AGRICULTURAL
AND FOOD
ENGINEERING
TECHNICAL REPORT

4

ISSN 1814-1137

Honey bee diseases and pests: a practical guide

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Foreword

Honey bees play a vital role in the environment by pollinating both wild flowers and many agricultural crops as they forage for nectar and pollen, in addition to producing honey and beeswax. The essential and valuable activities of bees depend upon beekeepers maintaining a healthy population of honey bees, because like other insects and livestock, honey bees are subject to many diseases and pests.

The apiculture industry plays an important role in generating employment and in increasing family income in the rural areas of the world. Many developing countries are trying to improve the quality of their honey products but they frequently encounter the main obstacle in apiculture; control of diseases and pests of honey bees.

Therefore, it is very important to publish a practical guide for beekeepers and technicians of apiculture in order to control and prevent the diseases and pests of honey bees. This report provides the basic and practical technology applicable to beekeepers in the world on the importance of various pests and diseases of honey bee.

This practical guide to honey bee diseases and pests by Wolfgang Ritter and Pongthep Akratanakul is the revised edition of "Honey bee diseases and enemies in Asia", published by FAO in 1987 as Agricultural Services Bulletin No. 68/5, and has been prepared under the auspices of the FAO programme on "Enhancing Food Quality and Safety by Strengthening Handling, Processing and Marketing in the Food Chain".

The publication is further evidence of the continuing endeavours of FAO to promote beekeeping in developing countries as a low-cost means of improving local diets, increasing rural industry and purchasing power and diversifying sources of foreign exchange.

Acknowledgements

Special thanks go to FAO for giving us the opportunity to share our knowledge and experience in apiculture industry development in the world. We particularly wish to express our sincere gratitude to the technical officers of the Agricultural and Food Engineering Technologies Service (FAO) for their valuable contributions and suggestions to improve and enrich this work.

Special thanks go to David Ryde for editing the report, and Larissa D'Aquilio for the desktop publishing.

Chapter 1
Introduction

All living organisms are subject to infestation or attack by their natural enemies, and honey bees of the genus *Apis* are no exception. Through their long history of evolution and natural selection, they have achieved a high level of eusociality, many thousands of individual bees living together in a tightly knit social organization. Since individual bees have more than frequent contact among themselves, and since trophyllaxis (the sharing and orally passing of food among members of the nest) is one of the most important and frequent aspects of the bees' social behaviour -- in that it allows hormones and pheromones to be widely distributed throughout the colony-- whenever a pathogenic organism is present in the colony it will be spread with great ease.

The effective defense against disease is one of the most essential achievements of the bee colony. The individual bee's immune system functions in a similar way to that of vertebrate animals, although the most effective defense mechanism that can lead to self-healing of the bee colony is the social behaviour of removing as many pathogen agents or parasites as possible from the bee colony.

This behavioural defence (entrance reduction and/or stinging) prevents parasites from penetrating the bee colonies, or their killing or removal. If the dead organism is too large to remove, as with mice, the bees completely cover it with propolis. This prevents release of the pathogens during decomposition of the body. Propolis is also applied inside the brood cells before new brood is reared. Disinfection of the inside of the cell is effected by covering with secretion from the mandible and propolis.

The most important defence against disease, however, is the bees' hygiene behaviour. The defence against brood diseases comprises identification and removal of affected brood. To this end the bees inspect every single brood cell. On finding an infected larva in a sealed cell, the cell capping is removed, and any sick brood is removed and finally eliminated from the colony. The beekeeper recognises defence activities against brood diseases from the scattered brood surface.

If adult bees fall ill they are either forced to leave the colony or are lost during the first foraging flight. Self-healing is therefore frequently possible by increasing flight activity. This may be initiated by foraging flights or during hibernation by cleansing flights, although it is only possible if the colony is sufficiently provided with pollen and nectar.

Despite these very effective defence mechanisms, diseases, parasites and destructive insects may represent a problem for bee colonies. Diseases may be spread by migration and sale of colonies, equipment and/or bees. With increasing globalization, bee colonies are transported over great distances and even between continents, in this way foreign species and their diseases are spread.

While the question of exactly how many species of honey bees of the genus *Apis* exist continues to be a subject of debate among taxonomists, there are at least three commonly recognized groups native to Asia. These are the *Apis dorsata* group (commonly called rock bees or giant honey bees), the *Apis florea* group (commonly called dwarf or midget honey bees) and the *Apis cerana* group (commonly called oriental honey bees. This group includes the Indian honey bee, Chinese bee, Japanese bee).

The introduction of the common or European honey bee (*Apis mellifera)* into Asia increases the total number of distinct species on the continent. However, new pathogen agents such as *Acarapis woodi* have been imported into Asia with the introduction of the European bee. On the other hand, parasites like *Varroa destructor* or *Tropilaelaps spp.* have managed to transit from their original hosts to the new bee species. This has completely changed the scenario of bee diseases for *Apis mellifera* in Asia and throughout the rest of the world. Viruses have been spread by *Apis mellifera* beekeepers migrating or shipping bees to new areas and infecting and sometimes decimating *Apis cerana* colonies. In view of the fact that all bee species in Asia often occupy the same areas the problem of disease has become especially urgent. A number of serious outbreaks of native diseases have already been caused in new areas resulting in immeasurable economic costs to small and large beekeepers alike.

Chapter 2
Microbial diseases

2.1 BACTERIAL DISEASES

American foulbrood disease (AFB)

Beekeepers in temperate and sub-tropical regions around the world generally regard American foulbrood (AFB) as possibly the most destructive microbial disease affecting bee brood. The disease did not originate in, nor is it confined to, the Americas. It is widely distributed wherever colonies of *Apis mellifera* are kept. In tropical Asia, where sunlight is abundant and temperatures are relatively high throughout the year, the disease seldom causes severe damage to beekeeping operations. The disease is contagious and the pathogenic bacterium can remain dormant for as much as and more than 50 years. Therefore, beekeepers and extension specialists throughout Asia should be acquainted with the symptoms of this disease and know how to cope with it should the need arise.

Cause

American foulbrood disease is caused by a spore-forming bacterium, *Paenibacillus larvae*, which only affects bee brood; adult bees are safe from infection. At the initial stage of colony infection, only a few dead older larvae or pupae will be observed. Subsequently, if remedial action is not taken, the disease will spread within the colony and can quickly spread to other colonies in the apiary as a result of robbing, drifting workers, or contamination caused by the beekeeper's hive manipulations.

In the same way the pathogen agent can spread to other apiaries. Natural transfer mainly takes place within a radius of 1 km around the apiary. Often spores enter the bee colonies via foreign honey. Commercially available honey may be highly contaminated; therefore, special attention should be paid near honey processing enterprises and waste disposal sites.

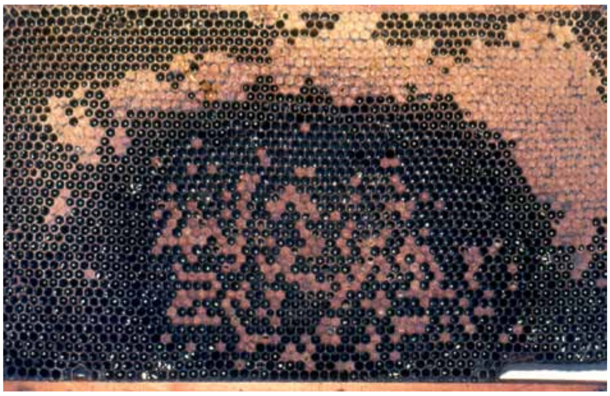

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Plate 1
Irregular pattern of sealed brood with sunken and punctured caps, typifying American foulbrood infestation.

Symptoms

At the initial stage of AFB infection, isolated capped cells from which brood has not emerged can be seen on the comb. The caps of these dead brood cells are usually darker than the caps of healthy cells, sunken, and often punctured. On the other hand the caps of healthy brood cells are slightly protruding and fully closed. As the disease spreads within the colony, a scattered, irregular pattern of sealed and unsealed brood cells (see Plate 1) can be easily distinguished from the normal, compact pattern of healthy brood cells observed in healthy colonies.

The bee brood affected by AFB is usually at the stage of older sealed larvae or young pupae, upright in the cells. Often therefore, a protruding tongue can be found with the rest of the body already decayed. At first the dead brood is dull white in colour, but it gradually changes to light brown, coffee brown, and finally dark brown or almost black. The consistency of the decaying brood is soft.

Once the dead brood have dried into scales, the test cannot be used. The dry brood lies flat on the lower side of the cell wall, adhering closely to it – in contrast to sacbrood. This scale is usually black or dark brown and brittle. Often, a fine, threadlike proboscis or tongue of the dead pupa can be seen protruding from the scale, angling toward the upper cell wall.

The pathogen bacteria may be identified using

Plate 2
Stretch test for American foulbrood disease.
** Irregular pattern of sealed brood with sunken and punctured caps, typifying American Foulbrood infestation.*

a microscopic preparation or, more frequently, by cultivation on selective culture media. The Columbia slant culture has proved to be most effective for this purpose. The result is controlled by biochemical or serological tests and more often by means of the Polymerase Chain Reaction (PCR). As PCR is very sensitive its suitability is restricted regarding the direct evidence in comb samples (see OIE Manual of Diagnostics, 2004).

Commercially available 'AFB diagnosing kits' are based on serological evidence of the pathogen agent. In general, they are appropriate for field use. But if there are clinically indifferent cases, misinterpretations may occur.

The examination of samples from stored food of sealed brood combs has become important in diagnosing AFB, although it is not effective in detecting evidence of an outbreak of AFB. However, it is suitable for population screenings in apiaries and in determining the pathogen pressure in the individual colonies. The diagnostic reliability of the samples from the food wreath depends on the quality of sample extraction. If samples are taken from newly gathered food or from other areas than the sealed brood combs, wrong diagnoses might be made resulting in false negative results.

Control

In several countries, where apiculture includes large commercial operations, frequent, efficient inspection services are particularly advanced and a 'search and destroy' strategy may be adopted in an attempt to minimize damage to apiaries caused by this serious honey bee disease. The procedure involves hive inspections by qualified apiary inspectors. The entire honey bee population that is infected by American foulbrood is killed and hive materials belonging to the colony, are disinfected or destroyed by burning. The bees are usually killed by poisonous gas such as the burning of sulphur powder. All the dead bees, the frames, the supers, the honey and the contaminated equipment are thrown into a 1m x 1m x 1m hole in the ground. Kerosene is poured over the pile and set alight. When all the material has been completely burned, the hole is carefully filled in, to prevent worker bees belonging to healthy colonies from robbing any remaining contaminated honey.

Although the above-mentioned method has proven effective, the practice of burning AFB infected colonies and equipment is costly, especially taking into account the high cost of beekeeping equipment. The destruction of brood combs and food combs is absolutely necessary as, apart from the bees, they are the main carriers of spores. Dry combs, without brood, can be preserved if an examination of wax samples in the laboratory does not reveal *Paenibacillus* spores. In which case the dry combs must also be destroyed. Old hives should be burned. Well conserved hives, however, should be disinfected. The inner part of a hive, once carefully cleaned, can quickly be singed out with the flame of a gas burner. The wooden surface should look slightly brownish. When this is not possible, e.g. if the hive is made from plastic, they should be cleaned and brushed with 3 to 5 percent sodium hydroxide. Before using other substances for disinfection you should make sure that no residues remain that could be dangerous to bees or the consumer of the processed honey.

The killing of the bees can be avoided if the

BOX 1
Stretch test

A simple way of determining whether AFB caused the death of the brood is the 'stretch test' (see Plate 2). A small stick, match or toothpick is inserted into the body of the decayed larva and then gently and slowly, withdrawn. If the disease is present, the dead larva will adhere to the tip of the stick, stretching for up to 2.5 cm before breaking and snapping back in a somewhat elastic way. This symptom called 'ropiness', typifies American foulbrood disease, but it can be observed in decaying brood only.

artificial swarm method is applied. A traditional method is to keep the bee colony in a dark environment for several days. The bees are pushed into a decontaminated hive with new combs, the bee entrance is closed and they are placed in a dark preferably quite cool room. Within two days, the bees have used up the contaminated food. The colonies can then be placed either at their former stand or within a distance of at least 3 km away. If the bees are kept in the dark for three days they forget their old stand and can be placed anywhere. On the third day, however, some food shortage may occur. Therefore, the colonies should be fed.

The direct artificial swarm method is less complicated. First, a clean, decontaminated hive is prepared. Instead of combs it contains three to six wooden bars, depending on the colony's strength, provided with a wax strip as a starter for further comb construction. Using a queen excluder fixed at the entrance or above the bottom of the hive should prevent disappearance of the queen. The prepared hive is placed at the colony's old stand subject to sanitation. Now the bees are pushed or brushed into the empty hive. Three days later, the combs that have been partially constructed by the bees are removed again and burned. Combs with midribs later replace these. Now sanitation is finished. The combs and the hive of the old colony are burned or decontaminated.

In some countries, beekeepers who destroy their AFB-infected colonies receive compensation, either directly from the government or from beekeepers' organizations.

Chemotherapeutic methods of controlling AFB involve the administration of antibiotics or sodium sulfathiazole, in various formulations, fed mixed with powdered sugar or sugar syrup.

Antibiotics and sulfonamides prevent multiplication of the agent, though it will not kill the spores. Therefore, multiplication may begin again shortly after treatment, which is why treatment must be repeated in shorter and shorter intervals. Over time the inner part of the hive, the food and honey become increasingly contaminated by spores. Stopping treatment without simultaneous disinfection leads irrevocably to a relapse. However, detectable residues remain even after a period of time has elapsed between treatment and honey extraction.

European foulbrood disease (EFB)

As with American foulbrood disease, the name of this bacterial bee brood disease is inappropriate. The range of distribution of European foulbrood disease is not confined to Europe alone and the disease is found in all continents where *Apis mellifera* colonies are kept. Reports from India indicate that *A. cerana* colonies are also subject to EFB infection. The damage inflicted on honey bee colonies by the disease is variable. EFB is generally considered less virulent than AFB; although greater losses in commercial colonies have been recorded in some areas resulting from EFB.

Cause

The pathogenic bacterium of EFB is *Mellissococcus pluton*. It is lanceolate in shape and occurs singly, in chains of varying lengths, or in clusters. The bacterium is Gram-positive and does not form spores. While many strains of *M. pluton* are known, all are closely related.

Symptoms

Honey bee larvae killed by EFB are younger than those killed by AFB. Generally speaking, the diseased larvae die when they are four to five days old, or in the coiled stage. The colour of the larva changes at it decays from shiny white to pale yellow and then to brown. When dry, the scales of larvae killed by EFB, in contrast to AFB scales, do not adhere to the cell walls and can be removed with ease. The texture of the scales is rubbery rather than brittle, as with AFB. A sour odour can be detected from the decayed larvae. The clinical picture and the odour can vary depending on the kind of other bacteria involved (*Bacillus alvei, Streptococcus faecalis, Achromobacter eurydice*). Another symptom that is characteristic of EFB is that most of the affected larvae die before their cells are capped. The sick larvae appear somewhat displaced in the cells (see Plate 3).

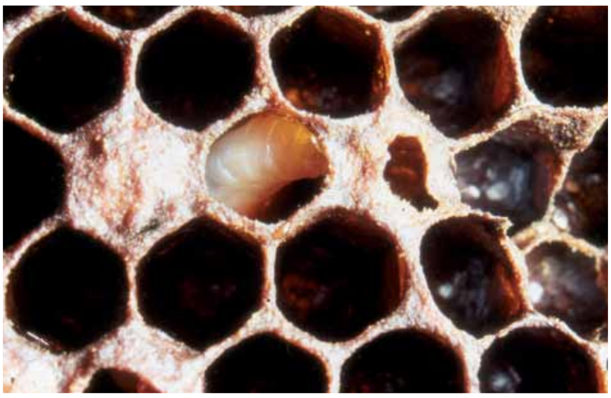

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Plate 3
Larvae in coiled stage, killed by European foulbrood disease.

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Plate 4
Brood killed by chalkbrood: white and black mummies.

When a scattered pattern of sealed and unsealed brood is observed in a diseased colony, this is normally an indication that the colony has reached a serious stage of infection and may be significantly weakened. However, this is the case with all brood diseases. EFB is transferred in the same way as AFB. *Melissococcus pluton* as a permanent form, does not form spores but capsules which are less resistant than the spores of *P. larvae*.

The detection of *M.pluton* is normally carried out microbiologically. Selective culture media (OIE, 2004; Bailey and Ball, 1991) are most appropriate. For further verification biochemical tests or the PCR can be applied. The gene technological test is very sensitive and is therefore less suitable for the detection of *M. pluton* in suspicious brood. A single-use test set is commercially available based on a serological proof like the AFB test set (see OIE Manual of Diagnostics, 2004).

Control

The choice of an EFB control method depends on the strength of the infection, i.e. how many brood cells and combs are infested. If the infection is weak, it is often sufficient to stimulate the hygiene behaviour of the bees. Either they are placed at a good foraging site or they are fed with honey or sugar water. An even better result is achieved if the individual combs are sprayed with a thinned honey solution. If the infestation is stronger it makes sense to reduce the number of pathogens in the colony by removing the most infested brood combs. Empty combs or healthy brood combs then replace these. Since the bees' hygiene behaviour is also genetically determined, replacement of the queen is also possible. Re-queening can strengthen the colony by giving it a better egg-laying queen, thus increasing its resistance to the disease and interrupting the ongoing brood cycle giving the house bees enough time to remove infected larvae from the hive. In serious cases, the same methods can be used as for AFB. Sometimes chemotherapeutic measures such as antibiotics are called for, however, their application, always risks the danger of residues.

2.2 FUNGAL DISEASE

Chalkbrood disease (*Ascosphaerosis*)

In Asia, chalkbrood is rarely considered to be a serious honey bee disease, although in Japan the disease has been reported to cause problems to beekeepers. In temperate America and Europe, however, cases have occurred in which chalkbrood has caused serious damage to beekeeping; therefore, Asian beekeepers should be aware of this problem.

Cause

Chalkbrood is a disease caused by the fungus *Ascosphaera apis*. As its name implies, it affects honey bee brood. This fungus only forms spores during sexual reproduction. Infection by spores of the fungus is usually observed in larvae that is three to four days old. The spores are absorbed either via food or the body surface.

Symptoms

Initially, the dead larvae swell to the size of the cell and are covered with the whitish mycelia of the fungus. Subsequently, the dead larvae mummify, harden, shrink and appear chalklike. The colour of the dead larvae varies with the stage of growth of the mycelia: first white, then grey and finally, when the fruiting bodies are formed, black (see Plate 4). When infestation is heavy, much of the sealed brood dies and dries out within their cells. When such combs are shaken the mummified larvae make a rattling sound. In the laboratory the fungus can be identified by its morphology (see OIE Manual of Diagnostics, 2004).

Control

As with other brood diseases, the bees remove the infested brood with their hygiene behaviour (see European foulbrood), which is especially effective for white mummies. Though as soon as the fruit bodies of *A. apis* have developed, cleaning honey bees spread the spores within the colony by this behaviour. During the white mummy stage the fungus continues to develop at the hive bottom. If the mummies are not removed quickly, the spores may enter the brood cells carried there by circulating air.

The beekeeper can stimulate the hygiene behaviour of the bees by changing the brood-rearing conditions. In this respect, it is most important to adapt the size of the hive to the strength of the bee colony. In this way the bees have a chance to inspect and clean the many brood cells.

Therefore, in most cases, the method of stimulating hygiene behaviour, already described under European foulbrood control, is sufficient for chalkbrood control. The beekeeper should ensure that the colony has a strong worker population, and that the hive is well ventilated and free from accumulated moisture. At early stages of chalkbrood infection, adding young adult workers and hatching brood, combined with sugar-syrup feeding, often proves to be helpful.

Currently there is no known successful chemical control against chalkbrood. It means that chemical treatment shows a little effect to control chalkbrood. In most cases, commercialised substances only show a positive effect because they are sprayed, or fed with sugar water as described above.

2.3 VIRAL DISEASES

Over the past years at least 18 virus types and strains have been recorded as disease pathogens of adult bees and bee brood, nearly all are RNA viruses. Laboratory examination for virus diseases is difficult, calling for sophisticated equipment and procedures, since particles of the virus are too small to be observed with ordinary light microscopes. However, they can rarely be differentiated with an electron microscope. Apart from serological methods, most of the known viruses can now be identified by genetic technologies (PCR).

The damage caused to colonies by viral infection varies considerably according to a number of factors, which include the type and strain of virus involved, the strength of the colony, weather conditions, the season and food availability. Basically, bees are well-protected against infection with their chitin body shell and gut coating. Parasitic mites sucking the blood of the bees, however, can penetrate this protection. Therefore, increased infestation by parasites is often accompanied by increased virus infection. Little known viruses such as Acute Paralyses Bee Virus (APBV), and Deformed Wing Virus (DWV) may become increasingly destructive in the future. As not much is known about the life cycle and pathogenity of most virus diseases, there are only a few ways to control them. Therefore, reflecting this situation, only the most widespread sacbrood is described.

Sacbrood disease

Sacbrood disease (caused by *Morator aetotulas*) is perhaps the most common viral disease of honey bees. In Asia, at least two major types have been recorded. Sacbrood disease that affects the common honey bee *Apis mellifera* and the sacbrood disease of the Asian hive bee *A. cerana. A* new type of sacbrood virus has recently been reported in Asian colonies of *A. cerana*. It is highly probable that the virus is native to the continent and that it has been with the Asian hive bees over the long period of its evolution. Since its first discovery in Thailand in 1981, it has been found in association with *A. cerana* in India,

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Plate 5
Honey bee larvae killed by sacbrood disease.

Pakistan, Nepal, and perhaps all other countries in Asia within the honey bee's range of distribution. Several reports indicate that nurse bees are the vectors of the disease. Larvae are infected via brood-food gland secretions of worker bees.

Symptoms

Field inspection to determine whether the pathogenic virus has infected a colonycan be easily carried out following symptomology.

Diseased larvae fail to pupate after four days; they remain stretched out on their backs within their cells (distinct from the mostly twisted position of larvae affected by European foulbrood. The anterior section of the larva, consisting of its head and thorax, is the first part of its body to change colour, changing from white to pale yellow and finally to dark brown and black (see Plate 5). On removing the larvae from their cell the inspector can easily observe that their skin is quite tough and that its contents are watery; the infected larva thus has the appearance of a small, watery sac. Dead larvae remaining within their cells eventually dry out to flat scales that adhere loosely to the cell floor.

Control

No chemotherapeutic agent is effective in preventing or controlling sacbrood disease. Colonies often recover from the infection without the beekeeper's intervention, particularly if the infection is not new to the geographic area. This mainly depends on the hygiene behaviour of the bees, which may be stimulated as with other brood diseases (see European foulbrood). Since the disease usually occurs when the colony is under stress (shortage of food, food-storage space, unfavourable climatic conditions such as damp during the rainy or cold season, unhygienic hive interior, poor queen, infestation with other diseases, etc.), the beekeeper should deal with severe cases by re-queening the colony, removing infected brood combs and taking other management measures to restore colony strength, such as providing food and adding worker population. If there is an extremely strong infestation it may be convenient to apply the artificial swarm method as for American foulbrood.

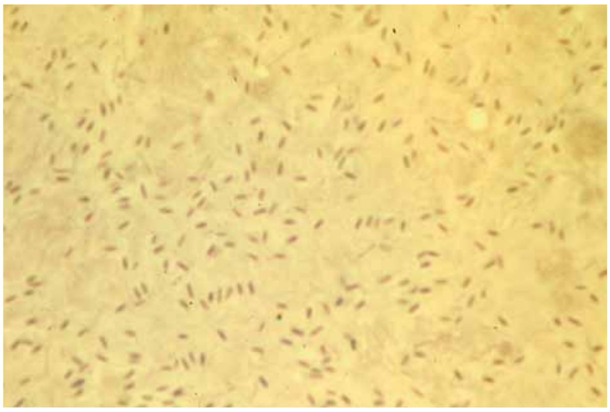

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Plate 6
Nosema apis spores (magnification factor 400 x).

2.4 PROTOZOAN DISEASE

Nosema disease (*Nosemosis*)

Nosema disease is generally regarded as one of the most destructive diseases of adult bees, affecting workers, queens and drones alike. Seriously affected worker bees are unable to fly and may crawl about at the hive entrance or stand trembling on top of the frames. The bees appear to age physiologically: their life-span is much shortened and their hypopharyngeal glands deteriorate, the result is a rapid dwindling of colony strength. Other important effects are abnormally high rates of winter losses and queen supersedures.

In climates with pronounced long periods of flight restrictions, i.e. no flight opportunities even for a day, the infection easily reaches a severe stage that visibly affects the strength of the colony. Less obvious infection levels in other climates often go undetected.

The damage caused by Nosema disease should not be judged by its effect on individual colonies alone as collectively it can cause great losses in apiary productivity.

Cause

The disease is caused by the protozoan *Nosema apis*, whose 5 to 7 mm spores infest the bees, are absorbed with the food and germinate in the midgut. After penetration into the gut wall the cells multiply forming new spores that infect new gut cells or can be defecated. The nutrition of the bees is impaired, particularly protein metabolism.

Symptoms

Unfortunately, there is no reliable field diagnostic symptom enabling a diseased worker bee to be identified without killing it, nor can the beekeeper recognize an infected queen. However, in severe cases of infection, it is sometimes possible to separate healthy from diseased bees, the abdomen of an infected worker often being swollen and shiny in appearance. On dissection, the individual

BOX 2
Heat treatment and fumigation

Heat treatment
Infected equipment is maintained at 49°C (120°F) for 24-hours, ensuring that hot air passes through all stacked combs during the entire period of treatment. The temperature must however be carefully regulated, because heat at levels higher than that specified will melt wax.

Fumigation
A pad of cotton or other absorbent material, soaked with 80 percent acetic acid, is placed over the top-bars of the comb in each hive. The hive bodies are stacked together, the entrance is closed, all cracks are sealed, and the stacks are placed in an open shed for about a week. After this period, the hives are opened and the pads of acetic acid are removed. The combs must then be allowed to air for 48 hours to rid them of acetic acid residue so that they can be used again. The spores in the food cannot be killed. Therefore, the food combs have to be centrifuged before decontamination. The food should not be used anymore for bees.

circular constrictions in the alimentary canals of uninfected bees are clearly visible, while the constrictions cannot be seen clearly in diseased bees. Easy separation, after killing, of first abdominal segments with intestines attached, which shows white if strongly infected, versus a normal transparent, darker grey/ochre colour if there is no or only a low infection.

The most reliable method of detecting Nosema disease involves laboratory procedures using a microscope for diagnosis. A simple diagnostic method used for adult workers is to use a sample of 20 suspected workers. The bees are killed, and their abdomens are removed and ground in water (2 to 3 ml per sample). A drop of the suspension of pulverized bee abdomens is then viewed under a microscope. If the disease is present, reasonably large individual bacilliform spores with bright, queen’s egg-laying capacity fluorescent edges (see Plate 6) will be observed. In the visual field of the microscope, at a 400 fold magnification, up to 20 spores indicate a weak, 20 to 100 a medium and 100 and more a severe infestation.

In productive beekeeping, a healthy queen with a good egg-laying capability is always required, and Nosema disease in queens is therefore critical. The queen’s egg laying ability can be reduced possibly inducing her supersedure. She may also become the major cause of spreading the disease within the colony. On the other hand, beekeepers are naturally reluctant to destroy queens in the uncertain possibility that they are infected. The microscopic inspection of her faeces makes it possible to verify the presence or absence of the disease in the queen. Placed alone in a Petri dish, the queen will defecate in about an hour, the faeces appearing as colourless drops of clear liquid. This liquid can be examined under the microscope for the presence of spores, without further preparation (see OIE Manual of Diagnostics, 2004).

Control
Nosema can best be controlled by keeping colonies as strong as possible and removing possible causes of stress. Colonies and apiaries should receive adequate ventilation and protection from the cold and from humidity. The bees should have the possibility of foraging regularly in order to defecate. This prevents spreading of the spores within the colony. Beekeepers should also ensure that their colonies and queens come from disease-free stock.

Hive equipment that is suspected of being contaminated by *Nosema apis* spores should be thoroughly decontaminated, preferably by heat and fumigation.

The best prevention is to change the combs once every two years. During normal wax processing the Nosema spores are killed.

The only effective chemotherapeutic method currently available for treating Nosema is to feed the colony with fumagillin (25 mg active ingredient per litre of sugar syrup), preferably at a time when the colony is likely to encounter stress conditions, such as during a long winter or rainy season. Fumagillin can repress and prevent infection in bee packages, in queens in mating nuclei and in wintering colonies. The active ingredient of fumagillin is an antibiotic. It is of the utmost importance that no medication be administered to colonies when there is a chance of contaminating the honey crop.

Chapter 3
Parasitic bee mites

Beekeepers throughout Asia generally agree that parasitic mites are among the most serious enemies of honey bees with which they have to cope. In tropical Asia, the success or failure of beekeeping operations with *Apis mellifera* depends largely on mite control.

Several major factors exacerbate bee-mite problems on the continent. First, all known major species of parasitic honey bee mites are currently present in Asia, most being native to the continent. Second, the complete eradication of the mites from an apiary is impossible, because the feral nests of native bees infested by the parasites serve as reservoirs of mite re-infestation of domesticated honey bee colonies. Moreover, some mite species are able to survive, or even thrive, on more than a single species of host bee.

Several species of mites have been reported as causing devastation to both *A. mellifera* and *A. cerana* beekeeping operations throughout Asia, though not all mite species found within the hives or in association with the bees are true parasites. Several species of pollen-feeding mites are occasionally found in hives or attached to foragers. These phoretic mites are mostly innocuous to beekeeping. Table 1 contains a list of parasitic and phoretic mites reportedly found in association with honey bees in Asia.

3.1 VARROA MITE (*VARROASIS*)

This mite is a native parasite of *A. cerana* throughout Asia. Since the initiation of beekeeping development projects with *A. mellifera* on the continent, it has been reported as causing damage in both temperate and tropical Asia. The overall effect of varroa infestation is to weaken the honey bee colonies and thus decrease honey production, often seriously. Occasionally in *A. melllfera*, and more frequently in *A. cerana*, heavy infestation may cause absconding. Today this parasite is found throughout the world, except for Australia and New Zealand South Island.

In temperate Asia, most beekeepers agree that varroa damage is a constraint to the success of beekeeping operations with *A. mellifera*, while in tropical Asia success is limited by the loss of *A. cerana* colonies through absconding, which is far less serious and frequent than damage to *A. mellifera*. Most treatment descriptions are for *A. mellifera*. Occasional removal of *A. cerana* male brood combs and keeping the hive in healthy condition are the way of prevention of varroosis for *A. cerana*.

Cause

Varroa destructor (previously confused with *Varroa jacobsonii*) is quite large, as compared with other mite species, and can be seen with the unaided eye. The shape of the adult female is distinctive: observed from above, the width of the body is clearly seen to be greater than the length, i.e. about 1.6 x 1.1 mm. The mite is reddish brown in colour and shiny and the body is dorso-ventrally flattened covered with short hairs (setae).

Adult females of *V. destructor* are found inside brood cells or walking rapidly on comb surfaces. Individual mites are often seen clinging tightly to

TABLE 1
Bee mites and their hosts

Mite	Mode of living	Host	Habitat
Varroa destructor	Parasite	*A. cerana**	Brood cell, adult bee
		A. mellifera	Brood cell, adult bee
Euvarroa sinhai	Parasite	*A. florae**	Brood cell, adult bee
Tropilaelaps spp.	Parasite	*A. dorsata**	Brood cell, adult bee
		A. mellifera	Brood cell, adult bee
Acarapis woodi	Parasite	*A. mellifera **	Trachea of the adult bee
		A. cerana	Trachea of the adult bee
Neocypholaelaps spp.	Phoretic	*Apis spp. **	Adult bee, pollen- storage cell

* Native host of the mite


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Plate 7
Varroa mite showing nymphal stages and male.

the body of adult bees, mostly on the abdomen, where the segments overlap, between the thorax and the abdomen and at the ventral entry. Adult males, and the immature stages of both sexes (egg, protonymph and deuteronymph), are not commonly seen outside the brood cells (see Plate 7). All immature stages of the parasite live inside the brood cells. They can be observed when infested cells are opened and the brood is carefully removed. The immature mites are bright white and the adult females are brown, while male mites are smaller than females and are rarely seen since they are only found inside brood cells.

Symptoms

Varroa causes injuries to honey bees by direct feeding. The adult female pierces the bees' soft intersegmental membrane with their pointed chelicera and sucks the bees` haemolymph ('blood'). The adult bee, however, is only damaged if the infestation is severe. *Varroasis* is a brood disease. If more than one parasitic female mite infests the brood cell the brood decays or deformations occur including shortened abdomen or deformed wings. If only one mite infests a cell symptoms may not be visible, although the bees' life-span is considerably shortened. Moreover, the bee's behaviour may be disturbed, e.g. in orientation or gathering food. Infested bees often have a reduced fat body that hampers the functioning of their glands or increases their susceptibility to pesticides. The semen production of drones may be considerably reduced.

Varroasis is a multi-factorial disease. Virus diseases that may have caused little damage before infestation by varroa mites often accompany it. Normally, the exoskeleton protects the bees from many virus infections. However, the mite penetrates this natural barrier transferring viruses or stimulating the multiplication of viruses with its saliva. In turn viruses seem to speed the development of *varroasis* enhancing the parasite's virulence. Other diseases such as nosema and sacbrood have similar effects.

Moreover, unfavourable climatic conditions or insufficient stocks of pollen and nectar can increase the process of disintegration. Without treatment the colonies normally die after two to three years, management errors may also cause the collapse of colonies. Colonies destroyed by the varroa mite are often left with only a handful of bees and the queen, the other bees having died during foraging or having drifted to neighbouring colonies, where the mite population can increase before killing these colonies also. In this way mites may cause colonies to die, as in some kind of domino effect, over wide areas.

The presence of adult bees with deformed wings, crawling on comb surfaces or near the hive entrance, usually indicates a late stage of heavy mite infestation. Several other methods may be used to detect mites. The most reliable, perhaps the most time-consuming, is direct sampling by the random opening of brood cells, particularly drone cells. The older the larvae/pupae the easier this procedure becomes. The brood is removed from the cell with a fine forceps and the cell is inspected for the presence of the mites (see Plate 8). Between 100 and 200 cells must be opened before an assessment of the level of mite infestation can be made.

To inspect adult bees, the bees are captured from the brood combs and placed in jars, into which chloroform, ether or alcohol is introduced on a piece of cotton wool. The bees are intoxicated and the mites crawl on the glass wall. Returning foragers may also be captured by hand at the hive entrance and held up against the sunlight; any mites attached to the bees' abdomens may be seen. Another method is to use specially constructed zinc, plastic or wood trays, built to the size of the bottom board, with a white or light-coloured floor. The trays, equipped with a screen of a mesh less than 2 mm fixed at about 1 cm above the tray floor, are placed on the bottom boards of the hives and are inspected one to three days later for the presence of dead mites. The screen prevents the bees from removing the dead parasites from the hive (see OIE Manual of Diagnostics, 2004).

The control of *V. destructor* is one of the most difficult tasks facing apiculturists and beekeepers throughout the world. The mite is a highly successful parasite, whose life history is well synchronized with that of its host. Two principal approaches to its control are currently available: chemical control and hive manipulation techniques, sometimes referred to as 'biological control'.

Plate 8
Bee larvae with varroa mites.

Chemical control

Chemical control is by far the most popular method of varroa control among Asian beekeepers and elsewhere. Although it creates the risk of honey contamination, the accumulation of residues within the hive and toxic effects to the bees, beekeepers claim that chemotherapeutic treatment is the quickest and most reliable method of mite suppression. Among the commonly-used mite-control agents are organic acids, ethereal oils, synthetic pyrethroids and amitraz.

The application of chemical substances can only be started after honey harvest, i.e. after extraction of the honey chamber, respectively the honey combs. This is the only way to avoid residues. A variety of convenient substances are available to the beekeeper for varroa mite control. Beekeepers must verify which substance is approved for use in their countries.

Some preparations have to be excluded because of their low effectiveness in colonies with brood. Among these are Perizin ® Bayer as well as the organic acids, lactic acid and oxalic acid. Resistance has developed in certain countries to a few systemic pyrethroids such as fluvalinate and flumethrin, contained in Bayvarol ®, Apistan and Klartan. Effectiveness must be verified in the country or region. The organic acids: formic acid, the ethereal oil thymol and the synthetic pyrethroids and amitraz may still be chosen to treat colonies with brood.

Formic acid

Formic acid can kill some of the mites in the sealed brood cells. It is recommended that the formic acid be allowed to evaporate in colonies with sealed brood for at least two to three weeks. In this way, mites emerging from the brood will also be killed. Various applicators have proved effective for this purpose. A small container equipped with a wick or paper felt is filled with 200 ml of 85 percent formic acid to evaporate for at least 14 days. The quantity to evaporate can be regulated by means of the length of the wick or the size of the paper felt. The container is either placed on top of the combs, in an empty upper section or after some combs have been taken out, in the empty space. The external temperature should not be less than 12°C (54°F) and not

BOX 3
Organic acids

Most organic acids are natural components of honey. In most countries, no fixed maximum residue limits have been fixed for them. Obviously, overdosing can 'over acid' the honey and change its taste. Overdosing should also be avoided to avoid damage to the bees.

Those handling acid must be aware of the risks and wear protective clothing. Formic acid is the strongest organic acid and can cause extremely severe skin burns if it comes in contact with the skin. Skin and eyes must be sufficient protected while the acid is being prepared and during its application. In addition, a bucket of water should be kept close by to serve as a 'fire extinguisher'. Having to search for water when acid is already on the clothing or the skin may result in deep wounds. The same is true for oxalic acid. Here special precaution is necessary when preparing the solution with the crystal form. To avoid inhalation, a special mouth protector must be worn.

more than 25°C (77°F). The formic acid should be introduced into the colony only in the late afternoon to avoid damage to bees and brood. In addition, physiological tolerance is improved if the entrance hole is wide open.

An easier way to introduce formic acid is to use a sponge or a similarly absorbent material. A solution of 3 ml of 60 percent formic acid is applied onto the sponge tissue per comb (Langstroh size). The quantity must be reduced accordingly for smaller comb sizes. A grid fixed above the tissues on the bottom of the hive, will prevent the bees from burning themselves with the acid. The grid should be as far away from the brood as possible. The application can be repeated three to four times at intervals of at least seven days

Oxalic acid

Contrary to formic acid oxalic acid does not act via evaporation but through contact with the bees. Thirty five grams of crystal oxalic acid (dihydrate) is thinned in one litre of sugar water (1:1). When handling crystal acid special precautions must be taken because of the health risks. Protective spectacles and acid-proof gloves must be work together with an adequate mouth protector. Depending on the size of the colony 20 to 30 ml of the suspension per chamber are dropped into the bee-ways. A repetition of the treatment can lead to damage to the bees. Applicators are available by which the acid can be evaporated.

Lactic acid

Lactic acid is clearly better tolerated by bees and does not cause problems in warmer climatic zones. The disadvantage is that every single comb must be extracted to spray the bees with the acid. The dosage applied per comb side is 8 ml of 15 percent acid. This treatment can be repeated several times at intervals of seven days

Etheric oils

The only etheric oil that is sufficiently affective against varroa mites is thymol.

Thymol

Thymol can be applied as a commercially available ready-made preparation or in crystal form. For this purpose, 0.5 mg thymol per bee-way are put into a gauze bag and deposited onto the combs for some weeks. In this way mites emerging from the brood will be covered.

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Plate 9
Adult female of Tropilaelaps spp.

Synthetic chemicals

Pyrethroids

Synthetic pyrethroids are contained in Apistan and Bayvarol, which have been developed for application to bees. The plastic strips are fixed in bee-ways in the brood nest. When the bees come into contact with them they transport the substance to the other bees, thus killing the parasitic mites on the bees. As the strips remain for several weeks in the colony mites emerging from the brood are affected. Synthetic pyrethroids are highly effective, although there is the disadvantage that mites may rapidly develop resistance to them. Therefore, their effectiveness should be controlled regularly. Synthetic pyrethroids are also available in formulations not specifically intended for use on bees.

Amitraz

Taktic and Mitac are trade names of products containing amitraz at different concentrations. The recommended dosage for use on honey bee colonies is 1 ml of 12.5 percent amitraz to 10 litres of water, sprayed lightly on bees, the comb surface of brood frames and hive walls. The amount of the solution to be sprayed at each application depends on the size of the colony, but is usually within the range of 80 to 250 ml.

Amitraz can also be used as a hive fumigant. Strips of filter paper 2.5 x 9 cm are soaked in a

Note that amitraz can kill bees. A major disadvantage of amitraz is that it has an ovicidal effect: when used as a hive spray it will kill eggs. It must therefore not be sprayed directly on frames containing a considerable number of eggs or newly-hatched larvae.

saturated solution of potassium or sodium nitrate and allowed to dry, then 0.1 ml of the product is applied onto each paper strip. Fumigation should take place in the evening, when the foragers have returned to the hive. The technique is simple: an impregnated strip of paper is fastened to an empty frame, lit and allowed to smoulder from the bottom end upward. The frame is inserted into the hive, supported by an empty super placed above the brood chamber. The hive entrance is closed, and all cracks are sealed with masking tape. The entrance can be reopened after 20 to 30 minutes. If sealed brood is abundantly present in the infested colony, the treatment must be repeated two to three times at four-day intervals.

Control by hive manipulation

The varroa mite depends on bee brood to complete its development cycle. Since the mite prefers drone brood to worker brood, empty frames are given to the colonies, which will rear drone brood in them. When the cells are sealed, the frames, containing the mites trapped inside the cells, can be removed and destroyed.

The mites can also be trapped in worker-brood frames by using vertical queen-excluders in single-storey hives. The queen is confined between two excluders and allowed to lay eggs in one frame only. Female mites in the colony will be attracted to this brood frame which, when the cells are sealed, is removed from the colony so that the brood cells infested by the parasites can be destroyed

3.2 TROPILAELAPS MITE

Modern beekeeping with *Apis mellifera* in tropical and sub-tropical Asia frequently encounters problems caused by infestation with *Tropilaelaps spp.* The mite is a native parasite of the giant honey bee *A. dorsata*, widely distributed throughout tropical Asia, and whenever *A. mellifera* is kept within the range of distribution of *A. dorsata*, mite infestation of the colonies cannot be avoided. Thus, in Thailand beekeepers consider *Tropilaelaps* to be a more serious pest than varroa-mites, even though it may be easier to control. Dual parasitism of *A. mellifera* colonies by both parasites sometimes occurs, the population of *Tropilaelaps* often being greater than that of varroa, as the *Tropilaelaps* mite can almost completely prevent multiplication of the *varroa* mite.

Cause

Tropilaelaps mites are much smaller than varroa mites, although the trained unaided eye can still see them. The adult female mite (see Plate 9) is light reddish-brown in colour, with an oval-shaped body about 0.96 mm in length and 0.55 mm in width. The mite's entire body is covered with short setae. A red streak running longitudinally on the ventral surface of the adult female, the fusion of her epigynial and anal shields may be perceived through a strong magnifying glass.

When the mites are present in a honey bee colony in large numbers, they can be observed walking rapidly on the surface of the comb. They are rarely found on adult bees.

In all its immature stages, the mite lives within the brood cells of the bees, feeding on the brood's haemolymph (Plate 10). Fertilized adult females enter the cells before they are capped to lay their eggs. The stages of development of the mite are as follows: egg, six-legged larva, protonymph, deutonymph, adult. Adult males of *Tropilaelaps* do not feed, their chelicerae (the organs originally used for piercing the bees' integument) having been modified to transfer sperm as with the varroa mite. The life cycle of the mite is well synchronized with that of the host bee.

Symptoms

The damage caused to colonies by *Tropilaelaps* infestation is similar to that brought about by *varroa* and the injuries inflicted on individual bees and bee brood are essentially the same. The abdomen of bees surviving mite attacks is reduced in size, and they have a shorter life-span than healthy bees (see Plate 11). In heavily infested colonies, bees with deformed wings can be observed crawling about the vicinity of the hive entrance and on the comb surfaces, while pieces

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Plate 10
Adult female of Tropilaelaps spp. on A. mellifera pupa.

of dead bee brood evacuated from the hive by the house bees can be seen in front of the entrance.

Inspection of hives severely infested by *Tropilaelaps* reveals an irregular pattern of sealed and unsealed brood as found with all brood diseases. Since this symptom can be taken as a sign of a poor-laying queen, the position must be verified. The best means is to open sealed cells gently and inspect them for the presence of the mite. If mites are present, adult females will be seen walking rapidly out of the cells. To obtain a reasonably accurate estimate of the level of infestation, 100--200 cells should be opened and the brood removed with forceps for close inspection (see OIE Manual of Diagnostics, 2004).

Control

Preventing infestation by the *Tropilaelaps* mite is nearly impossible. It has been discussed if the vicinity of *Apis dorsana* colonies might contribute to the transfer of the mite. As is applicable to other bee diseases, robbery or a too large bee density should be avoided.

Since it is almost impossible to avoid *Tropilaelaps* infestation of *A. mellifera* colonies kept commercially on the tropical and sub-tropical Asian mainland, the key question is how to cope with the problem. In recent years, apiculturists and beekeepers have learned how to partly solve it. Owing to the fact that the adult female of the mite can survive without bee brood as food for only up to seven days, its control is somewhat less complicated than that of *varroa,* although this should not be taken as meaning that *Tropilaelaps* is not a serious pest.

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Plate 11
Parasitism by Varroa jacobsonii or Tropilaelaps clareae usually results in deformation of the bees' wings.

Chemical control

The chemotherapeutic measures described above for the control of *varroa* are also effective in the control of *Tropilaelaps*. Not all preparations used for varroa control have been tested on the *Tropilaelaps* mite. Formic acid can be used successfully in its treatment. However, special attention must be paid in tropical areas regarding its dosage to avoid damage to the bees. The dosage per comb should not exceed 2 ml in a one-storey Langstroth-hive.

The formic acid is placed onto a cloth deposited in the rear section of the hive. Formic acid is strongly caustic; therefore, the user should wear acid-proof gloves and protective goggles. Applications of amitraz are very effective either as a liquid spray on the surface of the brood comb and hive walls, or as a hive fumigant, in the same dosages. The treatment requires three to four applications at four-day intervals. The precautions to be taken in treating *Tropilaelaps* are the same as for *varroa;* all chemical treatments must be suspended at least eight weeks before the honey-flow season arrives, and amitraz must not be used in spray form in the presence of large numbers of honey bee eggs and newly-hatched larvae.

Colony manipulation techniques

Many beekeepers prefer not to use chemicals to control *Tropilaelaps*, but to manipulate the brood-rearing cycle of their infested colonies in such a way that the mites are deprived of sealed and unsealed brood, their food, for at least three days. During this period, a large proportion of the mite population will starve to death.

There are several means of creating this brood-less situation in infested colonies. In smaller apiaries, the beekeeper can simply remove the brood-comb frames -- both sealed and unsealed -- from the infested colonies and put them in new hives. Before the new larvae hatch, the hives manipulated in this way will be short of brood for two to three days, time enough to starve most of the mites. The new hives with the removed brood frames are given mated queens, which are caged for 14 days, a period that allows most of the brood to emerge, while no new brood has been reared because the queen has been confined.

When the drone population in the colonies is high, and the beekeeper wishes to increase the number of colonies, the new ones may be given newly-reared, capped queen cells instead of mated queens. By the time the virgin queens emerge, mature, mate and are ready to lay, most of the brood will have emerged; the rest can be destroyed before egg-laying begins. There will thus be sufficient time to starve most of the mite population in the colonies.

The best time of year to carry out these colony-manipulation techniques is during a heavy pollen-flow season, enabling the colonies to rear brood after the period of brood deprivation. In some Asian regions, this season coincides with the monsoon months, when there is no nectar flow but when pollen is abundant. This is also the season in which beekeepers feed sugar syrup to their bees, rear new queens and propagate colonies. While colony manipulation to control *Tropilaelaps* is time-consuming, it causes no noticeable harm to the colonies, nor does it affect productivity. The availability of pollen, coupled with the feeding of sugar, enables both the treated and the newly-formed colonies to regain their full strength before the nectar flow begins.

Some beekeepers prefer to combine chemical treatment with the brood-deprivation technique. In this approach, all sealed brood is removed from the mite-infested colonies, which are then fumigated. The adult female mites, having no capped brood cells in which to hide, are for the most part killed by the fumigant, so that only one chemical treatment is required instead of three or four. Recent examinations have shown that, in special cases, the *Tropilaelaps* mite can survive longer than seven days without bee brood. Despite this, these bio-technical methods have the advantage that the number of mites in the bee colonies is drastically reduced and damage is avoided.

3.3 TRACHEAL MITE (*ACARAPIDOSIS*)

This mite, *Acarapis woodi*, infests the tracheal system of adult bees, queens, workers and drones, which are all equally susceptible to its attacks. Since it was first reported in *Apis mellifera* colonies in Europe in 1921, opinions regarding the extent of the damage it can cause to honey bee colonies have varied. Reports from India and Pakistan indicate that the tracheal mite caused severe losses of *A. cerana* colonies. However, the mite's range of distribution in Asia has not been firmly established, and many of the reported losses of *A. cerana* were later shown to have been inflicted by *Apis iridescent virus* and not by tracheal mites. After the first appearance of the *Acarapis* mite in North America it has led to increasing damage; therefore, beekeepers in Asia should remain vigilant.

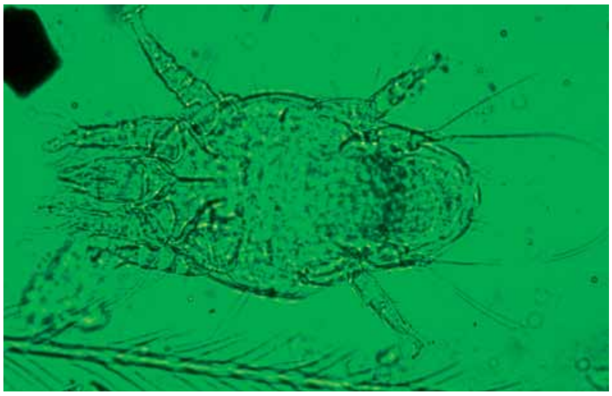

Plate 12
Tracheal mite, Acarapis woodi.

Cause

A. woodi is a very small mite (0.1 m) species that lives and breeds within the thoracic tracheae of adult bees (see Plate 12). The mite penetrates through the stigma (spiracles) into the first trachea pair of the thorax of 10-day old honey bees. There it lays eggs at intervals of a few days. After the deutonymph stage, male offspring emerge after around 12 days and females after 13 to 16 days.

Symptoms

Unfortunately, there are no reliable typical visible symptoms of infestation. Indeed, it has been demonstrated that bees severely infested with the mite can forage normally. Nevertheless, some differences exist with regard to the over-wintering capability of infested and healthy colonies. Infestation shortens the lifespan of the individual bees, so that severe infestation of colonies causes them to lose strength and thus increases a colony's susceptibility to winter losses.

The most reliable diagnostic method is laboratory dissection. Samples of 20 or more bees found crawling near the hive and unable to fly are killed, their heads and legs removed and their thoraxes dissected for microscopic examination. If present, the mites are usually found at the end of the first pair of trachea in the thorax (see OIE Manual of Diagnostics, 2004).

Control

Chemotherapeutic measures are widely adopted for mite control. Best results could be achieved with evaporating substances such as formic acid and ethereal oils.

Formic acid

Formic acid produces good results by applying it onto a cloth (20 ml of 65 percent formic acid) four times at intervals of seven days. The user must use special protection: acid-proof gloves and protective goggles. Treatment should be conducted during a period of low humidity and the temperature should not exceed 30°C (86°F).

Menthol or thymol

Menthol has a toxic effect on *A.woodi* in bee colonies. Crystalline menthol (50 g) or thymol (15 g) is placed in a gauze bag on the top of the bars to be kept there for one to two months. External temperatures should be around 21°C (70°F); otherwise the menthol vapours will not reach the mites in the trachea.

Chapter 4
Insects

4.1 BEETLE
There are several different beetles living in honey bee colonies. Most are harmless and feed on pollen or honey.

Small hive beetle (SHB)
Originally, this beetle *(Aethina tumida),* was only found in Africa, south of the Sahara. It first appeared in the southern United States of America in 1998 and has continued to spread north as far as Canada. Since 2002 this beetle has been found in parts of Australia.

In Africa, the beetle's original range, only weak colonies or storage combs are affected. However, in America or Australia, colonies of ordinary strength can be affected. The main reason for this seems to be the different defence behaviour of the imported European bees. On the other hand, the beetle also invades a colony during management activities, e.g. during honey extraction. There is a risk that the beetle may spread to Asia.

Cause
The beetle *Aethina tumida* (order: *Coleoptera*, family: *Nitidulidae*) is called the small hive beetle' (see Plate 13). This beetle lives and multiplies within and outside bee colonies. The beetle deposits larger deposits of nests of eggs within a bee colony, in fissures and recesses out of reach of the bees. The larvae of this beetle preferably live on and in pollen and honeycombs. The adult larvae leave the hive to pupate in the earth in front of the apiary. The period of development from egg to adult beetle is at least four to five weeks.

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Plate 13
Small hive beetle.

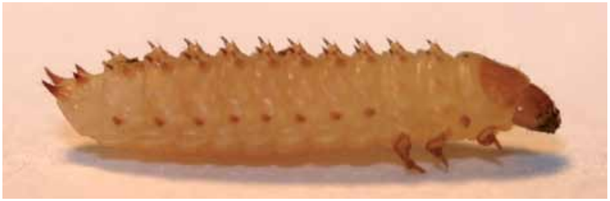

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Plate 14
Small hive beetle larvae.

Symptoms
The beetles and their larvae can infest bee brood and honeycombs in and outside the apiary. There they form eating canals and destroy the cell caps, and the honey starts to ferment. The beetles larvae and faeces also change the colour and taste of the honey and the combs appear mucilaginous.

The adult beetle is dark brown to black, around 5 mm long and 3 mm wide. Whereas the beetle may be found throughout the bee hive, the white larvae, around 11 mm long are mainly found in the combs (see Plate 14). They can easily be distinguished from the wax moths that may also be living in the bee colony because their legs are longer and they have a row of spines on their back and do not spin nets or cocoons. A minor infestation is difficult to recognize because the beetles immediately hide in the dark. The most secure diagnosis is achieved after chemical treatment when the dead beetles can be gathered from the bottom inlay (see OIE Manual of Diagnostics, 2004).

Control
The best way to protect against an infestation of the small hive beetle is to keep strong colonies and to remove those that are weak from an apiary. The removed honey combs should be centrifugally extracted one to two days after harvesting the honey. These can be stored at less than 10°C or in a dry environment having less than 50 percent

relative air humidity, which may prove too complicated for the individual beekeeper.

Currently, a successful control is made possible using a preparation named 'Checkmate', produced by Bayer (a.i. Cournaphos). This product has provisional market approval in some states of the United States. More than 90 percent of adult beetles and larvae may be killed with this preparation. Other chemical treatments are under development. However, the problem is that this beetle – contrary to the varroa mite – can live and multiply outside the bee hive, where it seems to prefer rotting fruits (e.g. apples and bananas) as nesting sites. This is why reinvasion is always possible. The beetle is extremely quick moving and can fly, which contributes to its rapid spread among bee colonies and apiaries.

4.2 ANTS

Ants are among the most common predators of honey bees in tropical and subtropical Asia. They are highly social insects and will attack the hives *en masse*, taking virtually everything in them: dead or alive adult bees, the brood and honey. In addition to this destruction, they can also be a nuisance to beekeepers and may sometimes cause pain from their bites.

Apiaries of *Apis mellifera* under ant attack become aggressive and difficult to manage; weak colonies will sometimes abscond, which is also the defence of *A. cerana* against frequent ant invasions.

Many ant genera and species are reported to cause problems to both traditional beekeeping with *A. cerana* and to modern beekeeping with *A. mellifera.* Among the most frequently recorded species are the weaver ant (*Oecophylla smaragdina*), the black ant (*Monomorium indicum*), *Monomorium destructor* and *spp*., *Oligomyrmex spp., Dorylus spp.,* the fire ants (*Solenopsis spp.*) and *Formica spp*.

Control

Beekeepers have found that the most effective method of controlling weaver ants is to search systematically for the ants' nests in the vicinity of the apiaries and, when found, to destroy them by burning. General recommendations to reduce ant nesting sites include eliminating brush and rotten wood from the apiary and cutting the grass.

A good general defence against ants in tropical apiaries is to place the hives on stands supported by posts 30-50 cm high and to coat the posts with used engine oil or grease. Frequent inspection and renewed application of grease are both necessary and a source of soil pollution. A more reliable method is to place the hive-stand posts in tin or plastic containers filled with either water or oil. Regular clean up is required to avoid the formation of bridges of vegetation or earth that can be crossed by ants and liquids need to be replenished frequently.

4.3 WASPS AND HORNETS

Nearly all countries in Asia report wasps and hornets as common enemies of their honey bees. Among the most frequently reported are social wasps of the genus *Vespa*, which are widely distributed throughout the world. Colonies of both *A. cerana* and *A. mellifera* are frequently attacked. Hornet invasion of *A. cerana* colonies generally causes the bees to abscond, and similar behaviour is reported of weak colonies of *A. mellifera*.

In addition to hornets of the genus *Vespa*, other wasp species have occasionally been reported to cause damage to apiaries. Among these are several species of the genus *Vespula*, which are distributed throughout temperate Asia.

Table 2 lists wasps and hornets that have been reported as major predators of the two honey bee species in Asia.

Predation by *Vespa spp*. on commercial apiaries is generally a seasonal problem. In Japan, and

TABLE 2
Wasps and hornets that attack bees in Asia

Scientific name	Recorded distribution
Vespa orientalis	India, Pakistan
Vespa mandarina	India, Burma, Thailand, Lao, Viet Nam, Democratic Kampuchea, China, Republic of Korea, Japan
Vespa tropica	Tropical Asia
Vespa velutina	Tropical Asia
Vespa cincta	Tropical Asia
Vespa affinis	Tropical and sub-tropical Asia
Vespa crabro	Japan, and perhaps all temperate Asia
Vespa mongolica	Japan, and perhaps all temperate Asia
Vespula lewisii	Japan
Vespula vulgaris	Republic of Korea

probably in the rest of temperate Asia, hornet attacks on apiaries reach their peak of intensity during September-October, whereas in tropical countries the most serious wasp invasions take place during the monsoon season, particularly from late June to August. Apiaries situated near the foothills and tropical forests suffer more acutely than those on the plains.

Studies of the predation of honey bees by *Vespa mandarina* in Japan and by *V. affinis* in Thailand appear to indicate that the attacking behaviour of the larger wasps, and perhaps all species of *Vespa,* is similar. Initially, a 'hunting phase' is observed, during which a few hornets capture and kill slow-flying bees one at a time, usually near the entrance of a weak colony's hive. Later, a 'slaughtering phase' sets in: some 20 to 30 hornets attack a weak colony *en masse*, using their strong jaws to maul the bees and dropping the dead and dying bees to the ground. Finally, when this phase has continued long enough for the colony under attack to have lost most of its defender workers, the hornets invade the hive itself, the honey and brood nest and the wasps carry away any surplus brood to their nest.

Plate 15
Apis mellifera colony invaded by Vespa tropica.

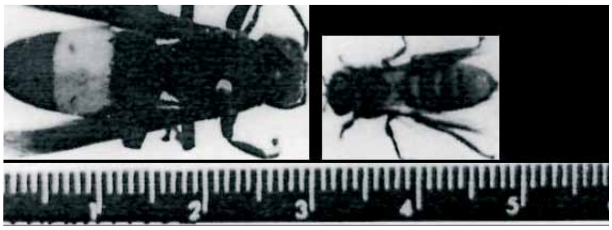


Plate 16
Comparative body sizes of (left) Vespa tropica and (right, top to bottom) Apis florea, A. cerana and A. dorsata.

Control

Thanks to their reasonably large body size (see Plates 15 and 16) the foraging range of *Vespa* can be a comparatively large area around their nests, which may have populations of many thousands of individuals. Beekeepers in Japan sometimes adopt methods such as bait-trapping, trapping at the hive entrance and using protective screens. Locating hornet nests by following flight passes of individual wasps back to their nests and then destroying the nests may be very time consuming and, if too many of these nests are in the area, not very efficient.

Where labour costs are not prohibitive, beekeepers have resorted to capturing and killing individual hornets foraging in the vicinity of their apiaries. In Thailand, this approach has proved to be quite effective, largely because the period of most intense hornet attacks is only two to three months. It has been seen that the real damage inflicted by hornet attacks on honey bee colonies occurs during the slaughter and occupation phases. Killing hornets in the early stage of predation has the effect of disrupting the hunting phase and preventing the predation process from reaching the more destructive phases. Mass destruction of the colonies is thus prevented or, at the least, minimized.

As a final, and more general, recommendation for protective action against hornet attacks when the hives cannot be relocated to a safer place, beekeepers should as a minimum preventive measure narrow the hive entrance. In this way, the final invasion of the hive can generally be avoided.

4.4 WAX MOTHS AND OTHER *LEPIDOPTERA*

The greater wax moth (*Galleria mellonella*)

The greater wax moth is often reported to cause damage both to honey bee colonies and to bee products in tropical and sub-tropical Asia. Empty combs, rendered wax, comb foundation and bee-collected pollen, if not properly stored and left unattended, almost always suffer considerable damage from wax-moth infestation (see Plate 17). According to many reports, the wax moth is a major pest of *A. cerana*, often causing colonies to abscond.

In wax-moth attacks on colonies, the adult female enters the hive at night, through the entrance or cracks in the walls, deposits her eggs directly onto the combs or in narrow crevices that permit oviposition and offers protection against removal by worker bees. From 50 to 150 eggs are laid in each batch; they are glued together and adhere firmly to the surface on which they are

W.RITTER

Plate 17
Best prevention of wax moths: keeping the apiary clean.

laid. The newly-hatched *Galleria* larvae feed on honey and pollen, and then burrow into pollen-storage cells or the outer edge of cell walls, later extending their tunnels to the midrib of the comb as they grow. At this stage the developing larvae are quite safe from the worker bees. As they advance into the combs, they leave behind them a mass of webs and debris; the complete destruction of unattended combs usually ensues within 10-15 days. In addition to stored pollen and comb wax, larvae of the greater wax moth will also attack bee brood when short of food.

The development time of *Galleria* larvae depends on two factors: food availability and temperature. Whereas in tropical climates the larvae require only 18-20 days before spinning cocoons and becoming pupae, in cooler climates this period may be extended.

When weak colonies are infested, the symptom of 'galleriasis' is frequently observed: the emerging adult worker and drone bees are unable to leave their cells because their bodies have been tied up by silken threads spun by the *Galleria* larvae.

Control

There are no easy or inexpensive chemotherapeutic measures for controlling the wax moth in living honey bee colonies once infestation has set in. The only possibility is treatment with *Bacillus thuringiensis*, in a watery suspension, sprayed onto the combs. The effect on the wax-moths larvae persists for several weeks.

Preventive measures include ensuring that the colonies, whether of *A. cerana* or *A. mellifera*, are strong and have adequate food stores; adapting the hive space to the strength of the colony; reducing the hive entrance; sealing cracks and crevices in hive walls; protecting the colonies against pesticide poisoning; controlling pests and diseases that might otherwise weaken them; and removing any wax and debris accumulated on the bottom boards of the hives.

Several measures can be taken to prevent or control wax-moth infestation in stored combs and hive products. Products that are vulnerable to wax moth attack such as empty combs, used hive parts and wax should be properly stored, preferably in tight, moth-proof rooms. As preferably formerly hedged combs are infested they should be stored apart from new ones.

Fumigation is the usual treatment; new combs should be treated less frequently. Among the most commonly used fumigants are naphthalene, ethylene dibromide and methyl bromide. All, including paradichlorbenzene, are very poisonous to bees and humans and, in addition, lead to residues in honey. The application of sulphur, however, is inoffensive. Sulphur powder is wrapped in newspaper and burned in a metal container. Liquid sulphur from sprayers can also be used. The development of wax moths can be interrupted for several months if the combs are heated at 48°C (118°F) for three hours.
All treatments should be repeated at intervals depending on the level of infestation. Regular control is therefore recommended.

The lesser wax moth (*Achroia grisella*)

As its name implies, the lesser wax moth is generally smaller than the greater wax moth, except when the latter is dwarfed owing to poor diet during its larval stage. Adult *Achroia grisella* are silver-grey in colour, with a distinct yellow head. The insect is quite small, with a slender body: normal body lengths of adult female and male are about 13 and 10 mm respectively. The life-span of the adult female is about seven days,

Plate 18
Brood surface (open cells with immature pupae) changed by wax moth.

during which she can lay 250 to 300 eggs.

Infestation by the lesser wax moth usually occurs in weak honey bee colonies. The larvae prefer to feed on dark comb, with pollen or brood cells. They are often found on the bottom board among the wax debris. As larvae prefer to form small canals between the bottoms of the brood cells the brood is lifted. The bees continue constructing cells heading upward leading to the typical scratched comb surface (see Plate 18).

Control
The methods employed in controlling *Galleria mellonella* are equally effective for the control of *Achroia grisella.*

Other *Lepidoptera*
Other moth species are frequently recorded in association with bees and bee products. The Indian meal moth *Plodia interpunctella* is reported to feed on bee-collected pollen. Moths found dead on the bottom boards of beehives include death's-head or hawk moths *(Acherontia atropos),* which invade the hives to feed on honey. Beekeepers generally consider them to be minor pests.

Chapter 5
Vertebrates

5.1 AMPHIBIANS

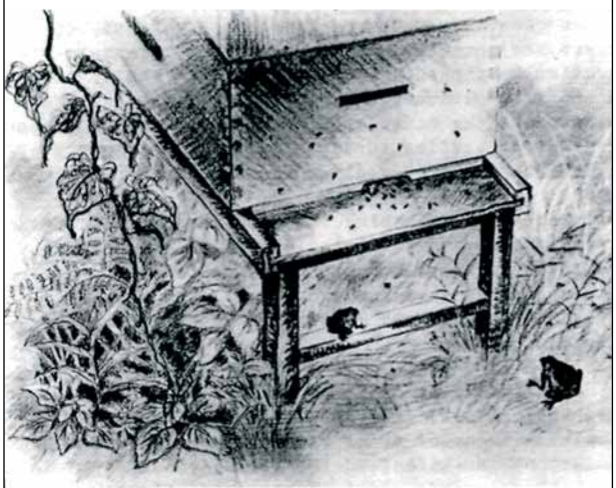
Beekeeping in tropical climates frequently suffers from damage caused by amphibians: toads including *Bufo melanostictus* and *Kaloula pulchra* and frogs including *Rana limnocharis* and *Rana tigrina*. The detection of this problem generally requires close observation: beekeepers are normally unable to observe intense predation by amphibians on honey bees in the daytime, when they are at work in their apiaries, because the heaviest attacks occur at night. Often the problem goes unrecognized until a substantial fall in colony populations is perceived.

One sign indicating that toads and frogs are preying heavily on the colonies is the presence of the predators' dark brown droppings, scattered in front of the hive entrance. If the dry faecal deposits are spread apart (e.g. with a twig), the remains of bee parts can be seen.

Continuous predation by toads and frogs, if not prevented, results in a loss of colony strength. While colonies with moderate or larger worker populations can withstand the predation and subsequently recover their full strength, weaker colonies are at considerable risk.

Toads and frogs have similar attacking patterns. On arriving at the colony, the amphibians wait in the vicinity of the hive entrance, preying on passing bees (see Figure 1). Colonies close to the ground provide easy access to the predators, for which guard bees at the hive entrance are easy prey. If the attackers are small enough to squeeze through the hive entrance of a weak colony, the outcome can be devastating.

FIGURE 1
Predation by toads on a honey bee colony



Control

Although in some circumstances predation on honey bee colonies by amphibians cannot be overlooked most beekeepers perceive the problem as minor. Placing the hives on stands 40 to 60 cm high is usually a sufficient protective measure.

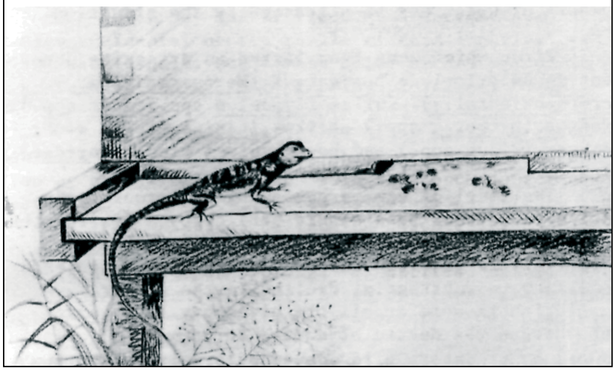
Where large numbers of the predators tend to congregate near an apiary, it may be necessary to fence it with fine-mesh chicken wire. Other methods such as trapping, baiting or poisoning have not been advocated.

5.2 REPTILES

Geckos, skinks and other lizards are among the most commonly found reptiles in tropical Asian jungles, woods, grasslands and urban areas. Among the reptile species that are regularly recorded as present in commercial apiaries are the tokay (*Gecko gecko*), which can be as much as 35 cm long, *Calotes spp.*, *Acanthosaura spp*. and the skink *Sphenomorphus spp*.

Arboreal reptiles such as many geckos and skinks can attack bees either near the hive entrance or on the limbs of flowering trees visited by forager bees. Smaller lizards, such as the gecko *Hemidactylus frenatus*, often hide in the empty space between the outer and inner covers of the hive (see Figure 2). In tropical areas, this type of predator frequently causes the sudden loss of the queen from a weak colony.

FIGURE 2
Predation on honey bees by a lizard



Control

The beekeeper can do little to prevent the loss of foragers to the highly mobile arboreal reptiles, usually well hidden in the trees. Beekeepers can destroy as many of them as possible when they are encountered, though this method is not recommended nor is it efficient. Hives placed on stands that are about 40-60 cm high are reasonably safe from reptiles attacking from the ground; coating the legs of the stands with used engine oil or grease may deter the reptiles from climbing up to the hive entrance. A well-kept bee yard that is frequently mowed, without dense bushes, shrubs and tall grass, that provide safe hiding places to the predators, has less chance of suffering losses from reptiles than an untended one. No reliable chemical control of reptiles is available for use in apiaries.

5.3 BIRDS

Birds prey upon many insect species and honey bees are no exception. Once airborne, the bees are virtually defenceless against birds, several species of which can tolerate their venomous stinging defence. The heavy traffic of bees flying in and out of the hives of commercial apiaries provides an exceptional opportunity for insectivorous birds, large numbers of which may be attracted by this situation.

Birds that have been listed as attacking honey bees in Asia include bee-eaters (*Merops apiaster*, *Merops orientalis*), swifts (*Cypselus spp., Apus spp.*), drongos (*Dicurus spp.*) shrikes (*Lanius spp.*), woodpeckers (*Picus spp.*) and honey guides (Indicatoridae).

The level of damage caused by apivorous birds varies. An attack by a single bird or by a few together rarely constitutes a serious problem, but when a large flock descends upon a few colonies or an apiary, a substantial decline in the worker population in some or all the hives may be observed. Whereas the degree of damage to commercial apiaries caused by predatory birds depends largely on the number of the predators and the intensity of the attack, the mere presence of a few predators in apiaries engaged in queen-rearing can inflict serious losses.

Control

While beekeepers regard insectivorous birds as pests, sometimes serious, other branches of agriculture generally do not consider them as problematic. In fact, birds that prey on insects are mostly considered to be beneficial to farming, in that they help in the control of insect pests. For this reason, before any attempt is made to solve the apiary's bird problems by mass killing of the predators, whether by chemical or physical means or by gunshot, the implications of this action on the environment must be seriously taken into account.

Where heavy predation by birds on apiary bees tends to occur at fixed periods (e.g. during the migration season of swifts), the most practical means of solving the problem is usually to avoid the birds, through careful site selection and by temporary relocation of the apiaries, at least until the migration period is over.

5.4 MAMMALS

Many groups of mammals may be considered as enemies of the honey bee. In general, they prey on colonies for honey and/or brood; some attacks are purely accidental or the result of animal curiosity. Such cases usually occur when apiaries are placed in or near forests and are not properly protected.

In Asia, as well as in most other parts of the world, beekeepers face the problem of colony destruction by bears. It has been said that once a bear has tasted honey and brood, it is almost impossible to keep it away from apiaries. Protecting colonies from bear attack is usually difficult, particularly when the animals are large and strong. Electrified barbed-wire fences are often used where bears represent a common problem; shooting and trapping them are other possible but very temporary control measures, which may go very much against efforts by others to manage and conserve sufficient numbers of large mammals in mostly declining populations. Moving hives closer to human habitation may be much more effective.

In several tropical countries of Asia, monkeys and other primates have been mentioned as pests of honey bees, opening hives and consuming honey and brood. As a result, frames are destroyed and colonies may abscond. Discouraging such behaviour by wiring lids to boxes and boxes to each other may be a solution. Other options may include suspension of the colonies, as in Africa, particularly for small-scale beekeepers.

It is important to note that among the primate pests of honey bees, people are probably the most destructive. Honey crops may be stolen, or brood and combs consumed on the spot. Occasionally, entire hives are made off with.

Finally, note that in areas where intensive modern agriculture is practiced, the loss of bees through human misuse of pesticides is probably greater than loss from all other causes taken together.

Chapter 6
Honey bee introduction and quarantine

Native bees are generally better adapted to the climate, changes in food supply and the pathogens present, etc. Importation of foreign bee species and races is therefore unnecessary. It has often been observed that honey bee colonies that have been introduced into new areas have had disastrous effects in spreading bee diseases and parasites.

Nonetheless, some honey-producing countries in Asia have met with a high degree of success in developing commercial beekeeping thanks to the introduction of colonies of productive European races of *Apis mellifera.* This is why foreign bees will continue to be imported to some countries and regions. Proper legal regulation and enforcement may help prevent the spread of disease; though it may not be sufficient. Providing quality stock and educating beekeepers about the risks of buying abroad is a necessary and long-term solution. In any of these cases the following basic guidelines should be respected:

- Before any attempt is made to introduce a new species or race of honey bee, it is important to study and evaluate the potentials and limitations of the native bees and their foraging ecosystems, including the availability of forage.
- If introductions are found necessary, the entire process -- along with all requisite precautions, including quarantine and interim colony inspection should be carried out by, or closely supervised by well-trained personnel.
- Periodic evaluations of the current state of the local honey bee industry should be made to determine whether introductions continue to be necessary.
- In countries or regions in which beekeeping with *Apis mellifera* has been reasonably well developed and there is no good technical reason to introduce more colonies or queens, the importation of new bee strains or races should be halted. It is preferable that beekeepers endeavour to improve their queen-rearing techniques and adjust their colony management schemes in order to obtain better yields.
- All honey bee species native to Asia have their own diseases and enemies and it is unavoidable that introduced colonies will come into contact with bees from feral nests. Since inter-species transmission of certain diseases and parasites takes place reciprocally, it is of the utmost importance that the introduced colonies be disease-free and parasite-free. Since this is practically impossible, larger scale movements, or any scale of introduction, should either be prevented completely or reduced to a minimum, e.g. by producing sufficient and high quality local bee stock.

Chapter 7
General measures for bee protection

In Asia it is virtually impossible to keep honey bee colonies free of diseases and parasites for long periods of time. The vast Asian land-mass carries millions of feral nests of native species, constituting great reservoirs of pathogenic micro-organisms and parasites almost certain to be transmitted or transferred to commercial hives whenever the ranges of distribution of the bees overlap. Drifting, robbing and foraging on the same blossoms are among the most common means of disease transmission and parasite transfer.

While each specific honey bee disease or parasite calls for its own specific control methods, the following general recommendations, if properly adopted, can assist in preventing or at least reducing damage to honey bee colonies.

- Strenuous efforts should be made to maintain vigorous colonies, with large, healthy worker populations, good laying queens and adequate honey and pollen stores. This is only possible with a constant sufficient pollen and nectar supply.
- The number of hive boxes and combs should be adapted to the colony strength.
- Diseases, parasites and predators likely to significantly weaken colonies should be properly controlled.
- Apiary sites should be selected with much care: strong winds, damp, unhygienic conditions and lack of food should be avoided.
- Colonies must be protected against poisoning by pesticides: frequent surveys should be made of the level and types of pesticides used within the foraging range of the bees.
- All hive parts and equipment should be kept clean and in good working order.
- Hives should be kept on stands, and apiaries should be securely fenced, whenever the danger of predators renders these precautions necessary.
- Hives should be manipulated with great care; all practices likely to induce robbing or cause bees to drift should be avoided, including overcrowded apiaries.

Other measures

- In general, good beekeeping practices are the best prevention (not drugs).
- Mechanical control may be the best first and second choice; certainly it is the safest where contamination or risk to human health is concerned.
- Raising awareness of neighbours, farmers and others about the benefits of the bees for health products and pollination may create better agricultural practices and thus better foraging and less toxicity to bees. Awareness-raising could therefore be considered a very effective preventive method as well as one that increases productivity.
- Hive disturbance, by beekeepers, outsiders and/or other non-beekeepers, should be kept to the absolute minimum.
- The utmost care in the choice and use of chemicals for disease control cannot be overemphasised, as most of these substances easily contaminate hive equipment and honey, create resistance in the pathogens and weaken the bees.
- Organic beekeeping methods describe and rely on control methods that are beneficial to the bees, bee products and human health.

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Honey bee diseases and pests: a practical guide

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The publication is further evidence of the continuing endeavours of FAO to promote beekeeping in developing countries, as a low-cost means of improving local diets, elevating purchasing power and diversifying rural activities.

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