they are also numbered so they can be returned to the same hive.

Hive quarantines have the advantage that AFB inspections do not need to be carried out when the honey is being removed as the supers and frames will be returned to the hives they came from. A second advantage is that the AFB inspections need not be as frequent or as comprehensive. If an AFB hive is missed, unless the hive is robbed out, there is little opportunity for the disease to spread.

Hive quarantines require significant additional work, however, they are not as bad as they sound. You do not have to save burning many hives before they are worth carrying out. They can also be very effective. One commercial beekeeper we were working with had a 25% AFB incidence when the problem was detected. The beekeeper destroyed the infected colonies and instigated a hive quarantine. The next year the incidence was 10 %. These were almost all AFB colonies that were infected the previous year. The incidence the third year was only 2%.

Hive quarantines have the advantage that they can be easily used by migratory beekeepers or beekeepers carrying out pollination as the hives do not have to be returned to the same sites. Lists of which hives are at which apiary need to be recreated, however, so the boxes can be sorted in the correct order in the spring.

Careful thought needs to be given to stored equipment. If there is a high AFB incidence it might be better for it to be destroyed or wax dipped.

Apiary quarantine

An apiary quarantine is significantly less effective than a hive quarantine at dealing with AFB problems but very much easier to institute. It consists of keeping the equipment from each apiary separate. Although AFB will still be spread between hives in the same apiary it will not be spread between apiaries. Once an apiary is clear of AFB it should usually stay clear. Hives in an infected apiary may however still become infected until the disease is eliminated or all the hives have been burnt.

Apiary quarantines are also a good safety precaution. If an AFB problem does occur it will be restricted to a single apiary rather than being spread through an entire beekeeping outfit.

It is possible to carry out a hive quarantine at the same time as an apiary quarantine. The hive quarantine can be used in apiaries with AFB while the equipment from hives in apiaries without AFB can be mixed together.

Apiary quarantines are difficult to manage for pollination beekeepers as the hives need to be sorted and returned to their original sites after pollination.

Outfit quarantines

The third option is an outfit quarantine. This is where a beekeeping outfit is divided into two on paper rather than physically. All apiaries where AFB has been found are included in one half and the clean apiaries in the other half. As apiaries are cleaned up or become infected they are swapped between halves. The method is much less useful than a hive or an apiary quarantine but can have its place.

Again it can be used in conjunction with an apiary or hive quarantine. Uninfected apiaries can be managed together while an apiary or hive quarantine can be instituted for infected apiaries.

AMERICAN FOULBROOD INFECTIONS

Any discussion on American foulbrood (AFB) must also include the issue of when is and isn't a colony diseased. The issue is important for both legal reasons and for reasons of disease control. As far as AFB is concerned a honey bee colony can be uninfected, contaminated, or diseased.

Uninfected hives

Uninfected means that the colony does not contain any AFB diseased larvae or any AFB spores. However, I have heard it suggested that if you looked hard enough you would find AFB spores in all hives. This is probably true of outfits with high disease levels. For example, we tested bees from hives belonging to a commercial beekeeper with a 25% AFB incidence. 82% of 400 hives with no symptoms of disease tested positive for AFB sores. If we had

looked hard enough we would have probably found spores in the remaining 12% of hives. However, this case is not typical. No positive results were obtained from samples from 200 hives belong to a beekeeper who had not reported any AFB hives for many years. These hives probably contained few if any spores.

Contaminated hives

Contaminated means that the hive contains AFB spores but not enough to create an infection or there are enough spores but they are in the wrong location to create an infection. The contamination may come about for a variety of reasons. It may be because the bees have robbed honey from another hive that was contaminated with AFB spores or because of bees drifting from a diseased colony. It may also have had contaminated hive parts added by a beekeeper.

In one trial we added 20 extracted supers from hives with low level AFB infections to 20 uninfected colonies. We were very careful that the outside of the supers were clean. We could not see any evidence of robbing or even any bees investigating the outside of the supers we added. However when we tested samples of bees from 20 uninfected hives at the same site that had not received added supers they all tested positive for AFB spores.

Generally the numbers of spores in a hive will decline over time if no further spores are introduced to a hive. Contaminated honey is consumed and contaminated bees defecate outside or die and are removed. While it is possible that enough spores will find their way to a larva to create an infection this will become less and less likely with time as the number of spores reduces.

Although lab tests can identify contaminated colonies the presence of spores, their presence does not legally require the hive to be destroyed. However, the presence of spores suggests that the colony is at risk of developing AFB and that there may be a diseased hive nearby.

Diseased hives

Technically a colony is diseased if it contains one or more diseased larvae (Figure 1) irrespective of whether diseased larvae are visible to the beekeeper or not. For every diseased larvae seen in a hive there may be many more diseased larvae that cannot be seen.

Fig 1 A larva with AFB

If the infection is very recent the diseased larvae may be hidden by cell cappings that have none of the symptoms we usually associate with AFB (e.g. darkened, sunken or chewed cappings). The bees themselves can also affect the clinical expression of the disease. Bees with good hygienic behaviour can recognise and remove diseased larvae before they exhibit disease symptoms that might be recognised by a beekeeper. Others do not chew cappings but either leave the cells untouched or remove the cell cappings and the diseased larvae completely. One hive we inspected had no sunken or chewed capping but did have a very spotty brood pattern suggesting there was something wrong with the colony. As AFB is always a possibility with a spotty brood pattern we started uncapping cells and found more than 70% of them to be infected.

Legally a colony is classed as having AFB if it contains, or has contained, a diseased larva. Colonies with only a few cells exhibiting disease symptoms may at times eliminate the disease symptoms either with or without eliminating the actual disease. Many beekeepers have reported being unable to find any sign of AFB when they have checked a hive a week after an inspector had diagnosed AFB in a hive. Even though a colony may no longer contain larvae with AFB symptoms, once it has been diagnosed with AFB it must be destroyed as specified in legislation.

Apart from the legislative requirements beekeepers are sometimes tempted to keep colonies in which AFB appears to have been cleared up. There are large risks in doing this. The hive may still be diseased although it shows no sign of it. There is therefore a risk of it infecting other colonies even up to a year later.

HOW BEES SPREAD AMERICAN FOULBROOD DISEASE

It is quite difficult to infect a colony with American Foulbrood disease (AFB) although some beekeepers seem to be very good at it. Under trial conditions to you need to feed about 5 million AFB spores per litre of sugar or honey to infect a colony. Other bee diseases like chalkbrood (fungus) and nosema (protozoa) are very contagious by comparison. Nosema can be found in all colonies in New Zealand. When Chalkbrood was first introduced to New Zealand in the early 1980's, it very quickly spread through the country in a couple of years.

American foulbrood disease can spread between colonies by a large number of mechanisms. These can be divided into two basic types, honey bee assisted and beekeeper assisted. This article describes the mechanisms by which bees spread AFB. Bee spread is much less common than beekeeper spread. Many examples of this can be seen where two beekeepers utilise the same area. One beekeeper's hives may have a very high AFB disease incidence while the other has a very low incidence.

Robbing

Probably the most common way bees spread AFB is by robbing other colonies that are weak or have died. In many cases the beekeepers have contributed to this problem by allowing colonies to become weak enough to be robbed.

Several years ago I was lucky enough to see what can happen when bees rob out a diseased colony. Eighty colonies were returned to the same site after they had been used for kiwifruit pollination. Twenty of these colonies were immediately moved to a second site. Two weeks later a further 20 were moved to a third site again. Of the 40 colonies remaining at the original site 35 contracted AFB and had to be burnt. None of the first group of twenty hives moved contracted AFB however 18 of second twenty hives moved developed AFB. Sometime in the two weeks between removing the first and second group of hives from the site the bees from the remaining 60 hives must have robbed out one or more diseased colonies.

As none of these 60 hives were robbed out the bees must have robbed a hive situated on a different site, or a feral colony. The most intriguing thing about the case was that at least 53 colonies had robbed out the same source. Unfortunately we were unable to find what they had robbed.

Drift

Bees drifting between colonies is another way AFB spreads, however, it would appear to be reasonably uncommon. It would have been even less common before man took up beekeeping because of the relatively large distance there is usually between feral colonies. The practice of keeping large numbers of colonies in close proximity increases the amount of drift and the chances of drift spreading AFB.

We carried out a trial with 24 pairs of hives. Each pair was as close together as possible to encourage drift. One hive had a low level AFB infection (less than 50 disease cells) while the other was uninfected. When we measured the level of drift, the equivalent of 50% of the bees swapped hives over a 20 day period. The pairs were together for

an average of 103 days. Only 2 of the uninfected colonies developed AFB. Drift is however likely to be a larger problem when colonies have more extensive AFB infections.

Anything that can be done to decrease drift will help reduce this source of spread. Having hives in straight lines and all painted the same colour increases drift. Circles and U shaped apiary patterns reduce drift.

Swarms

Swarms can carry AFB with them. The second colony I ever had was a swarm which developed AFB very soon after it was hived. For this reason it is better to hive swarms in old equipment so the loss is less painful. Swarms are best hived on foundation rather than drawn comb. By the time the bees have drawn comb and the queen has laid eggs many of the AFB spores they were carrying should have disappeared which will decrease the chance of the disease reappearing. This is similar to the methods used for shook swarming (shook swarming is illegal in New Zealand).

Swarms occupying infected cavities

Swarms sometimes utilise cavities that have previously been occupied by another colony. This is probably how much AFB spread before humans started keeping bees. The AFB spores themselves suggest this mechanism was important. The spores are very resistant and are able to survive long periods of time, probably more than 50 or 100 years. They can therefore survive the relatively long periods of time that may elapse before a cavity is re-inhabited.

HOW BEEKEEPERS SPREAD AMERICAN FOULBROOD DISEASE

Without the intervention of beekeepers, American foulbrood disease (AFB) probably spreads quite slowly. However modern beekeeping practices have increased the number of opportunities for AFB to spread. This article describes the way beekeepers contribute to the spread of AFB.

Swapping brood

The most significant way beekeepers spread AFB is moving frames of brood between colonies. Although you need to feed about 5 million spores to a colony to infect it with AFB, a single diseased larva may contain 2,500 million spores. If you wanted to infect a colony the most certain way of doing so would be to place a frame of brood from a diseased colony into it. There are many examples where beekeepers have created significant disease problems by swapping brood. Many of these have occurred while preparing hives for kiwifruit pollination.

Feeding pollen

This is another high risk activity. The design of most pollen traps ensure that many of the AFB scales that bees remove from a hive end up in the pollen trap with the pollen. For this reason feeding pollen can be another very good way of spreading AFB.

Feeding honey

Feeding extracted honey contaminated with AFB spores is also high risk. There are many horror stories where beekeepers have had to burn large numbers of hives after feeding extracted honey.

Extracted honey supers

Even though extracted honey supers usually contain less infected material than brood or pollen they are a major source of cross infection. This is because of the frequency with which they are swapped between hives. In most commercial outfits they are taken off one hive and placed on another hive at least once each year. Some large reductions in disease levels have been achieved by making sure extracted honey supers are returned to the hives they were removed from. The best indicator that extracted supers are spreading AFB is through a scattered occurrence of the disease with no pattern to it.

Other hive parts

Swapping other hive parts can also spread AFB. This can be a problem when a dead hive is broken up for parts. The floorboard is usually the biggest problem because bees often drop infected material on it

Robbing

Bees robbing honey from an infect colony is another major way AFB spreads (Fig. 1). In most cases beekeepers have contributed to the problem, either by allowing an infection to get to the stage that the colony is weakened enough to be robbed, allowing a diseased colony to die of other causes, or by not protecting it from stock so that it gets knocked over and robbed. Unfortunately, robbing also occasionally happens when an AFB hive is killed and stored in an inappropriate manner.

Drift

Bees drifting between hives is a lesser source of cross infection but still significant. The likelihood of drift increasing spread increases with the degree of infection and the amount of drift that occurs. Anything that can be done to reduce drift is usually worth while doing.

The remaining pathways with which AFB spreads are less important.

Beekeeping equipment.

Bee suits, gloves, and hive tools have at times been implicated in the spread of AFB. Bee suits probably never spread AFB, although gloves and hive tools may do very occasionally. It is therefore good practice to have a clean pair of gloves that can be worn after an AFB colony has been found so the infected gloves can be taken home and cleaned thoroughly. Hive tools can be cleaned on site using a flame.

Other mechanisms for spread

There have been a large number of other mechanisms suggested to be important for the spread of AFB including, truck decks, steering wheels, hive straps, queens, queen cells, foundation, flowers and the soil outside a hive.

Although some of these may occasionally pose a small risk they are so insignificant compared to the other ways the disease spreads, they can usually be safely ignored.

Fig 1 A colony being robbed

AMERCAN FOULBROOD CONTROL BY NUMBERS

Epidemiology is the study of epidemics and the way they spread. To the dismay of those of us with an aversion to maths, epidemiology is in part a study of numbers. Aspects of the epidemiology of American foulbrood disease (AFB) can also usefully be described by numbers which provide some useful insights into the spread of the disease.

The first issue is the spread between colonies. Any swapping of equipment between colonies carries a risk with it. However the way the equipment is exchanged affects the size of the risk.

In the first example three frames of bees and brood are removed from one hive and papered on to a second to increase its strength. At worst, taking it from an unrecognised AFB hive will create one more AFB hive. Fortunately most beekeeping activities fits this model where the activity doubles the number of AFB hives.

The second group is where an activity more than doubles the number of AFB hives. A good example of this is extracted honey supers. The infectivity of these has not been properly determined but it is safe to assume that it is less than exchanging frames of brood. For the sake of discussion we will assume that an extracted honey super from an undiagnosed AFB hive infects 75% of the hives they are placed on. The bigger the honey crop the greater the risk from the AFB hive. Two extracted honey supers from an AFB hive will infect 1.5 other colonies and 4 supers will infect 3 other hives if the supers are placed on different hives.

The situation gets worse when the components of an AFB hive are spread further. For example we saved a few supers of honey to feed nucleus we are over wintering. We went to great lengths to ensure the hives we took the honey from did not have AFB. This consisted of taking it from an apiary that hadn't had an AFB hive for a long time. Giving the hives 3 AFB inspections and testing the honey for AFB spores. This is because we are taking about 18 frames from each hive and putting one frame in each nucleus colony. If we took them from an AFB hive, assuming a 75% chance of a frame infecting a colony, then an AFB hive has the potential to create 13.5 new AFB hives.

Feeding extracted honey or pollen can be even more disastrous. There are a number of cases where beekeepers have fed extracted honey or pollen to a large number of other colonies. One of the hives supplying the honey or pollen had AFB with the result that one hive was turned into 20 or 30 AFB hives.

Another example of this is one we are sometimes contacted about. This is where a beekeeper has been producing queens and has found out the starter being used has AFB. Several hundred queen cells may have been started and placed in several hundred hives.

A good principle is therefore to assess the risk of removing something from a hive to place it into another. If it is only being placed in a single hive be careful. At least carry out a complete brood check. However if what you remove is going to be placed in more colonies you need to be very sure that the source of the material doesn't have AFB. If what you remove is going to be placed on or in 20 or more colonies then don't do it. Or at least understand the risks being taken and decide whether you really want to face the potential consequences if things go wrong.

Looking at the disease levels in a whole beekeeping outfit rather than in individual hives the numbers again provide some interesting lessons. Unchecked the AFB incidence in an outfit probably increases exponentially. Assuming each AFB hive creates a new AFB hive each year and none are found then the incidence will double each year (Fig 1). A doubling of AFB hives each year will increase AFB incidence from 1% to > 60 % in 6 years. If each AFB hives produces 2 AFB hives each year than the incidence will increase from 1 to > 60% in 4 years.

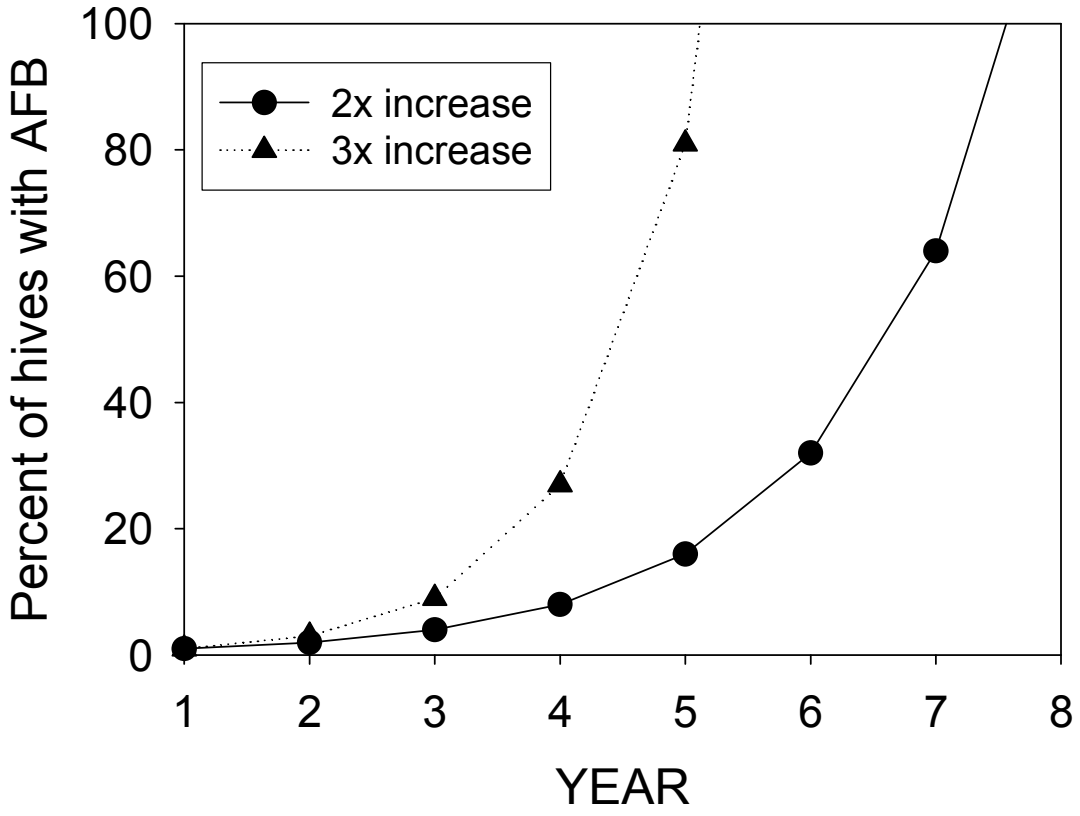

Fig 1 Increase in the percentage of AFB hives when the number doubles and trebles each year.

These rapid increases are the reason beekeepers are sometimes caught unaware with a major problem. If you have only a 0.5% incidence the worst that you can expect next year is 1% or 2% if things go wrong as there are not that many AFB hives available to infect other colonies. However if you have a 5% AFB incidence you are sitting on a potential time bomb. Get it wrong and you may have 20% next year.

ERADICATING AMERICAN FOULBROOD FROM NEW ZEALAND

New Zealand beekeepers are currently trying to eradicate American Foulbrood disease (AFB) - a disease of honey bees. Although this is something that no other significant beekeeping country has ever tried to do, New Zealand has a history of eradicating diseases, e.g. hydatids. Interestingly, the idea of eradicating AFB is not new to New Zealand beekeepers.

This from Volume 1 of the New Zealand Beekeeper 1939.

'the disease can and should be eradicated completely. Under the present system which has had many years' trial elimination of disease from all apiaries in New Zealand seems to be as far away as ever and it certainly high time that something more definite was done about it.'

Why is the goal to eradicate AFB from New Zealand desirable?

Once eradication is achieved there is no need to invest in AFB control

By looking for AFB and burning infected colonies New Zealand beekeepers have an eradication policy for their own hives. It therefore makes sense for the New Zealand beekeeping industry to have the same strategy.

Feeding antibiotics to control AFB is not sustainable long term. Many countries are currently finding that AFB is becoming resistant to the antibiotics being used.

Why is eradication possible?

AFB is difficult to spread. Large numbers of bacteria (500 million spores / litre) need to be fed to a colony to cause an infection. It is therefore not necessary to eradicate the bacteria itself, which is probably impossible, but just to reduce the number of bacteria to a point that the infection of new colonies is unlikely to happen.

Many beekeepers have eradicated AFB from their own outfits. If some beekeepers can do this then it is possible for all beekeepers to do so.

One problem for eradication is that the feral bee population cannot be inspected for AFB. However every cloud has a silver lining. Thanks to varroa, the feral honey bee population is being eliminated.

Another benefit of varroa is that it is changing beekeeping practices. Those beekeepers not really interested in keeping bees have lost or sold their hives. Also many beekeepers managing large numbers of hives per labour unit are reducing their hive numbers to better control varroa which also means they have more time to control AFB.

New Zealand is an Island, therefore not subject to continual reinvasion once AFB has been eradicated.

Most AFB is spread by beekeepers, so changes in the way beekeepers manage hives can have a dramatic effect on AFB levels.

So how can eradication be achieved?

Eradication can be achieved through a combination of two approaches.

1) The first is the traditional approach of trying to find and burn AFB hives faster that beekeepers can infect new hives. The approach taken is to have every hive inspected each year by someone capable of recognising AFB. This is achieved by a combination of training beekeepers, approved beekeepers carrying out the inspections and compulsory inspections. Assuring that all hives are thoroughly inspected each year at an appropriate time of yearcould by itself result in eradication.

2) The second approach is to educate beekeepers to reduce the rate with which new hives are infected.

As long as more AFB hives are found and burnt than are infected each year eradication will happen, the only question is how quickly. The trick is to get the right balance between search and destroy and prevention of infection.

What could stop eradication being achieved?

There are a number of threats to eradicating AFB

As far as we can determine we do not have European foulbrood (EFB) in New Zealand. When we get EFB we will need to feed antibiotics to control it. The use of antibiotics can at times make it more difficult to diagnose AFB.

Politics are also a threat. While everyone was part of the same beekeeping organisation, whether they wanted to be or not, there was little incentive for beekeepers to use the Eradication programme for political gain. However now that the beekeeping industry is splintered into a number of organisations competing for beekeeper members there is a larger risk that the programme will be damaged by beekeepers seeking political advantage.

If the Eradication programme is not well managed and objectives of the programme are not met, beekeepers will loose their enthusiasm for carrying it out.

If the participants in the eradication programme forget that reducing the spread of AFB is at least as important as trying to find infected colonies, eradication will not be achieved.

The final eradication may be difficult. It will certainly need a new approach. Once AFB has been isolated to some small areas, strategies like extensive inspections and investigations into hive movements can be used to track down the last infected colonies

In the end eradication can only be achieved by beekeepers, both commercial and hobby. Most AFB is found and destroyed by beekeepers and most AFB is spread by beekeepers. No outside agency can do it for beekeepers, it can only assist them. For this reason AFB eradication is about changing beekeeper's beekeeping behaviour.

WHY HAVE A PEST MANAGEMENT STRATEGY FOR AMERICAN FOULBROOD DISEASE

American foulbrood (AFB) disease of honey bees can be found in almost every country and is considered to be the worst disease of bees. Once the disease reaches a certain level it will always kill the colony. Any colony then introduced to the used equipment will also die. Unchecked incidences of the disease can reach 100%. In the 1900's AFB nearly destroyed the infant beekeeping industry in New Zealand.

Because of the severity of the disease every country uses one of two strategies for control.

Antibiotics

Most countries e.g. USA and Canada feed antibiotics to control AFB. This usually consists of feeding all colonies once or twice a year to prevent the disease, or just treating infected colonies. In the short term feeding antibiotics to honey bees is a cost-effective solution which allows management of the disease in a way that is compatible with normal beekeeping activities However, in the long-term there are problems associated with the use of antibiotics such as residues in bee products and treatment failure due to AFB developing resistance. Canada, USA and Argentina are currently struggling with the resistance problem at the moment.

2) Search and destroy

Some countries e.g. Australia and England have had a search and destroy strategy to manage AFB. This usually consists of some sort of Government programme where officials inspect colonies and beekeepers have to destroy any hives with AFB. The use of antibiotics is usually forbidden. This system has the advantage that it is sustainable and there are no resistance or residue problems. However, this strategy can be more expensive than the use of antibiotics due to the need for inspections and destruction of diseased colonies. In addition, the bigger, and often unrecognised cost associated with this strategy are those resulting from hive management restrictions needed to prevent the spread of AFB between hives.

New Zealand beekeepers have traditionally chosen the search and destroy approach to AFB control. However for this to be successful all beekeepers need to carry it out and one of the ways to achieve/enforce this is through supportive and empowering legislation. Whereas most beekeepers will successfully control AFB without the need for legislation some will not, and their hives will be a source of infection for their neighbouring beekeepers' hives. Without legislation there is nothing to stop beekeepers exposing AFB infected equipment to robbing bees, keeping hives with AFB, extracting honey from infected hives etc.

Historically, the legislation needed to control AFB in New Zealand was in the 1967 Apiaries Act and the AFB control programme was paid for by government. However about 10 years ago the Government told the Beekeeping industry that it was no longer going to pay for AFB control and that the legislation controlling AFB was going to be removed. The industry was then given two choices:-

To have no legislative control over AFB. The end result of this would have been New Zealand beekeepers having to resort to feeding antibiotics to control AFB.

For New Zealand beekeepers to write their own legislation to control AFB. This legislation had to be written in the form of a Pest Management Strategy (PMS) under the Biosecurity act.

As most New Zealand beekeepers do not wish to feed antibiotics to control AFB, the only option was to write a PMS. However it quickly became apparent that the legislation controlling PMS's (the Biosecurity Act) was complex and clearly not designed to make it easy for an industry as small as the beekeeping industry to write one. To make matters more complicated, the Biosecurity Act was new and nobody had written a PMS before. So not only was it a steep learning curve for beekeepers but also for the Ministry of Agriculture and Fisheries that controlled the legislation.

The first requirement of the AFB strategy was to have a goal. A committee of beekeepers was formed who asked the industry for submissions. From these it was decided that the primary goal was to eradicate AFB from New Zealand.

The next step was to write how this would be achieved and explain why the approach taken was the best. After a year, seven drafts, 100 pages and 55,000 words, weeks of committee meetings and public meetings all over New Zealand, it was completed. The beekeeping industry had done which many thought was impossible for them :-they had written a PMS.

The PMS is almost identical to the previous Apiaries act. There were only 2 major changes

1) Before the PMS every year every registered beekeeper was sent a statement of inspection form under the Apiaries Act. This required beekeepers to provide a signed statement confirming that they had checked their hives for AFB. Unfortunately many forms were signed without the inspections being carried out, and many people signing forms were not competent at inspecting hives for AFB. The PMS changed this by requiring the inspections (certificate of inspections) to be carried out by people (approved beekeepers) who could prove they could recognise AFB. By being 'approved' beekeepers could also avoid having to provide a certificate of inspection for their own hives.

2) The PMS recognised that no outside agency could eradicate AFB. All it could do was help beekeepers to eradicate it by providing a free AFB testing service, counselling and an education programme.

MANAGING STAFF WHO ARE MANAGING AMERICAN FOULBROOD DISEASE

Many beekeeping operations employ staff who are often required to work unsupervised. In most cases this works well however unfortunately there are a number of examples where it has lead to disaster with large numbers of hives needing to be destroyed because they have developed American Foulbrood Disease (AFB).

When this happens it is tempting to put the blame on the staff concerned.. However when something goes wrong with a research project my team are quick to remind me that 95% of all problems are caused by bad management. Unfortunately as a manager of staff I have to agree with this even though it means I always have to take the blame.

Same goes for beekeeping. If a staff member makes a bad mistake it is probably due to the way he or she was managed.

So what does good management look like as it relates to AFB control.

1) Rules

Have a set of beekeeping rules you expect your staff to follow so the can be in no doubt what is required

e.g.

Do a three frame inspection of the brood of any hive you open
Do a full frame inspection of any hive that is to have bees, honey or equipment removed
Shake the bees off frames before inspecting for disease
Mark AFB hives with the letters AFB on the from of the top box with a crayon
Report to ……. Within 244 hours of finding the diseases
Etc

2) Training

Ensure staff have sufficient training to be able to work unsupervised and know how to recognise and deal with AFB