Mites- The Tiny Killers to Push Honeybee Colonies into Collapse and Integrated Pest Management

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Abstract

This article is designed to give an overview of damage to honey bee's colony by parasitic mites, integrated pest management, available treatments and information on further pest control. Parasitic mites have caused massive economic losses and expenses for beekeepers and their destructive power is evident from the huge number of colonies lost since the past few decades. Parasitic mites present in most colonies in certain localities, if left untreated, these usually cause the colony to collapse. Parasitic can feed and survive on both adult bees and their brood, and feed on the host's haemolymph (blood) through punctures made in the body wall with their sharp mouthparts. Mites transmit pathogens like viruses and bacteria, and without human intervention, infestation with mites means certain death of honey bees sooner or later. The signs of infestation may not be obvious until colonies are heavily infested, however, there are several methods that can be used to detect the mites and estimate their infestations at a much earlier stage. These include counting dead mites that collect on the hive floor and counting mites inside sealed brood cells. This is a disaster not just for beekeepers, but also to farmers in most countries where honey bees are the main pollinators of crops such as apples, oilseed rape and almonds. Mites remained the number one management problem for beekeepers and scientists alike, and management of parasites has now become a routine part of bee husbandry. The onset of resistance to the treatments available and the potential impact of secondary infections may make controlling of mite more difficult in the future, and it will continue to be a serious threat to the long-term sustainability and prosperity of apiculture as well as environment. Mites control methods can be divided into two groups, management methods (biotechnical methods) and chemical controls (varroacides). There are a few effective and approved miticides (chemicals that kill mites) to immediately treat mites with one of these treatments by carefully following the directions on the package. Because mites can develop a resistance to these medications, it is prudent to alternate between two or more of these from one season to the next. In practice, the best controls result from using a combination of methods at different times of the year depending on the level of infestation is Integrated Pest Management or 'IPM, as reliance on a single approach is not a long term solution.

Keywords: Parasitic mites; Miticides; Varroacides; Biotechnical; Honey bee

1. Introduction

Mites are the most common, notorious and troublesome pests invading of honey bee colonies. The mites cause varroosis, which is a very serious and complex infestation of honey bees. Mites are mobile and can readily move between bees and within the hive, however, to travel between colonies they depend upon adult bees for transporting through the natural processes of drifting, robbing, and swarming. Mites can spread slowly over long distances in this way; however, the movement of infested colonies by beekeepers is the principle means of spread over long distances. Individual bees infested with mites during their development usually survive to emergence, but may show signs of physical or physiological damage as adults. These include shorter lifespan, reduced weight, shrunken and deformed wings, and reduced natural resistance to infections. Some broods infested may die, usually at the pupal stage of development and remain in the cell until removed by adult bees. As mites feed, as well as take essential nourishment away from the developing bee, these act as the vector and can aid in virus spreading, so that in heavily infested colonies they become much more widespread and potentially harmful by reducing the bees lifespan. Mites may also worsen the harmful effects of other common bee diseases such as Acarapisosis caused by the tracheal mite, *Acarapis woodi* (De-Jong, 1997; Downey et al., 2000; Martin, 2001; Sarwar, 2015 a).

Varroa mite (*Varroa destructor*) is a shiny, reddish-brown, shield-shaped about 1.5 mm wide and 1 mm long, and this move about quickly and can be seen crawling on the surface of both adult and immature honey bees or on hive parts, and sometimes a few dead mites can be found on the bottom board of the hive. They feed on both brood and adults by puncturing the body and sucking the body fluids of the bee and reproduce in sealed brood cells. They spread rapidly from one hive to another as bees drift into the wrong hive or when bees rob honey from the colonies that are too weak to defend themselves. Tracheal mites (*A. woodii*) are microscopic internal parasites of adults honey bee, *Apis mellifera*, and the Asian honey bee, *A. cerana*. They primarily infest the largest breathing tubes, or tracheae, near the base of the bee's wings and feed on body fluids by puncturing the walls of the tracheae. Mites move from old bees to young bees that have just emerged from their pupal cells. Mite-infested bees have shorter life spans, a reduced ability to keep themselves warm during the winter months and can cause winter die-offs of colonies if most of the adult bees become infested (Anderson and Trueman, 2000; Hunt, 2010). Currently, there are two species of Tropilaelaps mites documented as serious parasites *Tropilaelaps clareae* and *Tropilaelaps koenigerum*, affecting both developing brood and adult honey bees. The mites are reddish brown, about 1 mm long and 0.6 mm wide, and move freely and rapidly on combs and rely on brood for feeding. The natural host of the mite is the giant Asian honey bee, *Apis dorsata*, but Tropilaelaps can readily infest colonies of *A. mellifera*, the Western honey bee. It is also associated with other Asian honey bees, including *Apis laboriosa*, *A. cerana* and *Apis florea*. Parasitisation by these mites can cause abnormal brood development, death of both brood and bees, leading to colony decline and collapse, and can cause the bees to abscond from the hive (Wilkins and Brown, 2005).

2. Mite Effects on Colonies and Signs of Colony Collapse

Small numbers of mites infesting a colony will usually cause it no obvious harm, however, as the level of infestation rises; the risk of harmful effects also rises. In poorly managed colonies where infestation is allowed to increase, signs of damage to the entire colony start to become evident. Severe infestation slows the replacement of old adult bees with healthy young bees, and may lead to the rapid spread of harmful bee viruses in the colony. At this stage, the normal processes of foraging, brood rearing and colony defense diminish and the colony's entire social organization begins to deteriorate- a process known as colony collapse. Colony collapse is usually very rapid (taking only a few weeks) and may affect even strong colonies that have shown no outward signs of damage. However, a closer look would reveal many mites on adult bees (with deformities) and heavily infested sealed drone and worker broods, often with many mites per cell. Colony collapse can occur at any time of the year, but it seems to occur most often in August and September. However, spring colony collapse, which in turn leads to mite invasion of neighboring colonies, can be quite common in March, April and possibly into May. The signs of colony collapse include a sudden decrease in the adult bee population, usually with few dead adult bees present, bees with deformed wings and abdomens, numerous mites on remaining bees, on worker and drone pupae and on the hive floor, and various abnormalities of the brood (e.g., bald brood, poor brood pattern, patches of neglected and dead brood often discolored brown and partly removed by the bees. Researchers agree that it is a wise aim to keep the varroa population below about 1000 mites; above this level the risk of damage from the mites, associated pathogens and the effect of feeding on the bees can quickly become very significant. However, higher threshold levels of around 4000- 5000 mites are generally used. Mites populations in infested colonies increase naturally through two processes, the reproduction of mites in brood cells and the influx of new mites into the colony through invasion (Bowen-Walker and Gunn, 2001; Ball et al., 2009).

Mites can be controlled by monitoring their infestation in bee colonies and the use of appropriate control methods to keep pest numbers below levels that are harmful. Therefore, this article describes the harms of the mites to bees, how it can be recognized and monitored, the latest approaches beekeepers can use to control the infestation in their hives, and a look ahead to the future. The development of strains of mite resistant to treatments used against them poses new challenges to beekeepers. Following the arrival of mites, beekeepers began to use pyrethroid treatments on an annual basis. The mites have responded to certain chemicals in many parts of the world by developing resistance to these routinely used chemicals (Eischen et al., 1998; Aumeier, 2001; Buchler et al., 2008).

3. Integrated Pest Management (IPM)

The Integrated Pest Management **(**IPM) means using a combination of different control methods at different times of the year in order to keep the varroa mites population to such a level that these can cause no significant harm to a bee colony. The IPM allows the beekeepers to choose the products or methods appropriate to them. It encourages careful monitoring so that treatments are used in line with known risk. These offer a very simple means of controlling mite numbers effectively. It is particularly useful to beginners and should be seen as an important part of an IPM approach that can be adapted as necessary (Delaplane et al., 2005; Sarwar, 2015 b; 2015 c). As a general rule, mite populations should be monitored three or four times a year. Monitoring of colonies routinely can tell to beekeepers how mites infestation is developing. Beekeepers can then use this information to decide what and when control methods will be appropriate. A range of monitoring methods is available to use ranging from the quick and approximate through to the complex and more accurate. Beekeepers will have to decide which of these suit to their own individual beekeeping practices. The aim is to keep the total population below 1000 mites per honey producing colony. A number of methods are possible, but counting natural mite mortality is the simplest and highly compatible with treatments (Guzman-Novoa et al., 2010):-

i. Put the clean paper or insert under the mesh floor for 5-7 days in summer, and up to 14 days in winter.
ii. Count the number of fallen mites at the end of the monitoring period and divide by the number of days to give the daily mite drop.

iii. Multiply the daily drop by 100 in March, April, September and October, 400 in November to February, and 30 in May to August, to give a good estimate of the total number of mites in the hive. Uncapping drone brood regularly will give a good idea of mite levels. When over 10% of pupae are infested, control will be required before the end of the season.

Beekeepers are now aware that reliance on a single approach is not a long term solution, thus, current control methods used by beekeepers against mites can be divided into two main categories like varroacides (use of chemicals) and biotechnical methods (use of methods based on bee husbandry) to reduce the mites population:-

3.1. Varroacides

This is use of chemicals to kill mites or otherwise reduce their numbers. These are applied in feed, directly on adult bees, as fumigants, contact strips or by evaporation. These may include authorized proprietary veterinary medicines and unauthorized generic substances.

3.1.1. Menthol Crystals

Menthol crystals provide a fumigant action that kills tracheal mites without harming the bees at certain temperatures. The crystals start to evaporate about 70°F and will melt to a liquid at about 102-105°F. Effectiveness of the product is dependent upon temperature, formulation (crystals or pellets), dosage, colony, size, condition of equipment, position within the hive and exposure time. Menthol should be used during a non-nectar flow period and after surplus honey has been removed to prevent menthol-flavored honey. Remove all menthol packets at least one month prior to a nectar flow to prevent contaminating marketable honey. Menthol crystals may reduce brood-rearing and affect clustering behavior if left on the colony beyond the recommended treatment period. Many beekeepers have reported excellent mite control with menthol packets placed on the bottom board in August and removed in November. Results may vary depending on local conditions. A yearly fall treatment should reduce the mite’s population and allow good over-wintering and good spring buildup.

3.1.2. Menthol Crystals and Vegetable Shortening-Sugar Patty

A combination of menthol crystals and vegetable shortening-sugar patty treatments should give optimum mite control. A vegetable shortening-sugar patty treatment has been shown to provide good tracheal mite control. This treatment is thought to disrupt the tracheal mite’s life cycle by reducing the ability of the female mite to detect young bees as hosts. The patties are made of two parts of granulated sugar and one part vegetable shortening. A baseball size patty should be flattened and placed on the top frame bars in the brood chamber. The patty can be placed on wax paper over the top frame bars, but this is optional. Patties should be placed in colonies during brood rearing periods and a fall or early spring treatment or both are recommended. Tracheal mites require their host to survive. Empty equipment that has been free of live bees for one week may be reused without mite treatment (Ellis, 2001).

3.1.3. Powdered Sugar Dusting

The dusting of colonies with powdered sugar as a means of varroa control has become quite popular with hobbyists. In an article, Oliver (2007) used the powdered sugar dusting for varroa mite management to cause phoretic (hitchhiking) mites to drop off the bees. Author found that powdered sugar has just the right size for sticking to the mite's footpads, plus has the added advantage of not adding any unwanted contamination to the hive. This research demonstrated that dusting with powdered sugar could effectively increase mite drop from a colony. When the bees are covered with powdered suga, their bodies become slippery and the varroa lose their ability to cling to the bees, the granules get into the gripping surfaces of the feet and they fall to the floor of the hive. Additionally, the powdered sugar promotes the dusty bees to clean themselves, causing more mites to be dislodged in the process. This technique has no adverse effect on adult bees and the capped brood, and the sugar particles do not enter the spiracles and their tracheal ducts in the treated bees. Here is the process described:-

i. Sift a pound of powdered sugar using a baking flour sifter, do this twice to ensure no lumps and this should be done on a day with low humidity.
ii. Put the sifted sugar into an empty and cleaned baby powder container or alternatively improvise the container.
iii. Smoke and open the hive.
iv. Remove frames one by one and dust the bees with the sugar.
v. Avoid dusting any open cells.
vi. Put the dusted frame back into the hive and repeat this process with each frame.
vii. When done, also put a little extra dusting along all the top bars.
viii. This should be repeated once a week for two to three weeks.

3.1.4. Biopesticides

Biopesticides are naturally occurring organisms or their by-products, and several have been registered for controlling mites in honey bee colonies. The efficacy of many biopesticides can equal that of conventional chemical pesticides. For instance, Apilife VAR product contains a combination of the essential oils thymol, eucalyptol and menthol to treat both varroa and tracheal mites. Several studies have shown that if used as instructed by the manufacturer, it destroys between 65 and 97 percent of the mites population within a hive. The delivery medium of this product is a vermiculite tablet, which must be broken into four pieces and placed in the four corners of the hive between the brood chambers. Each piece must be wrapped in wire mesh to prevent the bees from chewing and removing it from the hive prematurely. New tablets must be used every week for three weeks for complete effectiveness. The biopesticide sucrose octanoate, derived from the tobacco plant, has recently been developed for varroa control under the trade name Sucrocide. It is delivered by spraying adult workers with the substance once every week for three weeks to kill mites as they emerge from brood cells. Formic acid has recently been permitted the control of varroa mites, and it is the only chemical pesticide that can be used for organic honey production. There are several delivery methods for formic acid, such as placing pads soaked with liquid formic acid on top of the hive. The product cannot be used during a honey flow, and care must also be taken by the beekeeper while applying formic acid, as it is highly corrosive and poisonous to humans. Toxicity by essential oils for honey bee mite control is by direct contact of the pest. When varroa mites contact essential oils such as wintergreen or tea tree oil mixed into oil or grease, they are killed on contact usually within a few minutes (Melathopoulos et al., 2000).

3.1.5. Chemical (Synthetic Pesticide) Treatments

Conventional means of varroa control involve synthetic pesticides being administered to a colony by placing plastic strips impregnated with the active chemical within the hive. While these treatments have traditionally provided very high levels of control, the varroa mite is becoming increasingly resistant to these chemicals, which makes them less reliable in some areas. For the control of varroa mites, Apistan, with the active ingredient fluvalinate, is a synthetic pyrethroid. It is sold as a plastic strip impregnated with the pesticide, and the strips are hung between the frames of a hive just outside of the brood nest. Fluvalinate is a contact pesticide and provides up to 100 percent control of varroa mites when properly used. In recent years, however, there have been increasing reports of varroa mites developing resistance to this pesticide. It is highly recommended, therefore, that Apistan should be rotated with other treatments to reduce the development of resistance to chemical control by the mites and to ensure its efficacy. Checkmite+, the trade name for coumaphos, is also sold as a plastic strip impregnated with the active pesticide. When the bees and mites come into contact with the pesticide, it can provide up to 100 percent control when used properly. Coumaphos is a member of the organophosphate group of pesticides, and residues can accumulate in wax and be harmful to bees at high levels. As with Apistan, there have been documented cases of varroa mites developing resistance to this pesticide, so it is important to alternate its use with other approved treatments (Delaplane and Hood, 1997; Natalia et al., 2009).

3.2. Biotechnical Methods

This is use of methods based on bee husbandry to reduce the mite population through physical means alone. Many of the most popular and effective methods involve trapping the mites in combs of brood which are then removed and destroyed.

3.2.1. Physical, Mechanical, Behavioral Methods

Mites can also be controlled through nonchemical means and cost of these controls is intended to reduce the mite population to a manageable level, not to eliminate the mites completely (Schmid-Hempel, 1998; Webster and Delaplane, 2001; Kassai, 2006).

3.2.2. Perforated Bottom Board Method

This method is used by many beekeepers on their hives and when mites occasionally fall off a bee, they must climb back up to parasitize another bee. If the beehive has a screened floor with mesh of the right size, the mite will fall through and cannot return to the beehive. The screened bottom board is also being credited with increased circulation of air, which reduces condensation in a hive during the winter. Studies done at over two years found that screened bottoms have no measurable effect at all. Screened bottom boards with sticky boards (glue traps) separate mites that fall through the screen and the sticky boards prevent them from crawling back up. Insecticide may also be applied to the sticky boards to help in killing the mites. It has been verified fact that in colonies with screen bottoms, the mite reproduction rate is lower. It should be stressed that cultural controls alone may not get rid of colonies of varroa mites and should be thought of as a means to delay the economic threshold and the need for a chemical application. Hopefully in the future, genetic bee stocks resistant to Varroa mites will become more available to beekeepers. Bees expressing varroa-sensitive hygienic behavior or auto-grooming are especially promising (Imdorf et al., 1995).

3.2.3. Heating Method

In this method, hive frames are heated to at least 104 degree F (40 degree C) for several hours at a time, which causes the mites to drop from the bees. When combined with the perforated bottom board method, this can control varroa sufficiently to aid in colony survival. In few countries, anti-varroa heaters are manufactured for use by professional beekeepers, and thermosolar hive has also been patented and manufactured.

3.2.4. Mechanical Control

Certain control methods involve changes in beekeeping management practices and the benefit of such mechanical control measures is that they do not use chemicals to reduce mite levels, thus they may be employed when the bees are collecting and producing honey. Research has shown some benefits from replacing the wooden bottom of a standard beehive with a wire-mesh screen or other nonsolid surface. Several studies have shown decreases in mite levels within colonies where hives have screened bottoms compared to solid bottoms. While the reasons for the decreased mite populations are unknown, the decrease may be due to better hive ventilation or to the loss of mites dropping through the floor of the hive. The benefits of bottom screens are minimal; however, such hives usually require additional methods of treatment. Varroa mites prefer to infest the drone brood in a hive, which consists of developing male honey bees. This is because drones are larger and take longer to develop, so female mites can produce more offspring per generation. Beekeepers may take advantage of this preference by placing special combs with drone-sized cells in their hives to the brood. These combs can then be removed before the drones and the mites emerge from their cells. Depending on the time of year, this practice can dramatically reduce the mite populations within colonies. Adult mites move through the hive by clinging to the backs of adult bees. Some research has shown that covering all the adults in a colony with fine dust sugar particles or certain pollen substitutes can cause the mites to lose their grip and fall off their hosts. This technique can be laborious and quite disruptive to a colony, but it requires no chemical pesticides (Elzen et al., 1998).

3.2.5. Mite-tolerant Stocks

Some of the more exciting advances in varroa mite control have been done through honey bee genetics. In recent years, much work has been done to develop particular strains of honey bees that have shown tolerance to the varroa mite. Though the mechanisms are not completely understood, some behavioral and physiological traits probably play a role in varroa resistance. Today, several strains of bees (Russian strain) are available that have been shown to reduce the number of varroa mites within their colonies that has been made available for commercial purchase (Robertson, 2005; Seeley, 2007).

3.2.6. Use Drone Comb to Capture Varroa Mites

Bee suppliers sell a special drone foundation that has larger hexagons imprinted in the sheet. The bees will only build drone comb on these sheets and that is useful, because varroa mites prefer drone brood over worker brood. By placing a frame of drone comb in each hive, beekeepers can capture and remove many mites. Once the drone cells are capped, remove the frame and place it overnight in your freezer. This will kill the drone brood and also the mites that have invaded the cells. Then uncap the cells and place the frame (with the dead drone brood and dead mites back in the hive. The bees will clean it out (removing the dead drone brood and mites). The cells will get filled again, and beekeepers can repeat the process (Fakhimzadeh and Hayes, 2011).

3.2.7. A New Way of Protecting Bees against Mites

Life in the hive is highly organized with busy honey bees working all around the queen. Worker bees distribute pollen, clean and look after larvae, or defend the entrance against enemy invaders like wasps and other honey thieves. But, the varroa mite, *V. destructor*, slips in unnoticed on the bodies of some worker bees, evading the strict door policy. It brings a deadly danger with it and this tiny brown arachnid can wipe out entire bee colonies. Like a tick, it fastens itself onto a bee with its jaws and so sneaks its way into the realm of the hard-working nectar collectors. Once inside, mites reproduce by laying their eggs in the honeycombs where new bees are raised. After ten to fourteen days, their offspring spread throughout the bee population along with the newly emerged bees. Particularly at the end of the flowering period, foraging bees from healthy colonies invade colonies weakened by varroa to steal honey. They then become infected and take back large numbers of mites to their own population. The researchers want to prevent this transfer of mites, since it is vital for effective mite control to stop new pests constantly entering the hive. They have therefore concentrated on the strategically most important point, and the joint efforts have led to the creation of the varroa gate, which is a structure at the entrance to the hive. Every bee must climb through this gate when leaving or returning to its own hive. At first sight it does not look anything special, but just a plastic strip with holes through which the bees fly in and out. Only a closer look shows the immense benefits of this innovation wherein the plastic strip is coated in chemicals. Whenever a bee passes through the gate, it touches the edge. This transfers a mite poison (acaricide) to the bee and kills any mites it may be carrying. The substance needs to be permanently available on the surface of the strip so that protection can last for several weeks.

4. Conclusion

These results support the conclusion that mites weaken honey bee colony populations and integrated pest management compromises for colony buildup. Overall, results suggest that varroa mites could have a high and negative impact on the survivorship of overwintered honey bee colonies. Moreover, these mites as well as tracheal and Tropilaelaps mites infection might significantly restrain the growth of honey bee colonies during the spring. General practices for all mite pests include rotation between different types of treatments whenever possible for mites management, this can prevent the development of resistance in mites (e.g., synthetic mite-strip in spring, followed by a formic acid treatment in fall). Use particular caution when using temperature - dependent treatments above recommended temperature thresholds (e.g., formic acid, thymol). Read all labels before applying any disease or mite control products to colonies and treat all colonies that require treatment in the yard at the same time. Monitor colonies to determine levels of mites infestation because knowing the severity of the infestation will enable to make an informed management decision on their control. The presence of multiple parasites or diseases may require treatment below the recommended treatment threshold levels. Oxalic acid should be used only as a follow-up treatment in the late fall, after a primary early fall treatment, unless monitoring reveals very low levels of varroa. Treatments need to be applied before infestations or infections reach damaging levels. Use of resistant bred honey bee queens in bee keeping operation may help colonies to resist diseases and pests naturally, however, treatment can still be required. It is recommended to replace 2 to 3 old frames in the brood chamber (typically the darkest) every year with newly drawn comb or foundation. This practice can be helpful to reduce the level of parasites and miticide residues in the bee hive.

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