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A Biological Method for Trapping *Varroa destructor* and Collecting Male Wasp Pupae

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Abstract: *Varroa destructor* is a kind of parasitic mite that seriously endangers the western honeybees. It has become the biggest pest threat to the agiculture of the world. At present, chemical drugs such as mite powders are worldwidely used to control the infection of *Varroa destructor*. While these anti-mite drugs may increase drug resistance of *Varroa destructor* and pollution of bee products. Although many biological methods have been adopted, the effect on mite control is not satisfactory. This paper discussses the use of plastic mould to modularize the movable honeycomb frame and make the modularized honeycomb into a biological trap. Based on the biological characteristics of *Varroa destructor* reproduction and its parasitic characteristics and reproductive regularity, a movable nest frame with plastic mould was modularized and made into a biological trap. Then the biological trap was set up in every colony to trap and kill *Varroa destructor* in a planned way, and the male pupae are harvested at the same time. The results showed that after a series of reciprocating trap, the trapping rate decreases geometrically, and the sex ratio was well controlled. This biological trap is of practical significance to reduce the damage of *Varroa destructor* to bee colony and to improve the economic benefits of bee farmers.

Keywords: *Varroa destructor*, Biological Trapping, Modularized Hive, Ambush, Male Pupae

1. Introduction

Before its renaming in 2000, *Varroa destructor* was known as Varroa jacobsoni Oudemans. It is one of the most threatening bee diseases and insect pests in the world beekeeping industry. It belongs to the order Parasitic Mites and the family Vamitidae (hereinafter referred to as "*Varroa destructor*"). [1] In this paper, we will give a brief introduction on its epidemic characteristics, damage, growth and decline rule. Moreover, in our research, we have found a new practical method, which can kill *Varroa destructor* and harvest male pupae at the same time. This biological method is easy to operate and can efficiently reduce the damage of *Varroa destructor*s to bee colony. It is worthy to spread worldwide to improve the economic benefits of bee farmers.

2. Epidemic Characteristics

The original host of bee mite is the Eastern bee. They formed a similar symbiotic and coadapation relationship during their long-term co-evolution. The bee mite begins to attract people's attention when it becomes a parasite of the western honeybee, which seriously affects the reproduction and production of the bee colony [2-3]. Due to geographical spread and inadvertent introduction, it spread from Asia to Europe, America and Africa. The accurately discovery of *Varroa destructor* for the first time in China has not been documented. Around 1956, the first infestation occurred in the Italian honeybee colonies raised in Jiangsu and Zhejiang provinces, and then spread gradually. [4] By 1960, the bee mite infestation broke out in most parts of the country and posed a great threat to the beekeeping industry in China. In recent years, the bee mite infestation has risen again. [5] If it

is not controlled, the bee colonies will cover within 1-2 years. Now it is the most serious pest endangering apiculture in the world. [6]

3. Damage of *Varroa destructor*

Varroa destructor are mainly parasitized on adult bees and larvae of honeybees, feeding on their haemolymph of the host. They reproduce quickly and do great harm to the western bees. Almost 100% of the bee colonies are infected. In bee farms around the world, the bee colonies are extremely declining due to the harm of bee mites, and serious collapse occurs frequently, especially in recent years. Normally, the average life span of bees without wasp mites is about 40 days in summer. [7] One wasp mite can only live for 36 days, two to four wasp mites can only live for 30 days, and more than four wasp mites can only live for 25 days. Therefore, once parasitized by wasp mites, the life span of bee colonies is obviously shortened, which directly affects the normal life of a bee colony. [8-9]

After parasitized by the bee mite, the larvae with incomplete wings or feet often crawl out of the colony, and the dead pupae are dragged out by the worker bees. Inside examinations reveal that adult bee mites are parasitic on the head, chest and abdominal ganglia of bees or on the dorsal side of the chest and abdomen, and large bee mites parasitize the hive in the male hive. As a result, the worker bee's body size decreases, the male's sexual function decreases, and the queen's life span shortens. The first reason is that once parasitized by 2-3 wasp mites, the weight of larvae will reduce by 15-20%, and the flight ability also be impaired. The life expectancy of bees which are parasitized by *Varroa destructor during* 1-10 days after emergence is even reduced by 50%. [10] The second reason is that bees harmed by *Varroa destructor* are easily invaded by diseases such as bacterial and viral diseases because of their wounds. The third reason is that bees often twist their bodies after being parasitized by *Varroa destructor* to get rid of them, resulting in exhaustion and eventual death; Fourthly, the developing colony is weakened by the parasitic population of wasp mites; Fifthly, the bee colony is not treated in time before rearing winter bees of suitable age in autumn, and the bee colony is disturbed by *Varroa destructor*, which makes the bees unable to cluster and the bee colony can not survive winter safely, and even results in serious losses. [11]

4. Growth and Decline Rule of *Varroa destructor*

The lowest parasitic rate of *Varroa destructor* is in spring, and this will increase steadily following the increase of bee colonies. According to the statistics of many years' investigation, if the *Varroa destructor* are not treated, they begin to propagate in early March. [12] The parasitic rate of *Varroa destructor* is 15-20% and the parasitic density is 23-25% by the middle of April. The parasitic rate reaches its peak in late spring and early summer with the steady parasitic rate 10~12% and parasitic density 15~17%. By the end of summer and the beginning of autumn, that is, from mid-August to early September, the colony *population* and the number of queens laying eggs were gradually reduced, due to obvious temperature difference between day and night and the reduced source of honey and pollen. At the beginning of overwintering, the numbers increased sharply, reaching the peak, and the highest level may be at 50~57%. [13-14]

5. Biological Methods of Killing *Varroa destructor* and Harvesting Male Pupae at the Same Time

5.1. Modularization the Movable Nest Frame with Plastic Mould

The structure of the *honeycomb* is divided into movable and interchangeable modules. Firstly, the base of the male hive is set in the cell frame, and the base of the male hive is tailored according to the size of the inner frame of the cell frame. Then, the movable tenon joints of the three corners of the cell frame are connected. When connected, the strip grooves in the middle of each side of the cell frame are linked up. Then, the tailored base of the male hive is inserted into the strip grooves; finally, connect the movable tenon joint to the unit frame clamp the base of the male hive into the groove on the fourth side. [15]

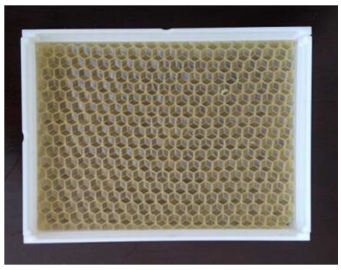

Figure 1. *Modular Honeycomb.*

5.2. Make the Modular Honeycomb into a Biological Trap

Install the *Varroa destructor* module into the standard nest frame which includes six modules. Then insert the whole set into the bee colony with 5-6 frames to make the bee house. After the bee house is built, the unit module honeycomb is inserted into the multi-queen colony of bee to lay eggs centrally as bait of the biological trap. After about 24 hours, the biological trap of *Varroa destructor* is done.

Figure 2. *Standard Nest Frame with Six Unit Modules.*

5.3. Trap and Kill Varroa destructor in the Worker Honeycomb in a Planned Way

The biological trap of *Varroa destructor* is set up in every colony to trap and kill *Varroa destructor*. In the breeding areas where bees and bee mites prefer to live, set up traps flexibly and implement biological trapping as planned to kill mite and harvest male pupae.

5.4. Ambush Method for Biological Trap of Varroa destructor

5.4.1. Determine the Location of the Ambush as Needed

The trap can be placed in the middle of the bottom of the honeycomb of the honeybee nest, at the left or right corner, and at the left and right corners, so as to trap and kill the bee mite flexibly.

5.4.2. Ambushing Time

Let the *Varroa destructor* get into the biological trap as much as possible for 15-16 days, take it out and set up a new trap at the same place. Repeat the above operation several times. Put these used traps in one trunk for two days, and change the partition board into screen board to prevent worker towing larvae, or concentrate them in a incubator of 35°C for two days. On the 18th day, the traps were placed in the freezer for 5 to 7 hours to kill the *Varroa destructor*. After the *Varroa destructor* is killed, cut off the hive and collect the pupa.

5.4.3. Ambushing Period

The growth and decline of *Varroa destructor* are related to bee colony *population*. Spring is the breeding season. There are many male hives in the colony. The parasitic rate of *Varroa destructor* increases with the growth of colony *population* until harms occur in summer and autumn. In beekeeping production, using the growth and decline of *Varroa destructor* and the annual life pattern of bee colony, traps are set up when bee colony propagates to strong colony with 3-4 frame and adds honeycomb to trap and kill *Varroa destructor*. At the same time, depending on the growth of colony *population* and the actual situation of external honey and pollen sources, the number of biological traps and the interval between traps can be flexibly controlled.

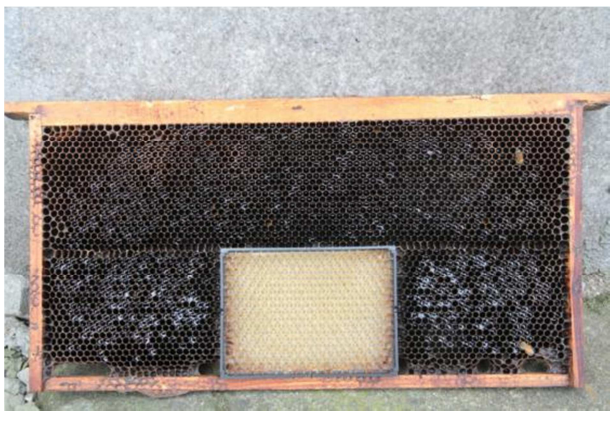

Figure 3. *Ambush at the bottom of the honeycomb of a honeybee hive.*

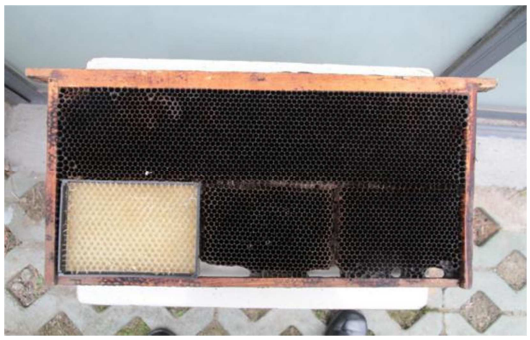

Figure 4. *Ambush at the left corner of the bottom of the honeycomb of the honeybee hive.*

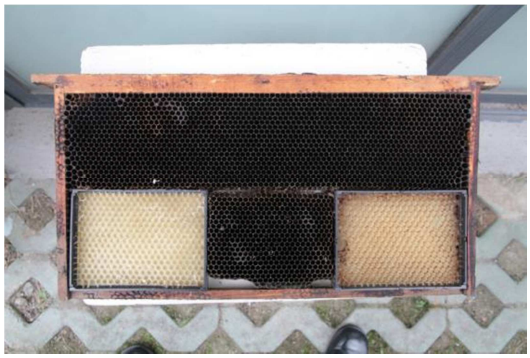

Figure 5. *Ambush at the left and right corners of the honeycomb bottom.*

Figure 6. *The worker bee is feeding the pupae of the drone on the trap of the Varroa destructor.*

Figure 7. *Drone wasp pupae to be harvested on the Varroa destructor trap.*

6. Scientific Significance of Trapping and Killing *Varroa destructor*

6.1. Making Full Use of the Biological Characteristics of Varroa destructor Reproduction in the Enclosure of Male Bee Larvae

According to the survey, the number of *Varroa destructor* in the larval hive is 5-12 times more than that in the larval hive of worker bees. One of the key points of trapping *Varroa destructor* is that the pupae is used as bait in this biological trap. The number of mites in a unit module is equivalent to that in one or two worker bee honeycombs. Taking a colony of 10,000 bees (1kg), the parasitic rate at 10% and parasitic density at 10% as an example, about 1000 mites were distributed in two worker bee *honeycomb*s. After the third bee *honeycomb* was set, about 500 mites were trapped 15 days later. If each of left 500 *Varroa destructor* gives birth to about 1.4 offsprings, there will be about 700 new bee mites. When the fourth *honeycomb* was added, about 350 mites were trapped 15 days later. In such a reciprocating way, the trapping rate decreases geometrically, which can control the harm of *Varroa destructor*. The second key point is that the average progeny of *Varroa destructor* hosted by male wasp pupae is 2.2-2.6, 69.23-85.7% higher than that hosted by worker bee larvae which is 1.3-1.4 on average.

6.2. Making Full Use of the Parasitic Characteristics of Varroa destructor and the Reproductive Regularity of Bees

Firstly, the biological trap of *Varroa destructor* is located in the middle, left and right sides of the bottom of the *honeycomb* of the honeybee nest, and the temperature is low, which is suitable for the parasitization and reproduction of *Varroa destructor*; secondly, drone larvae can secret hormone in the development stage to seduce *Varroa destructor*; thirdly, the development period of drone larvae is 12 hours longer than that of worker bees, and the feeding times of worker bees are more, which increases the invasion of *Varroa destructor* and consequently increase the chance of ambush and murder. Above all, according to their natural parasitic characteristics, *Varroa destructor* can be well controlled by trapping and killing in a planned way. Moreover, the pupae of drones can be harvested at the same time.

6.3. The Sex Ratio of Bees in Colony Is Determined by Worker Bees

In the mating season of bee colony, according to actual investigation, the actual sex ratio of bee colony is 17.37-68.28 (Zeng Zhijiang et al., 2004). When the bee colony reproduces to a strong colony of 3-4 frame bees, traps can be set up for biological trapping of *Varroa destructor*, and there will be no difficulties for workers not to accept or tow larvae until the end of autumn breeding and the end of capacity of the queen. The significance of biological trapping of *Varroa destructor* conforms to the theory of natural selection: under normal circumstances, the elimination rate of a colony can not exceed 10%, otherwise the population can not continue. In 1971, according to Haldane's theory, the population would be extinct if there were not enough reproductive excesses.

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