Managing *Varroa Mites*: Lessons Learned from Large Scale Honey Bee Field Trials

by JAMES D. MASUCCI

Most beekeepers and bee researchers agree that *Varroa destructor* mites and the viruses they spread are the top threat to beekeeping today. The threat of varroa is even more lethal when you combine the mite infestation with other stress factors that impact honey bees. Therefore, it is critical for a beekeeper to establish a mite management strategy. Establishing a strategy requires an understanding of the dynamics of mite populations throughout the year, how they respond to treatments, and how they affect colony health. Over the course of conducting large honey bee field trials to develop a biological mite control product, we've obtained a large data set looking at mite infestations, tools and timing for mite control, and the impact on honey bee colony health. The lessons that came out of our data should assist you in making your colony management decisions.

The data in this article are from a field trial with over 2000 hives, lasting 22 weeks. The trial was conducted at 11 locations throughout the U.S. (see Table 1) in cooperation with 10 commercial beekeepers. The trial initiated in the spring and ended in the fall, with start dates varying depending on the location and beekeeper operation. Six different treatment regimens were evaluated: a negative control (untreated), a positive control (a single, 8-week spring treatment with Apivar, a commercially-available mite-control strip), and 4 experimental treatments (to be discussed in a later article). In this article the focus will be on the two control treatments; Apivar-treated vs untreated colonies. There were 40 colonies per treatment at each location. Colonies were assessed for strength, queen status, and disease every 2-3 weeks and mite counts were performed every 2-6 weeks. By comparing treated versus untreated colonies we learned about the complexity of the interactions between mites, honey bee colonies, and the environment. These lessons should be shared, to help beekeepers better develop efficient mite management plans.

Lesson 1: Don't let mite levels get too high. You never quite recover from high mite loads.

Apivar strips were placed in the colonies at the start of the trial and remained in the colonies for 8 weeks with regular colony assessments/observations occurring over the next 14 weeks. Figure 1 compares the survival of colonies treated for mites (with the commercially available miticide) to the survival of non-treated colonies across all 11 locations in the field trial. At the start of the trial, the average mite load for all locations was ~2.3 mites per 100 bees. By the end of the trial, 22 weeks later, 73% of the treated colonies were still alive but only 38% of untreated colonies survived. That's a lot of colonies that were saved by just a single mite treatment in the spring, and it was surprising how quickly the untreated colonies succumbed to the mite pressure.

From these data alone, it makes sense to manage mites for optimal colony health. But when should you treat, and is it equally effective to

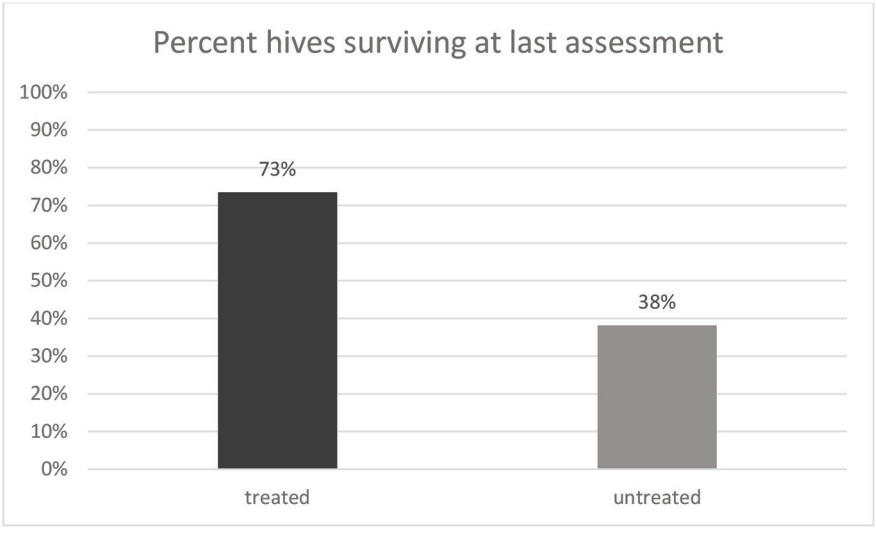

Fig. 1 *Figure 1 shows the percent of the starting colonies that were alive at the last assessment of the 22-week trial. Treated colonies received an 8-week Apivar treatment at the start of the trial whereas the untreated colonies did not. There were 440 starting colonies in each treatment spread out over 11 locations.*

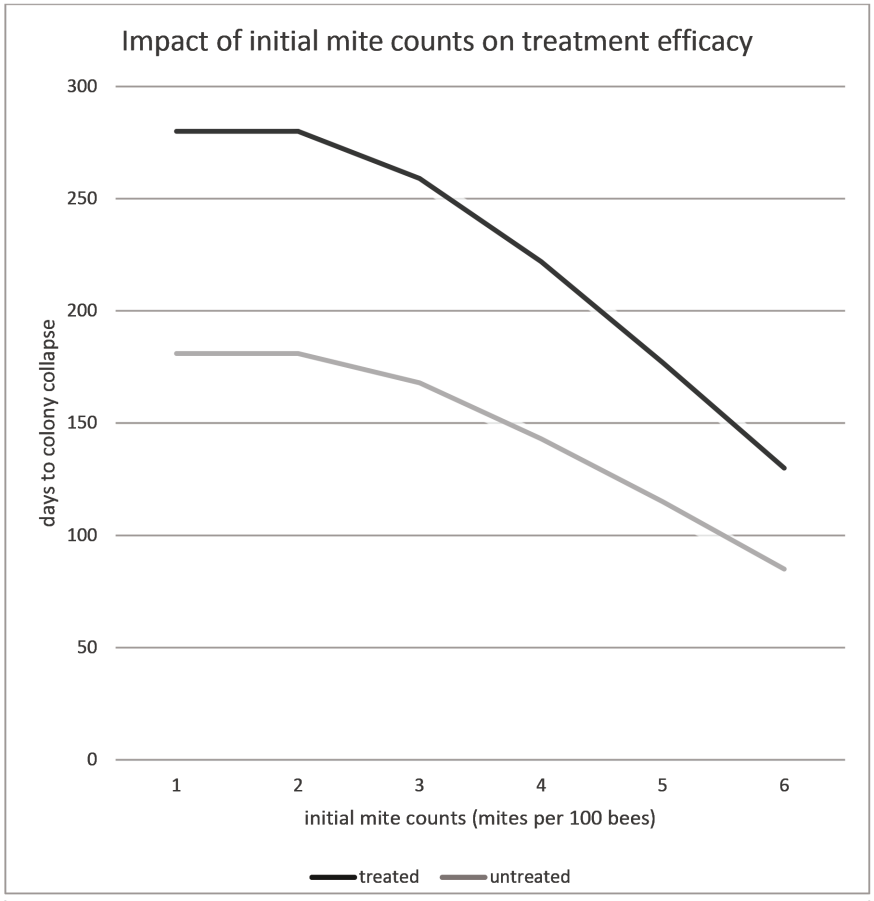

Fig. 2 *Model of the impact initial mite counts have on treatment efficacy and colony survival. The Y-axis is days to colony death. The X-axis is the initial mite counts in mites per 100 bees. The data used to generate the model was the number of days to the first assessment date when a colony was noted to have died. The distribution of dead colonies allowed the model to predict how long a colony with a given initial mite load would survive.*

	Starting mite load (Spring)		Surviving Colonies (Fall)	
Location	treated	untreated	treated	untreated
CA-1	0.3	0.4	47%	31%
ND-1	0.6	1.0	85%	27%
LA-1	0.8	1.1	65%	58%
TX-1	1.0	1.0	dnf	dnf
FL-1	1.1	0.5	83%	25%
ND-2	2.4	1.6	81%	9%
TX-2	2.6	1.3	38%	5%
ID-1	4.1	4.4	dnf	dnf
CA-2	4.2	4.0	dnf	dnf
NY-1	4.3	4.9	dnf	dnf
NC-1	4.3	4.4	89%	74%

Table 1 *Starting mite counts and the colony survival observed at each individual location over the 22-week trial. "Dnf" indicates that more than 50% of the untreated colonies died before the trial ended and did not finish the trial. In all cases, treated colonies fared better than untreated colonies.*

treat colonies with mite levels at 3 mites/100 bees as treating colonies with 6 mites/100 bees? To answer this question, all the individual hive data were used to model survival times for colonies with different starting mite infestation levels. The output of the model (Figure 2) shows that the time to colony death does depend on the starting mite infestation level. The lower the mite levels are at the time of treatment, the longer a hive is expected to survive. More importantly, the results highlight how the mite infestation level impacts the efficacy of the treatment. Treatment efficacy is optimal if mite loads are 2 mites/100 bees or lower. At this point, treated colonies are expected to survive about 280 days whereas untreated colonies are expected to last only 180 days (which was statistically significant). When the starting infestation level is 6 mites/100 bees, the expected lifespan of the treated colonies drops to 130 days, and the untreated control only survives to a mere 85 days, highlighting the need for excellent monitoring to inform varroa management.

Why is this the case? Previous studies have shown that virus levels, especially deformed wing virus (DWV), correlate with mite levels (Nazzi et al., 2012) and it has been shown that the viruses are a component to the colony's decline (Highfield, et al., 2009, Nazzi et al., 2012). In addition, studies have shown that virus levels can persist long after mite levels are reduced by miticides (Locke, et al., 2017). If you allow your colonies to get heavily infested with mites, you are doing long-term damage to the colonies that cannot be overcome by only treating for mites at that point. Therefore, it's best to keep mite levels under control rather than trying to rescue colonies with severe mite loads that have damaged bees and are more likely to be heavily infested with viruses.

The observation that mites cause long-term damage is also apparent when you look at starting mite counts at each location. Table 1 shows the starting mite levels and the survival rates of the treated and untreated colonies at each location in the trial. The trial started with 11 locations. Each location remained in the trial as long as 50% or more of the untreated control colonies survived. Of the 11 starting locations, 4 had mortality rates of the untreated control colonies that were high enough to remove them from the study (TX-1, ID-1, CA-2, and NY-1). Three of the 4 locations that had high mortality rates also had the highest initial mite levels at the start of the trial. Their levels were greater than 4 mites/100 bees. In the same way, 6 of the 7 locations that completed the trial started with less than 3 mites/100 bees. Also evident in Table 1 is the observation that treated colonies had a higher survival rate than untreated colonies at all 7 locations that reached the trial's endpoint.

Also apparent from our data is that colony survival is not as simple as choosing the appropriate mite level and treating. For example, if you compare the two locations with the highest initial mite levels, NY-1 and NC-1, you see that both locations started with approximately the same mite levels. However, NY-1 had to be removed from the trial whereas NC-1 had one of the best survival rates in the trial. Clearly, there is something more than just mite levels in play. It could be due to pathogenic infections (as discussed above), environmental

factors, or some combination of stress-factors causing the decline of those NY-1 bees.

The comparison of NY-1 with NC-1 shows how different apiary locations had different outcomes. Variability in outcomes was observed between and within locations, and this leads to the second lesson:

Lesson 2: Don't rely on your neighbor's assessment. Mite effects vary by location and even by colony.

Anyone who has inspected multiple hives knows that each hive has its own personality. If you have bees in multiple yards, you know that each yard can be dramatically different. In our trial we measured the same parameters at all locations. However, we could query the data in different ways to gain insights into the dynamics of mite populations, the impact of mite treatments, and the variation that occurs across locations, between different locations, and within a single location. The data show how different colonies can be even when in the same yard.

Although the across location analysis in Figure 1 highlights the message that mite infestations can be quite lethal, the complexity of mite infestations only becomes apparent when data from individual locations are evaluated.

We were able to compare bee yards in close proximity. Each location (i.e. NY-1) had multiple bee yards. Individual bee yards were separated by at least 300 feet and a maximum of a few miles. In several locations, we had two yards of 20 untreated colonies to help us determine the impact that location could have. We observed that colonies in bee yards quite close to each other could perform quite differently. As an example, Figure 3A shows colony survival of 2 groups of twenty untreated colonies that were both located within the same open pasture and were separated by approximately 900 feet. They were within line of sight (no physical barriers), all colonies originated from the same group of parent colonies, and they were managed similarly. Despite these similarities, we found striking differences in the number of colonies that survived (80% vs 55%). Figure 3B showed that both yards had initial mite levels lower than 1 mite/100 bees, but within two weeks differences in mite populations were apparent. By week 9, Yard 2 had twice the mite infestation level as Yard 1 and was well into the danger zone of

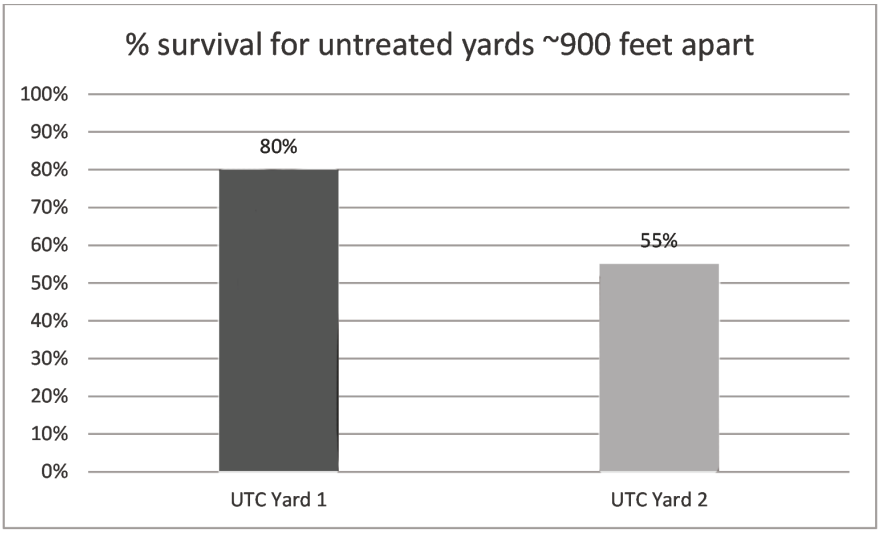

Fig. 3A *Comparison of the survival rate of untreated colonies from yards that were located ~900 feet apart in the same pasture. There were 20 colonies in each yard, each derived from the same batch of bees and queens from the same source. Mite levels are shown in figure 3B. These data highlight how colonies near each other can perform differently.*

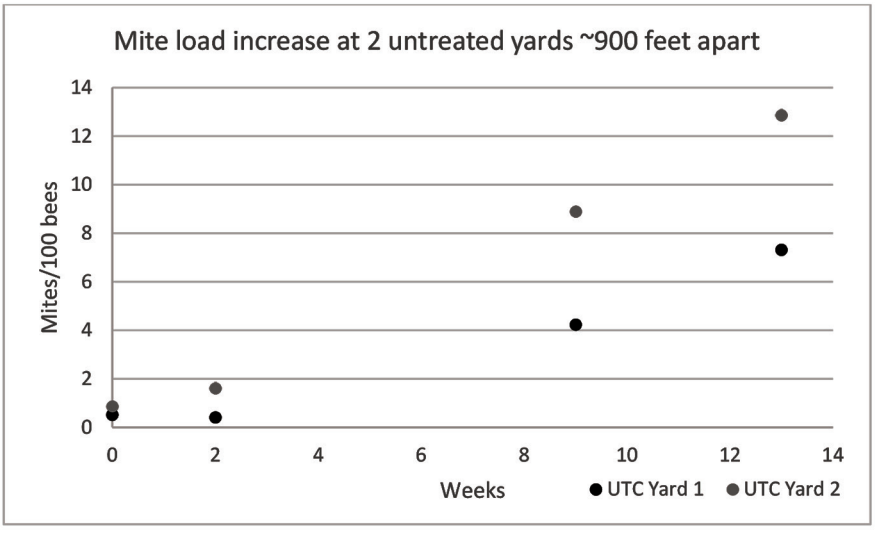

Fig. 3B *Comparison of the mite loads from the same yards described in Figure 3A. Even though the hives were derived from the same batch of bees, had similar initial mite loads, and were in the same pasture, their mite levels differed.*

>5 mites/100 bees. By week 13, Yard 2 had lost 45% of the colonies whereas Yard 1 lost only 20%. The status of the colonies was different despite being separated by a relatively short distance. What this means for the beekeeper is that you can't rely on your neighbor's data. What's happening to the bees in the next town over, or even next door, may not reflect what's happening with your bees.

Lesson 3: Mite treatments don't always work, and one bad colony can spoil a whole bee yard.

Unfortunately, properly timed treatments are no guarantee that you will escape a mite-induced catastrophe. Mite populations can recover surprisingly quickly after a mite treatment, and in some instances mite treatments fail to reduce the mite population. Both situations can wreak havoc on bee yards and the only way to know what's happening in your colonies is vigilant monitoring.

Figure 4A addresses the speed with which mite levels rebound after a mite treatment. The average mite infestation level of all treated colonies is graphed for the first 14 weeks of the trial. The mite treatments were placed in the colonies at the beginning of the trial and were kept in the colonies for 8 weeks following manufacturer's instructions. The treatment reduced the

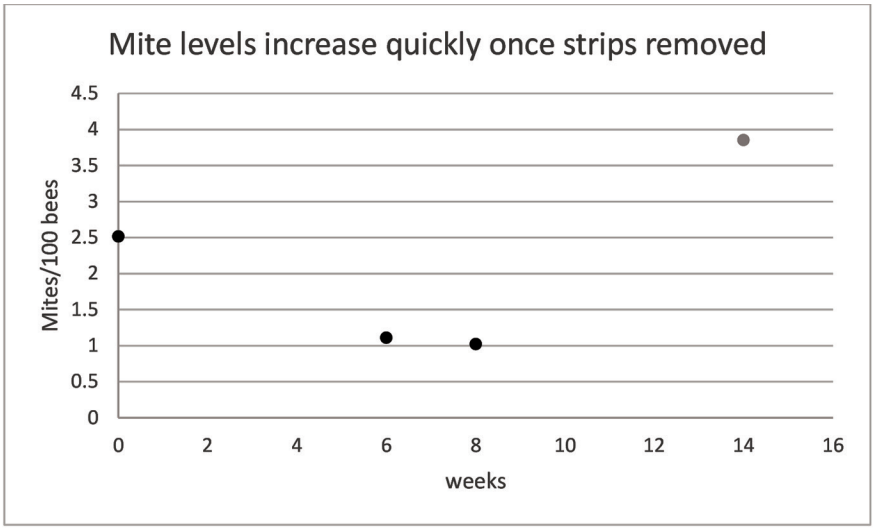

Fig. 4A *Average mite levels in treated hives at all locations. The miticide strips were in the colonies for 8 weeks as noted by the black dots. Notice how quickly the mite levels increased once the strips were removed (gray dot at week 14).*

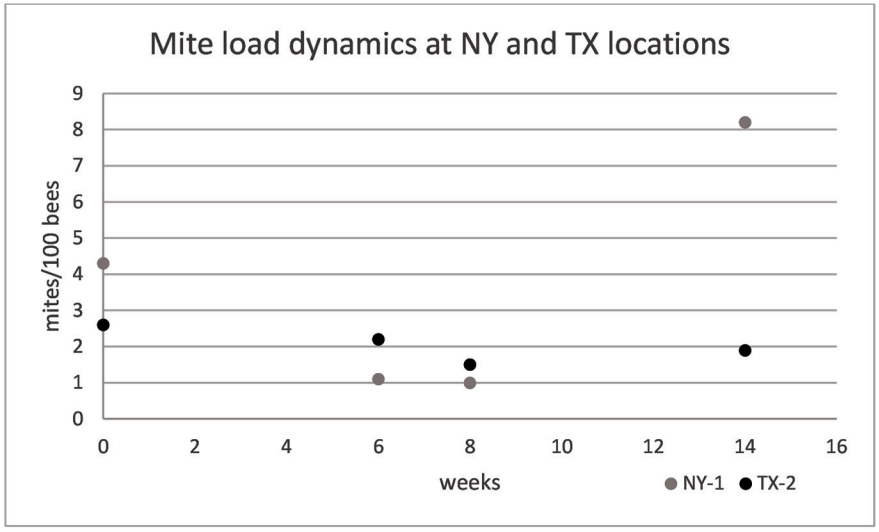

Fig. 4B *Comparison of the average mite levels in treated hives at 2 locations to show how differently populations can change depending on location. The miticide strips were placed in the hive at the start of the trial and removed 8 weeks later. The TX location (black dots) had mite levels remain low after the strips were removed whereas mite levels increased to above 8 mites/100 bees at the NY site.*

mite levels from 2.5 mites/100 bees to about 1 mite/100 bees, which was maintained for the entire 8 weeks the treatments were in the colony. However, just 6 weeks after the treatments were removed (week 14), mite levels were at 3.8 mites/100 bees, reaching levels that begin to put colony survival at risk. (If this reflects what's happening with your bees, are you prepared to treat every 6 weeks?) However, as you might expect, this was not the case for all locations. Whereas the data in Figure 4A represents the average of all locations, Figure 4B shows the two extremes of the trial locations. In TX-2, mite levels stayed below 2 mites/100 bees as you would hope happened in your bees after treatment. However, in NY-1, mite levels skyrocketed to 8 mites/100 bees in just 6 weeks!

What's driving this increase in mite population? Mite reproduction could explain some of it. Mites are only exposed to the Apivar strips when they are on the adult bees, not in brood cells. It is possible that some mites avoid exposure while the colony is being treated. It is likely, also, that mite reinfestation from neighboring colonies is partially responsible for this increase in mite population. One possible source of mite reinfestation is from hives in the same apiary. We found that 5% of the treated colonies had more than 5 mites/100 bees AFTER treatment, on the day the commercial strips were removed. This level of infestation is sufficient to have a large impact on colony survival and could be a source for migrating mites. This shows that nothing works 100% of the time and highlights the importance of monitoring mite levels before and after treatments.

Is one in twenty colonies with high mite infestation levels a concern? There are several research articles suggesting bees and mites drift between hives (Seeley and Smith, 2015). These studies have led to the idea of so-called "mite bombs." Colonies with high mite levels act as mite reservoirs to infest neighboring colonies, through robbing or drifting. We saw evidence of this as well (although nothing proven). In the fall of 2016, we set up a single location trial with 160 hives to look at overwintering survival in Alberta, Canada. Figure 5 shows how mite loads increased throughout the fall and winter at a yard that was treated with formic acid. At the beginning of this trial, the average mite level of the colonies was 2.3 mites/100 bees. That's pretty good for a fall score. If you evaluated just a few of the colonies, you would feel good about the state of the whole yard. But note the high mite loads in the two colonies in the upper left corner of Figure 5A. Similarly, there was a hive with 7 mites/100 bees in the lower right-hand corner. Now, look at the mite counts four weeks later, AFTER the formic acid treatment (Figure 5B). First, it's obvious that the mite treatment failed. Second, you can see how the mites seemed to spread from colonies with high mite levels. Ultimately, 50% of the colonies died in this bee yard, with those dying including the hives that were adjacent to the original "mite bombs" (Figure 5C). This example shows what can happen when just a few colonies are out of whack. It also highlights the importance of checking your hives AFTER you treat to evaluate the effectiveness of the treatment.

The 2016 field season taught us a lot about running field trials. We learned how results will vary from hive to hive and from location to location. We learned how rapidly mite infestation levels can change, how quickly they can rebound after mite treatments, and how quickly colonies can succumb to mite infestations. We also learned a lot from the beekeep-

ers and monitors we worked with, and that helped us design better trials in subsequent years. These lessons are also very useful for beekeepers. It's clear from our data that a mite management program is critical to maintain healthy hives. The program needs to be tailored to your locale and your bees and include frequent monitoring, before and after treatments. When mite levels get out of control, the possibility of spreading mites is real and the efficacy of treatments decreases. It's also clear that you can't count on your neighbor's observations to know what's going on in your hives, and treatments are not 100% effective all the time.

We performed a field trial with more than 2000 colonies for the first time in 2016. We evaluated treatments across 11 different U.S. locations to include different geographies and different beekeeping operations. The colonies used in the trials were managed by the beekeepers for all beekeeping practices except varroa mite treatments. This approach allowed us to test our product under "real life" conditions. In most research projects you want to minimize variability, but this is impossible when beekeepers in different environments require different management practices. The beekeepers know their bees better than anyone else. They know when they need to be fed and they know when they need to add a super. Therefore, allowing the beekeepers to manage their colonies was the best way to adapt the trial to multiple environments and confirm that what we learned in more controlled situations was valid in the "real world."

In an upcoming article, I will talk about what we learned about the biological product (BioDirect™) we've been developing. In the 2016 field season we looked at efficacy of our product in two different field designs and I will show you how the study design impacted the results. We saw survival on par with the commercial treatment and in the following year demonstrated increased efficacy when our product was used in combination with a commercial one. Stay tuned …

I would like to acknowledge the beekeepers and monitors that made our field trials possible. I also want to acknowledge the members of the Bayer Bee Health team, especially B. Chiapelli, J. Taylor, A. Inberg, D. Avni, M. Gleit, A. Ake, and J. Jaros. All of whom made the collection and analyses of these data possible.

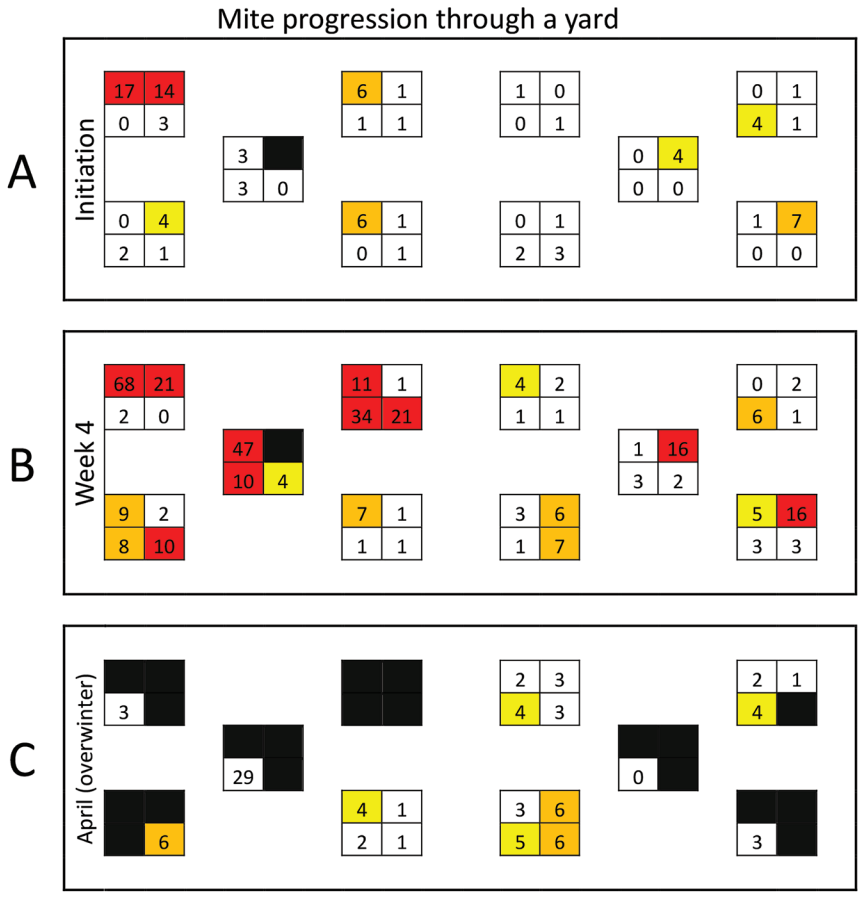

Fig. 5 *Progression of mite counts from August to the following April in a yard located in Alberta, CA. Each small box represents a hive, each larger square represents a pallet. Numbers inside each box are the mite loads (mites/100 bees) for the colony. Panel A is the condition of the yard in August. Panel B is the condition of the yard 4 weeks later. Panel C is the condition of the yard the following April. Black boxes represent dead colonies. Red boxes represent colonies with greater than 10 mites/100 bees. Orange boxes are colonies with 6-9 mites/100 bees. Yellow boxes have mite levels of 4-5 mites/100 bees.*

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James D. Masucci - I am a molecular biologist who found a way to combine my day job with my hobby. I've been with Monsanto/Bayer for 22 years where I've worked in Biotechnology, Regulatory, and Chemistry. I also currently run about 100 hives of my own and have my little sideliner business selling bees and honey. Being both a beekeeper and a bee researcher gives me the perspective of understanding what's important scientifically and what's meaningful to the beekeeper. In 2014, I joined the Bee Health Team to run the field trial program with the aim of developing a novel varroa-control biological product. Since 2016, I've been running some of the largest honey bee field trials ever performed to evaluate how our RNAi-based product (BioDirect™) compares with what's commercially on the market. This has given me the opportunity to work with some of the top commercial beekeepers in the U.S. and Canada and to evaluate large data sets under different management systems. I've not only learned a lot about how our BioDirect™ product works in the hives, but also a lot about beekeeping and mite management in general.