



Integrated Pest Management for *Varroa Destructor* in the Northeastern United States using Drone Brood Removal and Formic Acid

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Photo A. A mature adult female *V. destructor*.

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GEOGRAPHIC RANGE:

The methods discussed in this fact sheet were developed and evaluated in the northeastern U.S. Drone brood removal will benefit beekeepers throughout the U.S.; however, formic acid and other miticides acting as fumigants work best in areas where colonies are broodless or nearly broodless for at least four weeks during the fall or winter. When a colony is rearing brood, most mites are present in brood cells where they are protected from the effects of fumigants. During broodless periods, mites are present on adult hosts and are susceptible to fumigants. Since fumigants have a relatively short treatment period (about three weeks) compared to other pesticides (about six weeks), it is critical that the majority of mites be present on adult hosts for fumigants to be effective.

Introduction

This bulletin focuses on the management of the parasitic honey bee mite *Varroa destructor* (*V. destructor*) in the northeastern U.S. It contains information that will allow a beekeeper to: 1) identify *V. destructor*, 2) recognize the symptoms of mite infestation, 3) determine pest densities, and 4) implement an effective IPM program for keeping mite populations below the economic injury level.

The western honey bee, *Apis mellifera*, was introduced to the U.S. from Europe in the 1600s. Today, the honey bee provides essential pollination services for over 45 commercial crops grown throughout the U.S., adding \$14.6 billion to the value of the country's agricultural production each year. In addition, U.S. beekeepers produce between 170 and 220 million pounds of honey each year, more than 50% of total U.S. consumption. Hence, a sustainable supply of healthy and affordable honey bee colonies is a critical factor affecting farm productivity and the stability of farm incomes and food prices.

The parasitic honey bee mite *V. destructor* (photo A) is considered to be the most serious global threat to beekeeping and to the sustainable production of crops that rely on

(Introduction continued on page 2)

A. mellifera for pollination. *V. destructor*, which kills honey bee colonies of European descent within one to two years, has killed millions of managed and wild colonies in the U.S. in the past two decades. Apistan® and CheckMite+® have provided some relief, but control always has been unpredictable due to the fact that mite populations often rise rapidly during the honey-producing season, when treatment is proscribed by label restrictions. Consequently, colonies often suffer serious damage while the beekeeper waits for a legal treatment window to open. The threat from *V. destructor* has become a matter of grave concern as resistance to both Apistan® and CheckMite+® has become widespread.



Photo B. A worker honey bee with deformed wings.

To continue to be viable, the beekeeping industry requires sustainable management practices that will keep mite populations below the economic injury level and maintain the high quality of hive products. The best way to achieve these goals is to use a management program that relies on multiple tactics, rather than solely on chemicals. One such approach is referred to as Integrated Pest Management or IPM. IPM incorporates chemical and non-chemical tactics; however, for several reasons, IPM minimizes the use of chemicals whenever possible. First, chemicals add a recurring cost to a beekeeper's management program. Second, chemicals inevitably show up as residues in hive products, and that jeopardizes their reputation as pure and natural products. Third, chemicals can be injurious to the applicator and may pose a risk to the consumer. This raises the issue of liability, especially for beekeepers with employees. Fourth, the less a pest population is exposed to a pesticide, the more slowly it develops resistance to that pesticide. So, by minimizing the use of a pesticide, its useful lifetime is extended.

Origins and Distribution of *V. destructor*

V. destructor is an obligate parasite of cavity-dwelling *Apis* bees. It cannot reproduce on yellow jackets, wasps, bumblebees or any other species. Early reports of this mite on the western honey bee inaccurately identified it as *V. jacobsoni* Oudemans, which exists in a sustainable association with the eastern honey bee, *A. cerana*. In 2000, the genus *Varroa* was reported to consist of at least two species, *V. jacobsoni* (which infects *A. cerana*, but not *A. mellifera*) and *V. destructor* (which infects both *A. cerana* and *A. mellifera*). Consequently, literature reporting on *V. jacobsoni* and the western honey bee prior to that time actually refers to *V. destructor*.

The association of *V. destructor* with the western honey bee reportedly originated in the 1950s, when mites transferred to *A. mellifera* colonies introduced to the home range of *A. cerana*. Subsequently, *V. destructor* has established a nearly cosmopolitan distribution with respect to its new host, with Australia being the only mite-free continent. *V. destructor* was discovered in the U.S. in 1987. Due to the highly mobile nature of both the honey bee and the U.S. beekeeping industry, *V. destructor* quickly became endemic, and it can now be found in every state in the continental U.S.

Symptoms and Damage of *V. destructor*

An adult female, *V. destructor* is elliptical in shape with a width of 1.5 mm, a length of 1.0 mm, and four pairs of legs. Mature female mites are brown, dark brown, or cordovan (photo A). During immature stages, the bodies of *V. destructor* are light and translucent, but those attributes tend to disappear on adult hosts. Usually, there are no obvious symptoms at low levels of infestation. As the mite population increases, a suite of symptoms, collectively designated **parasitic mite syndrome**, becomes apparent. Initially, adult workers with damaged wings are seen (photo B). This damage is a result of DWV (deformed wing virus), which is introduced either directly or indirectly to the developing bee by the mite.

As the infestation rate increases, more damaged workers are seen and otherwise healthy looking bees may be seen crawling in front of the hive, unable to fly. This condition is also caused by a virus. Finally, the brood begins to dete-



Photo C. Deteriorating brood typical with high levels of *V. destructor*.

riorate, appearing to be infected with a variety of pathogens (photo C). Although these brood symptoms superficially resemble American and European foulbrood, the causative organisms of those diseases have not been identified in the deteriorating brood and treatment with antibiotics does not eliminate the condition. As the syndrome progresses, the worker death rate exceeds the birth rate, and most new worker bees that do emerge are seriously impaired. As a result, the colony's population begins a rapid decline. From the time that a colony first exhibits brood symptoms until its total collapse can be as little as three weeks.

Life Cycle of *V. destructor*

The life cycle of the mite can be divided into phoretic and reproductive phases. The reproductive phase begins when a mature female leaves her adult host, enters a brood cell containing a worker or drone larva shortly before it is capped, and sequesters herself in the bottom of the cell. Soon, the cell is capped; and shortly thereafter, the immature bee enters the pupal stage. Egg-laying commences about 60 hours after a cell is capped, and both mother and offspring feed on the host's hemolymph. Mature offspring mate within the cell, but only mature females survive outside the cell.

The number of offspring that reach maturity is positively correlated with the length of the host's capped stage, which is greatest for drones, intermediate for workers, and shortest for queens. Mites that reproduce on drone brood average 2.2 to 2.6 female offspring per host, while those reproducing on worker brood average 1.3 to 1.4 female

offspring per host. Mites cannot reproduce on queen brood due to its short capped period. Not surprisingly, mites are found more often on drone brood than worker brood, with average differences between 5- and 12-fold. Mites are only rarely found on queen brood.

The phoretic phase begins when the host emerges from its cell as an adult bee. The mature female mite may leave the cell with its adult host, or it may walk out of the cell and acquire an adult host. Mites remain on an adult host for a few days or weeks before entering a brood cell for the next round of reproduction. Mites are found twice as often on bees in the brood nest as on bees in the honey supers, and 10 times as often on brood nest bees as on foragers.

Transmission of *V. destructor*

Robbing by bees is a major source of transmission. As an infected colony become progressively weaker, its defensive capabilities decline, and it becomes susceptible to invasion by workers from nearby colonies (the robbers) seeking its valuable cache of honey. In the process of removing the honey, robbers become infected with mites and transport them back to their own colonies. Swarms from infected colonies also contribute to the local reservoir of mites. These colonies are particularly susceptible to being robbed because they do not receive any treatment for mite control. They weaken and die within a year or two and may be robbed by workers from nearby colonies. Drifting bees, especially in apiaries where colonies are kept close together, also contribute to the spread of mites among colonies.

Beekeepers also play a major role in the transmission of mites. Moving brood among colonies for the purpose of strengthening or equalizing colonies is a common practice that transmits mites. In addition, beekeepers often purchase colonies of bees in the spring to replace winter losses or to increase colony numbers. Some beekeepers purchase small nucleus colonies, usually called "nucs," from local or regional suppliers. These colonies consist of one to five combs of bees and brood and usually come with a queen. Others purchase package bees (2, 3 or 5 pounds of bees, usually with a queen) from a southern location. An estimated 1 million packages are shipped throughout the country each year. Each of these practices spread mites, including various types of pesticide resistant mites.

Migratory beekeeping also plays a role in transmitting mites. Over a million colonies are moved throughout the country each year as migratory beekeepers fulfill pollination contracts. After the bloom is over, colonies are widely dispersed to other locations for honey production. During the season, some of these colonies may issue mite-



Photo D. The 'cappings scratcher' method for surveying for mites.

infested swarms into local environments, while others may succumb to mites and be robbed by local colonies. Each fall, surviving colonies are returned to a few states in the south where colony numbers are restored. This brings colonies from many different regions of the country into close proximity to one another and provides many opportunities for the transfer of mites among colonies, including various types of pesticide resistant mites. In the spring, these colonies resume their migratory routes throughout the country, and the process is repeated.

Monitoring and Thresholds

Survey methods provide presence/absence information.

One such method is the "cappings scratcher," which requires one to impale a number of capped drone cells with a cappings scratcher, and then to pull the immature drones from their cells for examination (photo D). This method has been found to be highly effective in detecting mites when present at very low levels. A second survey tool is the "sticky-board," which takes advantage of the fact that mites often fall off of bees. Typically, a piece of paper is covered with a sticky substance (petroleum jelly or a vegetable spray) and inserted into the hive where it rests, sticky-side up, on the bottom board. The sticky-board must be protected from the bees. One way to do this is to build a wooden frame, cover one side with 1/8" hardware cloth, and attach the sticky-board to the other side (photo E). Sticky-boards are also available commercially. The board is removed after 24 or 48 hours and the mites are counted. Strictly speaking, the sticky board does not provide information about pest density; however, it is often used for that purpose. Lastly, mites

can sometimes be seen on adult bees or walking on the comb, but this is more common when infestation rates are very high and should not be relied on as a diagnostic method.

Sampling methods provide an estimate of pest density. This is the type of information needed to determine whether to apply a pesticide.

One method is the "ether-roll," which provides an estimate of pest density in terms of mites per standard volume of bees. Bees are collected from two or three brood-nest combs and placed in a quart glass jar. If only a few colonies are being sampled, shake bees directly into a dishpan. Scoop up ½ cup of bees and quickly pour them into the quart jar. If larger numbers of colonies are being sampled, a modified "Dust Buster" (DC *Insect Vac* from BioQuip®) can be used to collect a standard volume of bees, which are then transferred to the quart jar. You will need to experiment with the vacuum collector to determine the exact volume that yields about 300 bees. Spray a three-second burst of an automotive starting fluid into the jar, replace the lid, shake vigorously for 10 seconds, and then toss and roll the jar three times along its long axis. Mites, if present, will be seen adhering to the sides of the

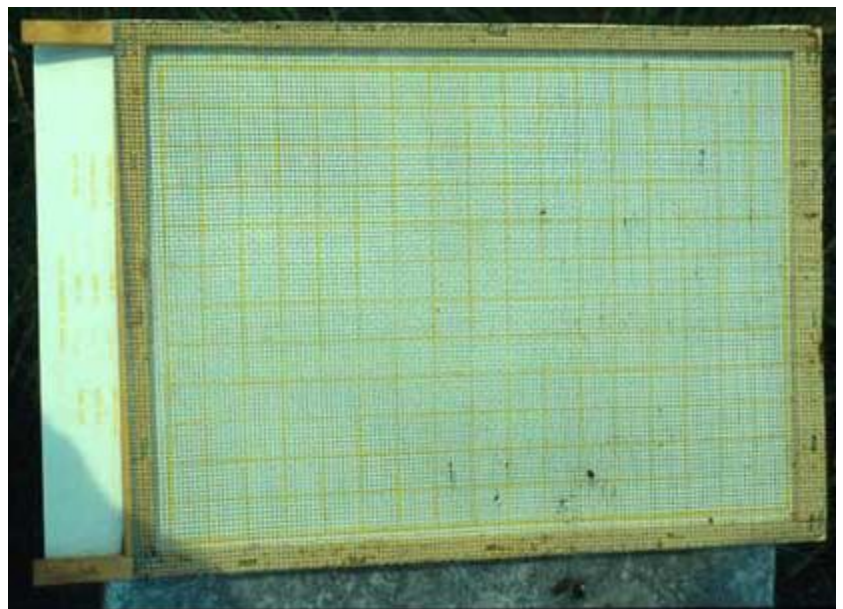


Photo E. The 'sticky board' used for surveying for mites.

jar (photo F). This method detects 50 to 60% of the mites actually present in the sample. The resulting ether roll count is usually converted to a standardized 300-bee ether roll count (SER) using the formula:

$$\text{SER} = (\text{ER}) / (\#B/300),$$

where ER is the ether roll count for the sample and #B is the number of bees in the sample.

An improvement in accuracy can be obtained by calculating the actual mite-to-bee ratio. This is done by collecting the bees as above and then separating the mites from the bees by agitating them for five minutes in a container with soapy water or alcohol and straining through a 1/8" hardware cloth screen. The screen catches the bees but allows the mites to pass through. Typically, bees are washed several times to remove all of the mites. Mites and bees are counted and the actual mite-to-bee ratio is calculated. You can convert the mite-to-bee ratio to a standardized 300-bee ether roll count using the formula:

$$\text{SER} = ((R * \#B) / 1.783) / (\#B / 300),$$

where R is the mite-to-bee ratio in the sample and #B is the number of bees in the sample. The conversion factor (1.783) is from Calderone and Turcotte (1998) [1].

Remember! For an estimate of pest density to be meaningful, each step in the sampling method must be standardized. This means monitoring mite levels at the same time each year, and monitoring all colonies exactly the same way. For the ether roll, this means collecting samples from the same place in each colony (two or three brood nest combs), collecting the same number or volume of bees in each sample, applying the same amount of starting fluid, and shaking the jar in the same manner. For the sticky-board, the same size board must be used each time, the sample must be collected at the same time each year, and the board must be left in place for the same length of time.

The decision to use or not to use a pesticide is based on an economic threshold. This is the pest density at which economic damage is expected if a treatment is not applied. Economic thresholds for *V. destructor* vary widely



Photo F. Mites adhering to the sides of a jar in the ether-roll test.

throughout the country. The values used below are based on studies conducted in the Midwest and Northwest, where blooming patterns, length of winter and winter temperatures are similar to those in the Northeast. Significantly different values are used in other parts of the country. Beekeepers should contact their local extension apiculturist for the most current recommendations for their area.

Rationale for IPM Program

For a colony to survive the winter in good condition, it must have a strong population of healthy worker bees in the fall (photo G). A colony exhibiting early stages of parasitic mite syndrome in mid-summer can usually be saved by the application of an effective miticide because it has time to produce several more generations of healthy workers in a low-mite environment. However, in the northeast-



Photo G. A strong population of workers ready for winter.

ern U.S., these symptoms often occur during or just prior to the fall nectar flow when chemical treatments are proscribed by label restrictions. By the time the flow is over, mite populations have increased dramatically and colonies have suffered severe damage. The result is a loss of colonies during the fall flow or shortly thereafter. This phenomenon is known as “fall collapse,” although it may occur in late summer, winter or whenever mite populations are allowed to increase to high levels.

Often, infected colonies look strong after the fall flow, and the application of an effective pesticide kills most of the mites present; however, the colony still collapses and dies over the next few weeks or months. Such colonies experienced significant, but less obvious damage while waiting for the fall treatment. The lesson is simple. One cannot assume that a colony will survive the winter if one waits until the end of the fall flow to apply a pesticide. Mite levels must be kept low during the summer in order that colonies can rear healthy workers during late summer and early fall.

IPM Chemical Control Methods

Available Products

Currently, there are three products with Section 3 (General Use) registration available for controlling *V. destructor*. These are Apistan® (fluvalinate), Mite-Away II™ (formic acid) and Sucroside™ (sucrose octanoate esters). In addition, CheckMite+® (coumaphos) and Api-Life VAR® (thymol, menthol and eucalyptus oil) have been granted Emergency Exemptions from registration (Section 18) by the US-EPA. These latter two products are only available in those states that have applied for and received Emergency Exemptions, which must be renewed each year.

Pesticide Resistance

Resistance to the two major pesticides, Apistan® and CheckMite+®, is widespread. This is problematic because the resistance status of the mite population must be determined before treating a colony, rather than after. Presently, such a determination is difficult to obtain. See <http://www.masterbeekeeper.org/> or to <http://www.ba.ars.usda.gov/beelab/> for information on making this determination. There is no known resistance to formic acid (Mite-Away II™) at this time.

Established pesticide tolerances

Honey may contain 0.05 ppm fluvalinate and 0.1 ppm coumaphos. Beeswax may contain 100 ppm coumaphos. Remember! These are limits, not goals. Always think of pesticides as a means of last resort. Formic acid and sucrose octanoate esters are exempt from tolerance when used in accordance with label instructions. Menthol, thymol and eucalyptus oil (the active ingredients in Api-Life VAR®) are also exempt from tolerance, but their exempt status is subject to periodic renewal.

How to minimize pesticide residues in hive products

The use of pesticides inevitably results in residues in wax and honey. To minimize this problem, and to ensure that residues do not exceed established tolerances, use pesticides only when necessary and only in accordance with label instructions. Use separate hive bodies and combs for your brood chambers and honey supers and keep them separate. Never move combs from the brood nest into the honey supers. An easy way to keep these combs separate is to use deep hive bodies for brood chambers and mediums or shallows for honey supers. Apply pesticides in the brood chambers, never in the honey supers. These practices will greatly reduce the level of pesticide residues in the honey and the wax cappings.

General recommendations for the use of pesticides

DO:

1. Read and follow the product label.
2. Follow all safety instructions, and wear all indicated personal protection equipment.
3. Apply the proper amount of pesticide in the manner specified on the label.
4. Remove the pesticide at the end of the specified treatment period.
5. Dispose of used pesticides in the manner specified on the label.
6. Follow any required withholding period. This is the minimum time that must elapse between removing a pesticide or antibiotic from a colony at the end of a legal treatment period and the addition of supers for honey production.
7. Place pesticide strips in such a manner that they will remain in contact with the bees when the cluster contracts. This is particularly important in the fall.

DON'T:

1. Leave pesticides in your colonies over the winter. It is illegal. It also increases the amount of time your combs are in contact with a pesticide, thereby increasing the risk of residues in hive products. It may also increase the chance of the mite population developing resistance to the pesticide.
2. Reuse products.
3. Use any chemical, pesticide or formulation of a chemical or pesticide to control *V. destructor* unless it is legal to do so in your state.
4. Use any pesticide in a manner inconsistent with its label.



Photo H. Comb of capped drone brood being removed from colony.

IPM Non-Chemical Control Methods Drone brood removal

Research: Mites are found most often on drone brood where they produce about twice as many offspring as on worker brood. Therefore, by removing capped drone brood from an infected colony, you remove a disproportionately large number of mites without affecting the worker population, and you remove those mites with the highest fecundity. Research at Dyce Laboratory for Honey Bee Studies at Cornell University has shown that the periodic removal of drone brood from a colony allows a beekeeper to skip the usual spring treatment, keep mite

levels low throughout the summer and prevent fall collapse (figure 1). It may also eliminate the need for a fall pesticide treatment. The only way to determine that is to estimate the pest density on a colony-by-colony basis after removing the fall honey crop.

Implementation: You will need four drone combs per colony to use this method. Drone foundation can be purchased from several supply houses. The foundation is wired into frames and drawn out by colonies. One piece plastic drone combs are also available. Use two deep hive bodies for brood chambers, and separate them from the honey supers with a queen excluder. Cull worker combs in the brood nest with more than 1 to 2 square inches of drone cells (photo H). Remember! The goal is to get the colony to consolidate all of its drone production in the removable drone combs.

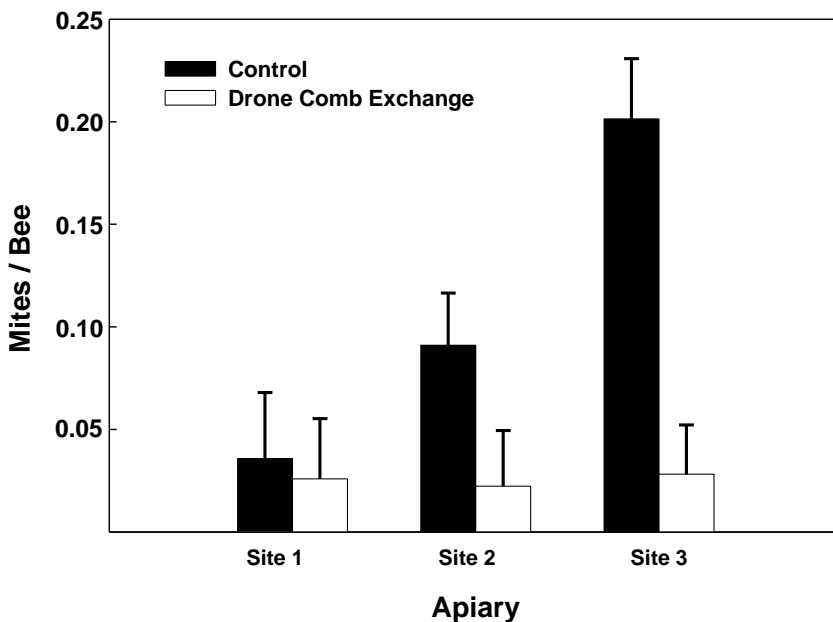


Figure 1. September mite-to-bee ratios in colonies with and without drone brood removal during the spring and summer in three apiaries.

Place two drone combs in the upper brood chamber, one or two combs in from each side. Visit your colony every 26 to 28 days, remove the drone combs (photo I) and replace them with the drone combs that you removed on the previous replacement date. Place the combs of capped drone brood in a freezer, and keep them there until you are ready for your next exchange. Allow frozen drone combs to come to ambient temperature before placing them back in a colony. Be sure to visit your bees at least every 28 days to exchange combs because you don't want too many drones actually emerging in your hive. If a drone comb becomes filled with honey, you will need to substitute an empty drone comb and extract the honey before reusing it. In the north, you can exchange combs up to six times a season using

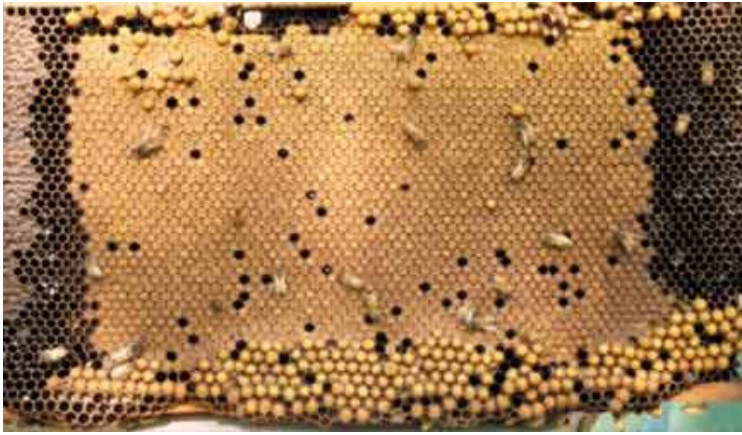


Photo 1. A worker comb with excess drone cells. Such a comb is best culled and replaced with a comb of 95-100% worker cells.

a 28-day interval between exchanges. The more often you exchange combs, the more you will suppress the mite population. The drone brood removal method has no known deleterious effects on colonies, and honey production may be marginally increased.

Screen bottom boards

Research: Many studies have shown that mites fall off of bees at relatively high rates, even when no chemical treatment is present. Many of these mites are still alive and manage to reacquire a host. It is commonly believed that mite populations can be suppressed if these fallen mites can be removed from the colony before they reacquire a host. The screen bottom board allows mites that fall from bees to fall out of the hive. Since they cannot re-enter the hive, they cannot re-acquire a host and they cannot contribute to the growth of the mite population.

Three years of research at Dyce Laboratory at Cornell University have shown that screen bottom boards have no effect on mite populations (figure 2). The reason for this is unknown, but it may be because the fallen mites are sick or old and no longer able to reproduce. However, research on the efficacy of screen bottom boards is mixed. Two other studies have shown numerical benefits from screen bottom boards, but the advantages were not statistically significant. One study has demonstrated a small but statistically significant benefit. Screen bottom boards do not appear to damage colonies. If effective mite knockdown agents can be identified, screen bottom boards may play a more significant role in mite management.

Mite-resistant stock

There are two stocks of mite-resistant bees available. One is descended from Russian queens imported to the U.S. The other is known as SMR stock (for suppressing mite reproduction) that was developed from bees already present in the U.S. Both are the result of work conducted at the USDA-ARS Honey Bee Breeding, Genetics and Physiology Lab in Baton Rouge, LA. Performance of commercially available variants of these stocks is mixed. However, stock improvement is ongoing, and you are strongly encouraged to try them.

Swarm prevention

A swarm from one of your colonies will establish a nest within foraging distance of its parent colony. Invariably, swarms will have some mites, and since they do not receive treatment to control the mites, they will eventually collapse and die. As they do, the colonies in your apiary will likely rob them and return to their nests with a large

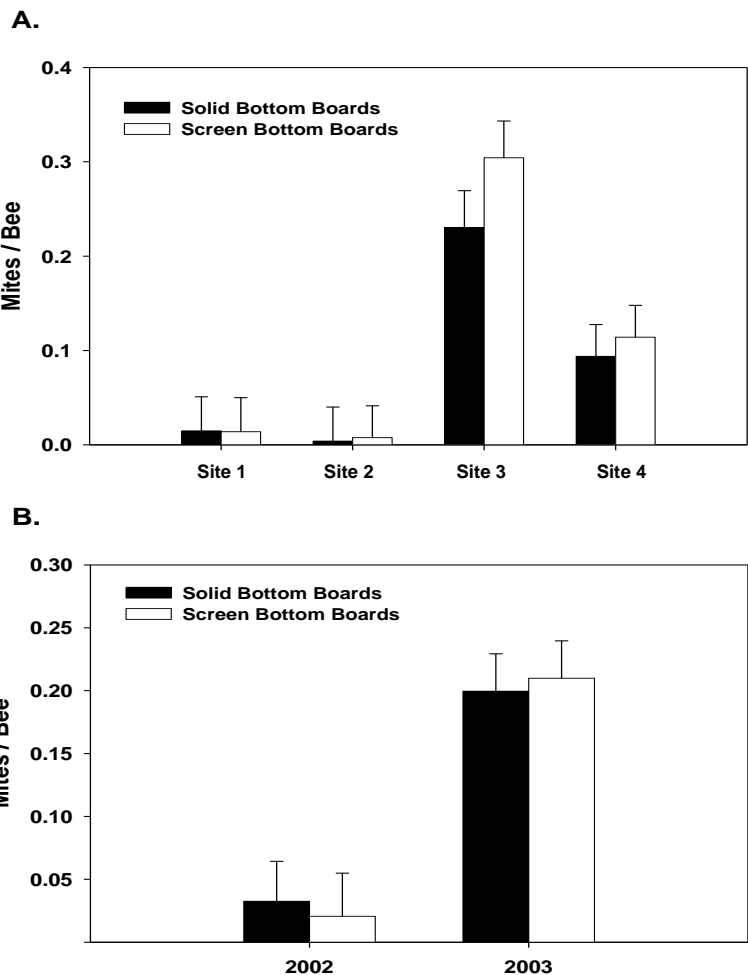


Figure 2. September mite-to-bee ratios in colonies with and without screen bottom boards during the spring and summer. No significant differences were found.

number of mites. Attend your bees, especially in the spring, when swarming is likely, and take all necessary steps to prevent it. Remember! A colony that you allow to swarm not only has created a future threat to your bees; it also will not produce nearly as much honey as if it had not swarmed.

Isolation

One way to reduce the rate at which mite populations rebound after treatment is to keep apiaries isolated from each other. Increasing the distance between apiaries reduces the chance of re-infestation from nearby collapsing colonies. A separation of three miles will provide some protection, while a separation of five miles is better. Isolation is not practical where colony density is high, and isolation cannot guarantee that your bees will not be re-infested because there may be wild colonies in the area. However, this method should not be overlooked when selecting apiary sites.

Treatment Regimes

Modified traditional program (without drone brood removal and without economic thresholds)

If you do not base your treatment decisions on an estimate of pest density, you will need to treat your colonies twice each year: once in the late winter or early spring and once near or immediately after the end of the goldenrod flow. However, even that may not be sufficient. Therefore, inspection for evidence of parasitic mite syndrome prior to the start of the fall flow is highly recommended, although it is not as effective as estimating pest density.

Late winter or early spring:

! Treat colonies with Mite-Away II™, Apistan® or CheckMite+®.

Late summer (about 2 weeks before start of goldenrod flow):

! Inspect colonies for symptoms of parasitic mite syndrome. Remove all marketable honey from colonies with symptoms and initiate treatment with Apistan® or CheckMite+®. Mite-Away II™ (formic acid) will not work well at this time due to the presence of large quantities of brood. Procrastination at this stage will result in the loss of your colony.

! Provide treated colonies with empty supers for fall honey production. Honey produced while pesticides are present in the hive may not be used for human consumption. However, it may be used as feed for other

colonies. This allows a beekeeper to remove both the surplus honey and the winter stores from healthy colonies that were not treated during the fall flow and to replace their winter stores with surplus honey from colonies that were treated. Using this method, you save the bees and harvest the same amount of honey.

Late summer - early fall (when the goldenrod flow is about 80% complete):

! Remove surplus honey.

! Reduce colony to two, full-depth hive bodies.

! Treat with an approved pesticide. Note! Mite-Away II® should be applied after the majority of brood rearing has ended but while daytime temperatures range between 50 and 79 °F. In Ithaca, NY we initiate treatment with formic acid during the last week of September or first week of October, but not earlier and not later than that.

Basic IPM program (without drone brood removal but with economic thresholds):

The best strategy for using a pesticide is to apply it only when the pest density reaches the economic threshold, that is, the level at which you must control the pest or expect to experience damage to your colonies.

Late winter or early spring:

! Treat colonies with Mite-Away II®, Apistan® or CheckMite+®.

Late summer (about 2 weeks before start of goldenrod flow):

! Estimate pest density in each colony with the ether roll.

! If an ether roll count is less than or equal to three, or if you observe any symptoms of parasitic mite syndrome, remove all marketable honey from that colony and initiate treatment with Apistan® or CheckMite+®. Mite-Away II® (formic acid) will not work well at this time due to the presence of large quantities of brood. Procrastination at this stage will result in the loss of your colony.

! Provide treated colonies with empty supers for fall honey production. Honey produced while pesticides are present in the hive may not be used for human consumption. However, it may be used as feed for other colonies. This allows a beekeeper to remove both the surplus honey and the winter stores from healthy colonies that were not treated during the flow and to replace their winter stores with surplus honey from colonies that were treated. Using this method, you save the bees and harvest the same amount of honey.

Late summer - early fall (when the goldenrod flow is about 80% complete):

- ! Remove surplus honey.
- ! Reduce colony to two, full-depth hive bodies.
- ! Estimate pest density in each colony with the ether roll.
- ! If an ether roll count is more than or equal to two, treat that colony with an approved pesticide. Note! Mite-Away II® should be applied after the majority of brood rearing has ended but while daytime temperatures range between 50 and 79 °F.. In Ithaca, NY we initiate treatment with formic acid during the last week of September or first week of October, but not earlier and not later than that.

Intensive IPM program (with drone brood removal, formic acid and economic thresholds)

The best strategy is to suppress mite populations during the summer with a non-chemical method, and then to treat with a natural product in the fall if the pest density exceeds the economic threshold. Drone brood removal can eliminate the need for a spring treatment and prevent fall collapse. Occasionally, it will result in the fall ether roll count being below the economic threshold level, eliminating the need for that treatment as well. Incorporating both drone brood removal and mite resistant stock into your management program may increase the number of colonies that do not require a fall treatment. At this time, it is recommended that you use a spring treatment if you did not use a treatment the preceding fall.

Late winter or early spring:

- ! Make sure two empty drone combs are present in the upper brood chamber.
- ! No chemical treatment is necessary at this time if the colony was effectively treated with a miticide the previous fall.

Apple blossom until just before the end of the goldenrod flow:

- ! Use drone brood removal every 26 to 28 days with the last exchange taking place when surplus honey is removed just before the end of the goldenrod flow. If a drone comb becomes filled with honey, replace it with an empty comb and extract the honey before reusing it.

Late summer (about 2 weeks before start of goldenrod flow):

- ! Requeen with mite resistant stock and check for acceptance in seven days.

Late summer - early fall (when the goldenrod flow is about 80% complete):

- ! Remove surplus honey from colonies.
- ! Reduce colonies to two full depth hive bodies.
- ! Determine pest density in each colony with the ether roll.
- ! If an ether roll count is ≥ 2 , treat that colony with Mite-Away II® (photo J). Note! Mite-Away II® should be applied after the majority of brood rearing has ended but while daytime temperatures range between 50 and 79 °F. In Ithaca, NY we initiate treatment with formic acid during the last week of September or first week of October, but not earlier and not later than that.
- ! If you do not need to treat a colony in the fall, you should treat it the following spring.

Notes on treatment regimes

Be sure to determine if the mites in your colonies are resistant to Apistan® or CheckMite+® before applying either of those products. Always use the appropriate product. There is no known resistance to formic acid (Mite-Away II) at this time.

Sucroicide™ and Api-Life VAR® are not included in the treatment regimes at this time because there is insufficient data available on which to base such recommendations. Preliminary tests have found Sucroicide™ to be ineffective in the northeast. It is also very labor intensive. Previous work with Api-Life VAR® was based on a single application and yielded highly variable results. Current label in-



Photo J. A formic acid pad similar to the Mite-Away II™ pad.

structions call for three applications at seven- to 10-day intervals. This may prove more effective, but confirming studies have not been published. Treatment regimes will be updated as information becomes available.

The drone comb exchange method must be used as indicated above in the 'Implementation' section. NEVER leave drone combs in colonies unless you are going to exchange them **at least** every 28 days.

Ether roll counts given above are 300-bee counts.

Other treatment regimes for *V. destructor* are constantly being evaluated by a number of researchers, and the number of available options is increasing rapidly. Check with your local extension apiculturist for the most recent updates before implementing any IPM program.

Important terms

drone and worker comb: wax comb built by bees for storing honey and pollen and for rearing drone (male) and worker (female) honey bees, respectively. The cells that make up drone comb are slightly larger than those that make up worker comb.

larva: the feeding stage of an immature insect.

pupa: the quiescent stage of an immature insect during which time it undergoes dramatic physiological and morphological changes as undergoes the transition from the larval stage to the adult stage.

brood: the immature stages of the honey bee, including the egg, larval and pupal stages. Immature workers and drones develop in worker and drone cells, respectively. Queens are reared in special queen cells, which are seasonal and relatively few in number.

capped stage: the period when a cell containing an immature bee is capped with wax. A brood cell is capped from the late larval stage until the bee emerges from the cell as an adult.

hemolymph: insect blood.

pest density: the number of pests in a sample of known size. Mite density can be measured several ways. Some of these include the number of mites per adult bee, the number of mites per 300 adult bees, or the number of mites in a

standard volume of adult bees.

economic injury level (EIL): the lowest pest density that causes economic damage.

economic threshold level (ETL): the pest density that triggers an action designed to prevent the pest population from reaching the economic injury level. The ETL is always less than or equal to the EIL.

pesticide: includes many kinds of ingredients used in products, such as insecticides, miticides, fungicides, rodenticides, insect repellants, weed killers, antimicrobials, and swimming pool chemicals, which are designed to prevent, destroy, repel, or reduce pests of any sort.

pyrethroids: a class of synthetic pesticides with chemical structures similar to pyrethrum, a naturally-occurring substance in chrysanthemums with pesticidal activity. Generally, moderate to high doses of pyrethroids are necessary to cause acute toxicity in mammals. Apistan® (fluvalinate) is a pyrethroid used for controlling *V. destructor*.

organophosphates (OP's): a class of synthetic pesticides containing phosphorous. Generally, very low doses of OP's can cause acute toxicity in mammals. OP's can also cause cumulative, irreversible nerve damage at sub-lethal doses. CheckMite+® (coumaphos) is an OP registered for control of *V. destructor* in some states.

organic acids: a group of carbon-bearing acids, including acetic, formic, lactic and oxalic acids. Organic acids can cause severe burns to the skin, eyes and respiratory system. Mite-Away II™ is a formulation of formic acid registered in the US for control of *V. destructor*.

essential oil: the volatile and aromatic liquid or semi-solid obtained from a single botanical species, primarily through a distillation, expression or extraction process. Essential oils are blends of many compounds, the various compounds being natural products, many of which act as antibiotics and/or pesticides. One such compound, thymol, is derived from thyme oil and is the primary active ingredient in Api-Life VAR™, a product registered for control of *V. destructor* in some states.

tolerance: the maximum residue limit, which is the amount of pesticide residue allowed to remain in or on a treated food commodity. If residues exceed the tolerance level, the commodity is subject to seizure and destruction.

Some pesticides are exempt from tolerance (e.g. formic acid), while others have a time-limited exemption that must be periodically renewed (e.g. thymol, menthol and eucalyptus oil).

off-label use: the use of any registered pesticide in a manner inconsistent with its label.

Integrated Pest Management (IPM): a pest management program based on the coordinated use of multiple tactics (including biological, cultural, genetic, mechanical and chemical) and environmental data (pest densities, economic thresholds) and designed to maintain pest populations below the economic injury level with the least disruption to the environment.

SARE Research Synopsis

Research on the efficacy of drone brood removal for the management of *V. destructor* in colonies of the honey bee *A. mellifera* L. was funded by Northeast SARE, USDA and the Organic Farming Research Foundation (Santa Cruz, CA). Experimental colonies were treated with CheckMite+ in the fall. The following spring, quantities of bees and brood were equalized, but colonies were not re-treated. The brood nest of each colony consisted of 18 full-depth worker combs and 2 full-depth drone combs housed in two, 10-frame hive bodies. Each worker comb had < 12.9 cm² of drone cells. Drone combs were kept in the second and ninth positions of the upper brood chamber.

Standard management practices were used throughout the season, including the addition of honey supers above a queen excluder. Colonies were randomly assigned to one of two groups. In the control group, drone combs remained in place throughout the season. In the treatment group, drone combs were removed on June 16, July 16, August 16 and September 16 and replaced with empty drone combs (16 June) or with drone combs removed on the previous replacement date. In the early fall, the average mite-to-bee ratio was significantly greater in the control group than in the treatment group (figure 1).

Drone brood removal did not adversely affect colony health as measured by the size of the worker population or by honey production. Fall worker populations were similar in the two groups. Honey production in treatment colonies was greater than or similar to production in control colonies. These data demonstrate that drone brood removal can serve as a valuable component in an IPM program for

V. destructor and may eliminate the need for other treatments on a colony-by-colony basis.

Research on the efficacy of screen bottom boards for the management of *V. destructor* in colonies of the honey bee *A. mellifera* L. was funded by Northeast SARE, USDA and the Organic Farming Research Foundation (Santa Cruz, CA). The study extended over three years.

In the first year, 64 colonies were randomly assigned to one of two groups: a treatment group in which colonies received screen bottom boards and control group in which colonies received regular, solid bottom boards. Equal numbers of colonies from both groups were randomly assigned to four apiary sites for evaluation. In both the second and third year, 32 colonies were randomly assigned to one of two treatment groups, but colonies were kept in a single apiary each year. Mite-to-bee ratios were estimated in the early fall each year.

The average mite-to-bee ratio in the treatment group was not significantly greater than the corresponding ratio in the control group in any year (figure 2). Screen bottom boards did not adversely affect colony health as measured by the size of the worker population or by honey production. Fall worker populations were similar in the two groups. Similarly, seasonal honey production was similar in the two groups. These data demonstrate that screen bottom boards do not provide any benefit as a mite control tactic during the honey producing season.

This fact sheet is based on a SARE-funded project. For more information, please visit www.sare.org > Project Reports > 'Search the Database' for project #LNE00-130



References

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