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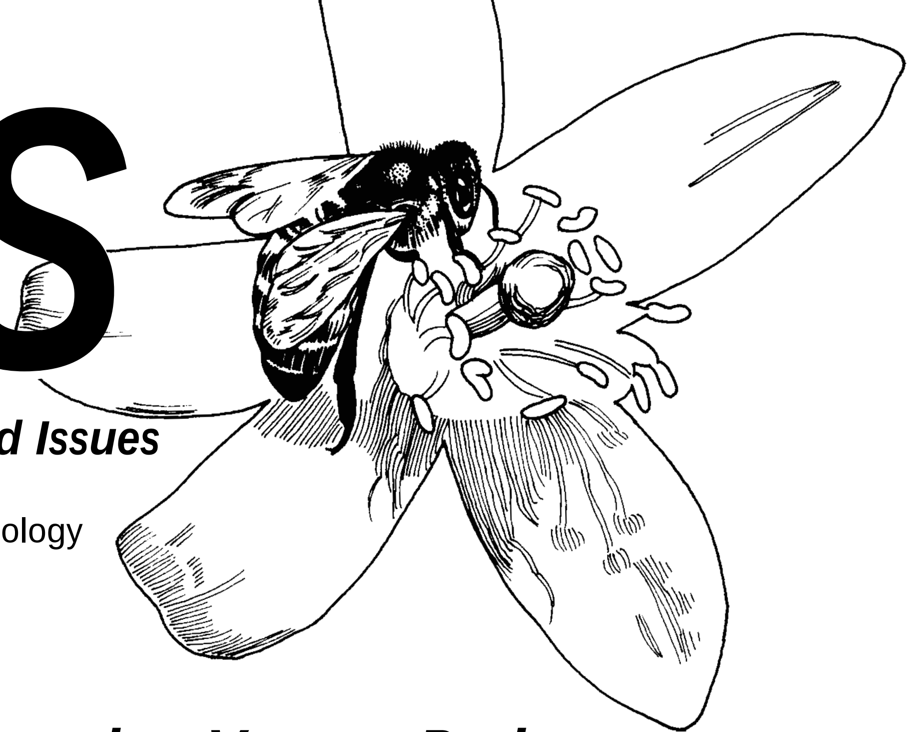

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Managing Varroa Resistance to Pesticides: Not IF but WHEN

It seems many in the beekeeping community continue to be dismayed that Varroa is becoming resistant to fluvalinate[1]. Most authorities believed it would only be a matter of time. There was also ample warning from Europe; it should not have been a surprise[2]. Even now, resistance does not yet appear to be widespread. The industry is fortunate to have had 10-plus years of service from Apistan®, formulated on fluvalinate. Nevertheless, resistance has now been detected and it has caused another pesticide to be launched, coumaphos, formulated as Bayer Bee Strips[3]. Already in back of some minds is the realization that this chemical, too, will spawn generations of resistant mites. Even more frightening is the possibility that mites will emerge resistant to both legal materials.

Development of resistance to pesticides is not new to arthropods, those hard-carapaced, joint-legged animals (insects, spiders, ticks, scorpions, shrimp, crabs) that are the most successful group of organisms on earth. Many of these creatures have had to develop mechanisms to neutralize materials plants employ against them. This is usually done through compounds called enzymes. This adaptable group of chemicals is responsible for much of what goes on in life. Humans use them, for example, to help digest starch; honey bees employ them to assist in converting the complex sugar (sucrose) into its component simpler parts (fructose and glucose) that are the major ingredients of honey. Plant eaters use enzymes to help detoxify poisonous materials found in plants. Taking the process one step further, some arthropods incorporate toxic materials from plants into their own bodies for defensive purposes. Perhaps the best example of this is the monarch butterfly. Its larva feeds with impunity on the milkweed plant full of lethal cardiac glycosides. These are then incorporated into the adult making it poisonous to predators[4].

With any hard insecticide or miticide, therefore, the concept that reigns supreme is not **if** an arthropod will become resistant, but **when**. Over the years, many agriculturalists have not taken this to heart. Instead they have blamed the product or attempted to find another culprit for the inevitable resistance when it makes its appearance. In this regard beekeeping is decades behind other agricultural endeavors[5]. U.S. apiculturists, in fact, were able to bask in the knowledge that they were not under the same constraints as other agriculturists. For decades, many beekeepers unflinchingly vilified growers who used toxic materials that often resulted in honey bee loss. The ability to take the high ground, even gloat over *Continued next page*

1 http://www.ifas.ufl.edu/~mts/apishtm/apis98/apapr98.htm#1
2 http://www.ifas.ufl.edu/~mts/apishtm/apis97/apmar97.htm#3
3 http://www.ifas.ufl.edu/~mts/apishtm/apis99/apjan99.htm#1
4 http://home.ici.net/customers/midgef/butfly.html
5 http://www.ifas.ufl.edu/~mts/apishtm/apis93/apnov93.htm#3

> "Now beekeepers are forced to learn the same lessons others before them have."

the fact that this was not a part of apiculture, crashed in flames when the first Varroa mite was detected in 1987. Beekeepers literally tore the fence down moving en masse from the pesticide-nonemployment to the application side. Subsequently, they went through the same stages of denial when resistance began to appear, blaming first the product and manufacturer, before it was finally confirmed to everyone's satisfaction. Now beekeepers are forced to learn the same lessons others before them have. This includes not only adapting to higher costs, but trying to comply with intricately worded labels and coming to grips with the fact that resistance to almost any pesticide is always there and sooner or later will show its head.

Resistance is a fact of life in production agriculture. Some 450 species of arthropods are now resistant to at least one, or in some cases, several pesticides[6]. Perhaps the champion is the Colorado potato beetle (CPB). This insect has developed resistance to 15 separate chemicals since 1950; the only sure way to kill it now is to use a blowtorch on stubble fields. The phenomenon also has been seen in all kinds of insects from flies to mosquitoes. Fortunately, beekeepers can take advantage of this experience in trying to manage resistance in their own field. It turns out a preferable word may be mitigate, connoting a more active approach to slowing the phenomenon's appearance.

The resistant developmental process is a moving target. Many shades of gray make the phenomenon difficult to detect. A semantic controversy engaged in by some is the use of the word tolerance rather than resistance. No matter which is used, the best practical definition is when a treatment no longer works. However, such a determination may not be obvious. This remains a particular problem with Varroa because it is such an integral part of the honey bee colony. Dr. Jeff Pettis at the Bee Research Laboratory in Beltsville, MD has developed a practical test to determine resistance to Apistan® (fluvalinate)[7]. This may be modified to get a relative idea of how far the phenomenon has progressed. Results should also be compared with tests in the field using ether roll, sticky board technology or past experience in controlling Varroa mites to further determine their validity.

The appearance of resistance looks to be yet another example of Garrett Hardin's "Tragedy of the Commons[8]." Dr. Marjorie Hoy, eminent scholar–Davies, Fischer and Eckes professor of biological control, of the Department of Entomology and Nematology here at the University of Florida, recently gave a seminar on the development of the phenomenon, the source of much of the information provided here. She says it is strictly a matter of the number of applications, the residue length, and the genetics of the pest, and is the collective fault of both the companies producing pesticides and consumers using them. Her conclusion is that the only truly effective way to prevent resistance is to stop using pesticides.

If one looks at other examples of resistance to pesticides in production agriculture, it becomes more obvious why this occurred for Varroa. Perhaps the most important factor is prolonged exposure to one pesticide. Certainly this was the case with Apistan®, the only legal, effective material applied for over a decade to many generations of mites. Selection pressure was also very high. Apistan® may have been too good in restrospect. It killed off over 98 percent of the mites, but didn't get them all. Those left over became a potent source for a resistant population to emerge. The idea that bee populations must be cleared totally of Varroa also contributed greatly. In the beginning and continuing to this day, the concept of Varroa eradication (i.e. "Varroa-free") persists. As a result, many beekeepers treat when they see only one mite; some leave treatments in over prolonged periods and others may apply the material prophylactically, just like treating for American foulbrood using Terramycin®. Other factors that contributed were strong links between Varroa and its host (they feed and reproduce only on honey bees). The ability to be carried on the backs of flying bees from one colony to another adds a significant reinfestation dimension.

Factors responsible for development of resistance to pesticides, according to Dr. Hoy, are generally grouped into two major categories: controlled and uncontrolled. Unfortunately, most fall into the latter category. In general, these are genetic, biological and ecological. The mite's genetics and biology remain much of an enigma. Its ecology does too. Many of its behaviors are obscured because Varroa lives integrated within a colony of social insects, itself very complex. Only basic research on this relationship is likely to reveal any more insight beekeepers might use to actively control the mite without using pesticides. A few have been identified, particularly use of drone trapping and specially designed sticky or Varroa trapping boards[9]. This basic study, unfortunately, is often subrogated to pesticide development and application.

It is not surprising that most research and funding in Varroa control has concentrated on toxicological work. This is the one area where the beekeeper and researcher have the best and easiest control. In this kind of work, formulations and applications can be actively tweaked and their effectiveness quickly measured. It is also where the money is. The materials developed are often viewed as "magic bullets" that will take care of the problem in an extremely effective, quick-acting and relatively inexpensive manner. The downside is the long-run certainty of resistance when the pesticide development process must begin anew. Unfortunately, there is little incentive on the part of entrepreneurs to invest in other areas. This is the case with natural products or processes, which although they may be effective, do not represent the best possible return on an economic investment. Again, much of this is also true in other forms of production agriculture. Indeed, the loss of legally registered chemicals in small crops not warranting huge economic investments continues to be a crisis all across the agricultural spectrum.

According to Dr. Hoy, models of pesticide resistance management have been developed by researchers where the phenomenon has been detected. However, debate continues about how effective each is. Apiculture appears to have gone through several types on its way to its present situation. Some of this experience may be pointed to as an example of why models don't work as well as researchers would like. Saturation uses high doses of chemicals in an attempt to overcome any resistance that might be present. This is often employed for high-value crops like apples. Synergists have even been used to make already-toxic materials more poisonous. These are very hard on nontarget organisms (the environment). However, in many systems of this nature resistance appears. Much of this is applicable for Varroa. In the beginning, low treatment thresholds, the idea of "mite-free colonies," meant that a lot of treatment was probably carried out that was not absolutely necessary. The now-illegal use of Maverik®-soaked wooden strips, originally carrying a Section 18 label, is an example of saturation, as is reported use of other non registered materials (e.g. amitraz formulated in Ovicin®). Dr. Bill Wilson reported at this year's American Beekeeping Federation in Nashville on Dr. Patti Elzen's work revealing that in fact amitraz resistant mites have been detected in managed bee populations.

Another strategy is moderation. Its philosophy is to reduce the selective pressure and conserve organisms (genes) that are susceptible. This means less frequent applications with relatively low dosages of less toxic chemicals. Some beekeepers are moving in this direction, applying materials only when absolutely necessary and using less than the recommended dosages. Unfortunately, there is controversy in this arena, with some investigators suggesting that underdosing actually contributes to resistance development. This points to the fact that the genetic cause of resistance is often unknown. In addition, the lack of suitable action threshold levels for Varroa works against this concept[10].

Multiple attack appears to be the model beekeeping is now leaning toward. This is characterized as a rotational philosophy involving several pesticides. Again this has been employed in other high-value crops and some medical emergencies. Whether to rotate or mix chemicals is vexing, according to Dr. Hoy. Mixing might enable them to be used at lower dosages. Beekeepers now find themselves with two legal materials. Whether to choose mixing or rotating, however, is a question that cannot easily be answered in this case because there is not enough information about the mechanism of resistance by Varroa. Because two classes of pesticides (pyrethroids and organophosphates) are being employed, however, rotation is considered the best strategy and beekeepers are asked not to use both materials simultaneously.

Another problem found in production agriculture is that after pesticide use, pest populations may rebound to higher levels than before. This resurgence is often the result of killing off natural enemies of the pest species during the application process. To date, no such organisms have been found for Varroa. Finally, replacement can occur in many systems. Organisms that are not a problem or pest may become one as a consequence of trying to control another pest species. The specter of the small hive beetle for beekeeping is raised here. Is it possible that the beetle has been around a longer time than thought and only showed itself as problematic after colonies were exposed to chronic dosages of pesticides for Varroa control?[11]

There are other risks of pesticide use. Evidence suggests that sublethal doses of fluvalinate can lead to problems such as queen supersedure[12]. There have been increasing numbers of complaints about queen survival and introduction from consumers of package bee and queen operations, which routinely include pesticide strips in their shipments. Newer research shows that drones taken from treated colonies are less likely to successfully mate with queens and may have shorter life spans than males from untreated hives. In addition, there is always the possibility of contaminating bee products, the bee nest (beeswax) or even the bees themselves.

In the end, as Dr. Hoy recommends, only by reducing use of pesticides can beekeepers come to grips with either effects of sub lethal pesticide doses or resistance. This is the stated goal of integrated pest management (IPM), a technology that relies on a careful estimation of the pest population. The number of insects (or mites) causing measurable economic loss to a crop (or bee colony) is referred to as the economic injury level (EIL). IPM practitioners attempt to find a level of pest population that will provide the best indication that economic injury is likely to occur. At that point, and only at that point, are active measures (e.g. pesticide application) taken to reduce the pest population. This is called the economic threshold (ET). For example, in a bean crop it might be determined that only when there is a certain amount of leaf damage, which translates into a specific number of caterpillars on a plant, is pesticide application necessary. A key element here is the realization that some pest population will always be present in beans and that economic production can be supported at some level without treatment. A corollary is that eradication is impossible and should be dismissed as a possibility[13].

Appearance of resistance in Varroa indicates that the low thresholds being used, in some cases the presence of a single mite, should now be revisited. It is reported that some bee populations can tolerate a certain number of mites without treatment in both Brazil and México[14]. The same is probably true of colonies in the United States. Because U.S. beekeepers have had at their disposal the economic resources to employ pesticides, however, treatment threshold levels have as a matter of course been set very low. In other words, beekeepers in this country have had the luxury of not having to set reasonable economic thresholds. If one looks carefully around the world, however, the pesticide action thresholds are higher, and in some cases non existent, as is the case in Vietnam.

There are other ways besides pesticides to keep the mite populations below damaging levels. These include trapping them in drone brood, on sticky boards and by specially designed bottom boards. Another strategy is to identify Varroa-tolerant honey bees and then propagate them. This is currently being done through the Baton Rouge Bee Laboratory. At the present time, honey bees from eastern Russia (Vladvostok) have been taken out of quarantine and tests will begin this spring to see how tolerant these bees are to U.S. Varroa. An advantage of these is that beekeepers could do this technology on their own, basing their results on experience and thus reducing the eventual amount of pesticide use in colonies. Unfortunately, this is a long-range solution not suitable to most beekeepers.

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7 http://www.ifas.ufl.edu/~mts/apishtm/apis98/apapr98.htm#2
8 http://members.aol.com/trajcom/private/trajcom.htm
9 http://www.ifas.ufl.edu/~mts/apishtm/apis98/apdec98.htm#6
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14 http://www.ifas.ufl.edu/~mts/apishtm/apis97/apmay97.htm#2

In addition, a greater challenge than finding a genetically tolerant bee population will be keeping it, given the complex nature of the honey bee's mating system[15].

Other strategies to reduce pesticides include the use of smoke[16]. Other so-called soft chemicals such as natural acids, essential oils or botanicals are also a possibility. Although a few of these "natural products" have been shown to be somewhat effective, they do not kill the number of mites as do registered hard pesticides. However, resistance to these materials may not prove to be as problematic. Methods in applying such chemicals, however, have not been worked out, are full of risk for bees, and the action thresholds are unknown[17]. It is useful to remember that most natural products or biopesticides are poisonous compounds that plants have made to ensure their consumption more risky and less likely. Their use may also be construed as illegal or non registered materials by regulatory authorities, and they are capable of contaminating a honey crop. One product in this arena that might soon be available is formic acid, now used widely in Europe[18]. This material has also been found effective for tracheal mite control.

Most of the control methods suggested above are active. They are applied or exerted by the beekeeper. However, another group should not be forgotten. These are referred to as passive, or collectively called "good bee management." With all the folderol about mites, and now the small hive beetle, the fact that honey bees can often take adequate care of themselves is easily overlooked[19]. This paradigm changed considerably with the coming of Varroa, which has a fatal, immature relationship with the honey bee. Research has shown that well-nourished bees, for example, overcome effects of parasitization by Varroa better than less-nourished sisters. Other forms of stress can also lead to a weak response to Varroa and may be somewhat responsible for what has been called Bee Parasitic Mite Syndrome (BPMS)[20]. The Varroa mite's depredations along with effects of other organisms (tracheal mites, American foulbrood, nosema) and reduction of proper nutrients in a polluted, human-developed environment may result in what one wag has dubbed SAD and BAD bees[21]. Excessive moving and manipulating bees in migratory honey production or commercial pollination, taking the insects' honey and feeding them syrup in return, and over-smoking them during inspections all contribute to a weaker organism.

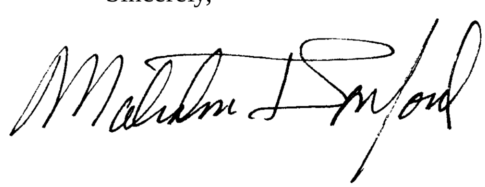
In conclusion, like many other areas of production agriculture, beekeepers have begun a stint on what is called the "pesticide treadmill." This means relying and concentrating on continuous and often increasing use of more and more powerful pesticides. Like any addiction, reliance on chemicals is difficult to extricate oneself from. Going "cold turkey" is extremely painful and economically fatal. The one hope beekeepers have is the use of integrated pest management to reduce the amount of hard chemical use through a variety of alternative measures to help control the Varroa mite population in a colony. This means that adequate thresholds must be established for each control measure, something that present reliance on pesticides mitigates against. In the process, beekeepers can take advantage of the honey bee's built-in passive controls by eliminating as many stresses on colonies as possible. This has always been the hallmark of the true bee master, one who can work within the confines of the honey bee's elaborate biological and social systems to help this insect at critical times, but at the same time not hinder a colony from achieving its collective goals. ■

GardStar® Labeled for Small Hive Beetle

I AM IN RECEIPT of information that GardStar 40% EC, an emulsifiable concentrate containing 40% permethrin under EPA Reg. No. 39039-8, which has been registered in all 50 states for numerous pest control uses is now approved for for small hive beetle. It may be used any time of year as needed by sprinkler can application to the ground in front of bee hives and by low-pressure spray application to apiary grounds for pest cleanup prior to hive placement.

The product is packaged in 4 fl. oz. bottles with a 15-ml self-dispensing chamber that is graduated in 2.5 ml increments for easy mixing. Permethrin is toxic to bees by contact, so care must be taken that colonies are not at risk during application. As with all pesticides, the product must be used according to label instructions. ■

Sincerely,



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