

Research progress on VARROA DESTRUCTOR

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Abstract: Varroa destructor is the most serious threat for western honeybees worldwide. It parasitizes mostly on honeybee's pupae and larvae, resulting in impaired development, decreased immunity, residual wings, loss of flight ability, and even direct death. At the same time, it can cause a series of diseases, greatly infesting bee colonies. This paper introduces the classification, distribution and biological characteristics of Varroa destructor, and discusses its transmission mode, harm form and common control measures.

Key words: Varroa destructor, Honeybee Occidentalis, parasite control, parasitism

1. Introduction

Varroa destructor is an ectoparasitoid mite belonging to the genus *Vara*, which specially parasitizes adult bees and larvae of honeybees. Before the 21st century, the scientific community did not find the genotypic specificity of Varroa destructor. Thus, it was generally classified as *Varroa jacobsoni* species. It wasn't until 2000 that Australian scientist D. Anderson used mtRNA sequencing to distinguish Varroa destructor from *Vara Jacobi* as independent species. The discovery set the stage for a series of breakthroughs in the study of bee parasitic mites.

Initially, Varroa destructor parasitized eastern bees, and they formed a stable symbiotic relationship in long-term co-evolution, so it did not pose a threat to eastern bees. However, when the mite spread to western honeybees, it caused serious damage in most parts of the world. At present, the mite has not been found only in Australia, Hawaii and a few parts of Africa.

The survival ability of Varroa destructor is strong and the harmness is high. In earlier times, it was believed to feed on the hemolymph of bees.[1] But new research suggests that the mite actually feeds on the fat bodies of bees.[2] The parasitization of mite makes western honeybees lose nutrition and causes serious direct harm, including loss of flight ability, decreased immunity, shortened life span and so on. In severe cases, it can lead to the collapse of the whole bee colony. At the same time, The mite punctures the bee's body, causing serious indirect

damage such as large-scale diseases and insect pests, which threatens the world beekeeping industry.

At present, the main control methods include chemical control, biological control and plant extract control. In early years, the chemical methods were widely used. But in recent years, in consideration of the harm on bees and the mites' increasing resistance to drugs, the scientific community has gradually turned its attention to other, less side-effect and more promising methods of control, including biological control and plant extracts.

2. The classification and distribution of the varroa destructor

2.1 Varroa jacobsoni oudemans

In 1904, biologist A.C.Oudemans discovered a female mite on Indian bee colonies in Java and named it *varroa jacobsoni oudemans*. In his judgment, Oudemans considered the female to belong to an unknown genus because they had no upper jaw, but only a fixed lower jaw. Then, in 1951, Gunther found the same mites on Indian honeybees in Singapore. However, since he did not know the discovery and naming of this mite by Oudemans, Gunther named it as a new species-- *Myrmozerconreidi*. Again, no males were involved in the mites found this time. In 1963, Chinese scientists Zhang Jiaqi et al. acquired both the male and female mites of *varroa jacobsoni* in the bee body and honeycomb. This is the first discovery of males of this species in the literature [3].

2.2 Varroa destructor

In early 2000, Denis L. Anderson collected mite samples from eastern and western bees for extensive studies. He sequenced the mtDNA in mitochondria of mite samples and found that the eastern honeybee parasitic mite, previously classified as *Varroa jacobii*, should be divided into two separate species, *Varroa jacobsoni* and *Varroa destructor*. At present, the most destructive mites to western bees in the world belong to the Korean and Japanese/Thai haplotype of *Varroa destructor*. The former is more widespread, harming western bees in many places, including Europe, Asia and Africa, the Americas, and New Zealand, while the latter is found only in Japan, Thailand and North and South America[4].

2.3 Varroa destructor in China

The mites found currently in western honeybees raised in China only belong to the *Varroa destructor*[5], which originally parasitized eastern honeybees and is widely distributed throughout Asia, including the cold climate of the Russian Far East. After a long period of coevolution, the bee mite and its original host, the eastern honeybee, have formed a less harmful near-symbiotic relationship. The exact time of the discovery of *Varroa destructor* in China is not documented. While the earliest recorded large-scale harmful event occurred around 1957, when the mortality of Italian bee colonies reared in Jiangsu and Zhejiang increased sharply due to the influence of the mite[6].

3. Biological characteristics of *Pterygoides varicoides*

3.1 Form

The life of an individual can be divided into five stages: egg, larva, prophase, anaphase and adult.

3.1.1 Eggs

At this stage, the eggs are round, milky white and can be divided into limbed or unlimbed eggs. The limb eggs are about 0.65 mm long and 0.43 mm wide. While the unlimbed eggs were small, and they turned yellow, dried, then died. In most cases, females begin to lay limbed eggs about 60 hours after sealing of the bee.

3.1.2 The larvae

The larva usually develops inside the egg, which has a thin, transparent membrane. A fist-like embryo with four pairs of limb buds can be seen through the egg membrane. The larvae mature in the egg, and then break out of the shell.

3.1.3 Protonymph

Mite in this phase is approximately round, milky white and transparent. It is about 0.63 mm long and 0.49 mm wide. (4) Its body surface is covered with sparse setae,

and it has four teams of appendages. The feet of the mite in protonymph are horned and its tarsus have small suckers.

3.1.4 Deutonymph

After molting, the mite turns into the phase of Deutonymph, when females are 0.9-1.1 mm long and 1.14-1.6 mm wide and are heart-shaped, whereas males are 0.7-0.8 mm long and 0.74-0.88 mm wide and are round-shaped. Usually, male and female mites can be distinguished by their setae characteristics. The female have more setae, and the setae of the male only distributed in the anal area. At the same time, the midplane of male mites is more osseous.

3.1.5 Mature Mite

In adult stage, there are great morphological differences between male and female mites. Female mites are brown, transverse oval, with a distinct uplift on the back, covered by a keratinized backplane, and reticular pattern. The thoracic plate, genital plate, ventral femoral plate, ventral plate and anal plate constitute the ventral surface. The web is flat and slightly depressed. The piercing and sucking mouthpiece is located under the body, with six feet, short and thick.

The male mites are pale yellow, slightly smaller than the female mites. The back plate of the male mite is connected with the web, covering the entire dorsal area of the body and the edge of the ventral surface. The sex organs grow below the mouth parts, and the antennae have movable concave appendages for transferring semen.

3.2 Breeding

In the mating phase, the male mite stops feeding. 48 hours after entering the larval chamber, the female and male mites mated, after which the male mites die. Female mites have swollen abdomens which restricts their movement. About 94.8% of the females are able to lay eggs after entering the beehive. Female mites have 3-7 oviposition cycles in their life and can produce up to 30 eggs[7]. However, there is no generation overlapping [8][1]. Female mites lay one to seven eggs in a cell, and in most cases two to five eggs. Although the mite has strong ability in laying eggs, its egg's survival rate is considerably low. Among the eggs, only 35.8% could form new female mites, and the mortality rate was 3.8%. 17% of the mites formed males and 9.4% died. About 33% of the remaining eggs fail to develop into adult mites[7]. Studies have shown that when the same type of larvae are present, the reproductive capacity of *P. megalae* in smaller cells is significantly higher than that in larger cells [7]. This could be due to the fact that the most suitable temperature for mite development is 32-35°C, which is the same as the temperature of bee larval chamber[7]. The cocoon formed by the worker bees in the drone bee house enlarges the space and accordingly changes the internal environment such as temperature and humidity in the cell. Female mites, on the other hand, are extremely sensitive to unfamiliar environments in large cells (such as

temperature changes, etc.), which has an impact on reproductive behavior[8].

3.3 Life habits

3.3.1 Suitable temperature

The survival ability of *P. japonicae* was relatively strong at different temperatures, and the optimal development temperature was 32-35°C. Normally, the mite can survive for up to seven days outside the hive in normal temperatures. When the temperature is as low as 10 ~ 13°C, the mites appear frozen, but at -30°C--10°C, it can survive for 2-3 days. When the temperature rises to 42 ° C, the mites appear in a coma and begin to die at 43-45 ° C [7].

3.3.2 Feeding habits

Using radioisotope labeling, researchers claimed that the mites feed on the hemolymph of bees[2]. However, recent studies have shown that the mites feed on fat bodies rather than hemolymph [9]. For honeybees, the fat body is distributed in the blood cavity of larvae and pupae; and in adult bees, it is distributed in the abdomen. By comparing the parasitism and feeding position of large mite on bees, it was found that a small number of the mites parasitized on the breast of bees, most of them on the abdomen, while none on the head. This supports the idea that the mite feeds on the fat body of bees.

3.3.3 Life history

The life history of *Varroa destructor* is generally divided into five stages.

- ① Retention period: After the bees leave the hive, female mites are attached to the body surface of the male or worker bees. The presence of adult bees outside the hive increases the chances to spread to other colonies. This phase lasts from 4 to 13 days.
- ② The active stage before yolk formation: At this stage, the female mites leave the bee and enter the larval cell (usually only one female mite enters a cell). After that, female mites are not active, which reduces the likelihood of being found and removed by worker bees.
- ③ Active stage of the first yolk formation: After the closure of the cell, the female mites parasitized on the body surface of large or bee pupae and began to lay eggs after 60-64 hours.
- ④ The second active stage of yolk formation: on the surface of the bee pupae, the female mite continues to lay eggs until the bee compound eye changes color.
- ⑤ Mature mating stage: in the cell, a new generation of mites develops to sexual maturity and completes mating, after which the female mites enter the first stage (retention period) as the bee pupae emerge from the cell.

3.4 Transmission line

3.4.1 Transmission line

In the 20th century, a large number of western bees were introduced into Asia and came into contact with eastern bees. Because the eastern bee carries the parasitic large bee mite, the bee mite enters the hive of the western bee. In 1952, the Soviet Union officially reported the first large-scale infestation of *Varroa* mite in western honeybee colonies in the Far East. It was also in the 1950s that mite infests were prevalent in Asian countries. In the 1970s, *Varroa* mites were introduced into Europe and South America, and subsequently into North America. As a country that has banned the import of bees for nearly 40 years, the mites were also found in New Zealand in 2000[10].

3.4.2 Route of transmission

The transmission routes of *Varroa* mite are extremely rich. Currently, it is known that there are inter-colony transmission (with adult bees as intermediate hosts), flower transmission, and transmission among bee-eating insects (wasp, etc.)[11]. At present, further study on the transmission route and related biological characteristics of bee mite is still in need. What is certain, however, is that treating only a small number of colonies in an apiary is not effective because of the widespread intercolony transmission of the mite. At the same time, robber bee should be avoided as much as possible in order not to increase the possibility of mite transmission between robbed and robber bee colonies.

4. The harm of large wasp mite

Varroa destructor does harm to honeybee pupae and larvae by feeding on their fat bodies. Parasitized bees are often stunted, have stump wings and lose the ability to fly. At the same time, the life span is shortened, the collecting and feeding ability is decreased, the pesticide tolerance is decreased, and the environmental sensitivity and immune ability are decreased. Moreover, severe mite infesting can lead to the death of bee colonies. Specifically, there are the following ways of harms.

4.1 Young bee and pupa

The pupae is killed when parasitized by large numbers of mites, and the dead pupae will be dragged out of the hive by the worker bees. Honeybee larvae exposed to two or three large mites lose about 15-20% of their body weight, and their ability to fly is also greatly reduced. Parasitization of a honeybee within 1-10 days after eclosion reduces its life span by 50%[12]. And bees with foot and wing mutilated due to mite parasitism will lose the ability to fly and can only crawl on the ground near or at the door of the beehive.

4.2 Adult bees

When parasitized by the mite, adult bees often try to get rid of the mite and wriggle their bodies, causing a lot of physical exertion and eventually exhaustion to death. At the same time, the size of the workers will be reduced, so as the sexual function of the drones. In addition, the life span of the queen bee will be significantly shortened.

4.2.1 Indirect damage from other diseases

When parasitizing, the wasp mite punctures the body of bees, which makes it easier for pathogens carried by bee mites and bacteria and viruses on the body surface of bees to invade the bees. Studies have shown that Kashmiri bee virus, acute paralysis virus, Israeli acute paralysis virus, remnant wing virus and other pathogens all infect bees through this route [13]. Among them, remnant wing virus (DWV) has been identified to cause bee disease, resulting in deformed wings and significantly shortened abdomens of adult bees. Finally, the worker bees lose the ability to clean up, and the queen bees may abscond, leading to the collapse of the bee colony [14].

4.2.2 Overwintering of the colony

In the autumn breeding period, if the mites in the overwintering colonies are not treated in time, the colonies may fail to cluster and overwinter successfully. This can cause serious losses in the bee colony.

5. Prevention and control of Varroa destructor

5.1 Chemical control

5.1.1 Synthetic chemical drugs

Synthetic chemicals, such as fluvaterate and fluthrin, are commonly made into acaricidal tablets (acaricidal tablets). Pieces of wood immersed in the drug are suspended in the bee-path between the spleen of the comb. Through direct contact, the active ingredient is delivered to the bees to exert its effects. However, these two acaricides can lead to a certain degree of resistance in the wasp mite after long-term use. Researchers have reported the evolution of mite resistance to this acaricide, and pointed out that the L925V mutation (leucine at position 925 is mutated by valine) is associated with resistance to fenvalerate fluamide [15]. At the same time, it is also found that there is a dynamic balance mechanism of drug resistance. Therefore, moderately reducing the amount of cyfluprethroid acaricide used can improve the effectiveness of mite control and inhibit the damage to bees [16]. In addition to pyrethroid acaricides, myatomin is also a highly effective synthetic chemical acaricides. However, in the long-term use, Varroa destructor also becomes resistant to it, and the median lethal dose (LC50) will increase with time [17].

5.1.2 Organic acid drugs

The mite's resistance to organic acids, including oxalic acid, acetic acid, formic acid and other natural synthetic drugs is relatively low. Therefore, this kind of drug is by far the best substitute for synthetic chemical acaricides such as cyfluthrin. Among them, formic acid is liquid and highly volatile. Before application, make a bottle cap with ten pinholes and place in the bottle a drop of absorbent cotton with 6 ml formic acid. During break off brood, the vial should be placed in the corner of the hive, and formic acid should be replenished once every three days for five consecutive times [7]. The dosage need be controlled, and the bees should be ventilated in time. Otherwise, excessive formic acid volatilization may lead to chaos in the bee colony, which can reduce the mortality of mite and increase the mortality of bee larvae.

At the same time, oxalic acid is also widely used in bee feeding, mainly with sugar aqueous solution. The control effect of oxalic acid was positively correlated with its concentration in sugar water. But increasing the concentration of oxalic acid also increases the risk of bee poisoning.

5.2 Biological control

5.2.1 Use drones to control mites

Compared with worker bees, wasp mites are more often parasitized in the combs of drones. Thus, in order to attract mite, for the medium or above medium size bee colony, the drone can be bred by manually adding the spleen of the drone. When the bee mites from the worker's hive into the male hive house, the male bee spleen should be out of the house 2-3 days before. At this time, the mites should be killed by sulfur fumigation, and then the bee spleen put back into the bee colony to remove the drone spleen. Studies have shown that the number of mite mites can be reduced by three-quarters by regularly removing the spleen of drones. After inserting at least 1/3 of the drone chamber into the empty nest, the spleen of the drone was removed within 21 days. And when this is combined with weekly bee control during May and June, the effectiveness of mite removal can be enhanced. At the same time, attention should be paid to sterilizing the drone with a steam wax-melting device immediately after splenectomy, killing all the drone larvae and mites, and recovering the beeswax [12].

5.2.2 Fungal treatment of mites

In recent years, fungal mite control measures have been widely adopted. By using the insect pathogen, which is the natural enemy of Bumblebee mites, the mites can be parasitized and die, which also avoid the influence on bees and bee products. Such insect pathogens include *Metarhizium anisopliae*, *Hirsutella thompsoni* and *Beauveria bassiana* [18].

5.3 Plant extracts

The apiculture industry has been pursuing safe and effective methods of killing mites. Therefore, Chinese herbal acaricides, which are less toxic to bees and have strong inhibitory effect on large wasp mites, have gradually attracted more and more people's attention. Lin et al. found that among the 11 common essential oils (asarum, pteris rosewood, cardamom, Qiang Huo, fennel, galangal, patchouli, Platycladus platycladus, peppermint, Rhizoma plantarum), Pteris rosewood, fennel, patchouli, peppermint, asarum plantarum and Rhizoma plantarum have obvious antimite effects. Among them, the effect of rosewood and fennel is the best. At the same time, they have no obvious side effects on the growth and development of bees. Therefore, appropriate doses of plant extracts have the potential to replace chemical acaricides [19].

6. Conclusion

This paper introduces the classification, distribution and biological characteristics of *Varroa destructor*, and discusses its transmission mode, harm form and common control methods. Oriental honeybees are the original hosts of the mites, and they have formed a stable symbiotic relationship in long-term co-evolution. After the introduction of eastern honeybees to Asia, the mites spread to western honeybees through contact, causing serious damage in most parts of the world. The mites have strong survival ability and mainly parasitized on the larvae and pupae of honeybees. A new study suggests that *Varroa destructor* survives by feeding on the fat bodies of bees, which replaces the long-held belief that mites feed on bee hemolymph. The direct harm caused by mites to bee colonies includes impaired development, decreased immunity, reduced pesticide tolerance, the appearance of residual wings, and significantly shortened life span. At the same time, it also causes indirect harm, such as the transmission of pathogens, leading to large-scale pests and diseases.

At present, the mainstream control methods include chemical control, biological control and plant extract control. Among them, chemical control has quick effect, but has side effects such as strong toxicity and increased resistance to bee mite. By contrast, biological control and plant extract control have less side effects and great potential for mite control. Further research on mite control methods to enhance the effectiveness of mite removal and reduce the side effects on bees, bee products and the environment is still the focus of future scientists.

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