

Comparing the Effectiveness of Different Control Methods Against Varroa

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Varroa mites are one of the main challenges faced by beekeepers in the United Kingdom (UK) and many other countries. There are numerous ways of controlling varroa, with different levels of effectiveness. For example, research we have carried out at the Laboratory of Apiculture and Social Insects (LASI) shows that, on average, one round of trapping varroa in drone brood in spring kills 46 per cent of the varroa in a colony. By comparison, a single treatment of oxalic acid, 2.25 g, via sublimation to a broodless colony in winter kills an average of 97.6 per cent. This was the result of a LASI study of 89 hives treated with 2.25 g of oxalic acid dihydrate in December 2013 (Al Toufailia, et al, 2013). The initial varroa level was 14.7 (range: 2–33) mites per 100 bees.

Given that 97.6 per cent is approximately twice 46 per cent, does this mean that oxalic acid is twice as effective at killing varroa as trapping in drone brood? At first glance this seems reasonable. But why not compare the proportions of varroa that survive? That is, 2.4 per cent versus 54 per cent. It now appears that oxalic acid is more than twice as effective as trapping. Which of these two measures is better? From a beekeeping perspective, the proportion surviving is highly relevant to the effectiveness of control. This is because it is the surviving varroa that will reproduce and cause the population to build back up. However, the proportion surviving is still not the most useful measure of effectiveness to a beekeeper.

Comparisons

A natural way to compare the effectiveness of different methods of



Uncapping sealed drone cells to count varroa

controlling varroa is to compare the number of times the varroa population in a colony needs to double to build back up to the level before treatment. Doubling is biologically relevant because populations tend to increase geometrically (also called exponential growth) – 1, 2, 4, 8, 16, etc – rather than linearly – 1, 2, 3, 4, 5, etc – when overcrowding and lack of resources are not limiting factors, as will be the case in a honey bee colony with relatively few varroa following treatment. Note: when varroa are more numerous, they will start interfering with each other's reproduction or harming the host colony so that the varroa growth rate will start to decline.

Returning to trapping varroa in drone brood, it is easy to see that the 46 per cent mortality caused by this control method reduces the varroa population in a treated colony by the equivalent of slightly less than one doubling. That is, after one doubling the 54 per cent that have survived would be 108 per cent, or slightly more than before treatment. By contrast, the reduction with oxalic acid is equivalent to slightly more than five doublings (ie, the surviving 2.4 per cent

become 4.8, then 9.6, 19.2, 38.4, 76.8 per cent, etc). In other words, oxalic acid applied to a broodless colony is more than five times as effective as one round of trapping in drone brood.

Population Growth

To know that a control method will require the varroa population to double one or five times is a useful step forward. However, to make these figures more relevant to beekeeping we also need to know how quickly varroa populations increase in honey bee colonies. For example, does a particular method control one year of potential varroa population growth, or more than one year, or just a fraction of one year?

In one research project (Al Toufailia, et al, 2014), we determined the increase in the varroa population over one year in 42 colonies. The year began in mid January 2013 and continued until mid December. We were able to make accurate estimates of the number of varroa at the start and end dates because the colonies were broodless and we also estimated the overall populations of worker bees in each colony at the start

and end. We took samples of worker bees from each colony and extracted the phoretic varroa from the workers using a jet of water. By combining estimates of the number of varroa per 100 worker bees with estimates of the total number of worker bees in each colony and the extent to which this had changed over the year, we could determine the growth of the varroa population in each colony. Although the studied period of varroa population growth was only 11 months, very little change in varroa population would have taken place in the month after the December sample as there was no foraging and little brood rearing. As a result, the 11 month figures for varroa population growth also apply to one year.

We found that the varroa population increased 40.2 times, on average, over one year. This is equivalent to a little over five doublings (ie, 1–2, 2–4, 4–8, 8–16, 16–32). For those who are mathematically inclined, it is exactly 5.33 doublings as $2^{5.33} = 40.2$, to 3 significant figures. The greatest varroa population growth in any colony was 65 times (just over six doublings) and the least was 7.4 times (just under three doublings). In other words, to provide one year of control it is necessary to have a method that will kill at least 97.5 per cent of the varroa. This is because the 2.5 per cent that survive will need 5.33 doublings to build the population back up to what it was before (ie, to 100 per cent). By comparison, a method that kills 50 per cent of the varroa provides slightly less than 1/5 of a year of control (actually $1/5 \cdot 5.33 = 0.187$ years), the time taken for one doubling given 5.33 doublings in one year.

Control Methods

LASI research in the *Sussex Plan for Honey Bee Health & Well Being* has compared a variety of varroa control methods, including Apistan®, trapping in

drone brood and oxalic acid. Oxalic acid only kills varroa that are phoretic on adult bees, not the varroa in sealed cells. In a colony with a large number of sealed cells, approximately 60–70 per cent of the adult female varroa are in these sealed cells (Al Toufailia, 2016). As a result, only about 30–40 per cent can be killed by oxalic acid. Treating a hive with normal large amounts of brood in spring, summer or early autumn will result in approximately 70 per cent of the varroa surviving. It will take only half of one doubling, or approximately one tenth of a year, to build back up. Even a small patch of 500 sealed cells, as can easily occur in December, the month with the least brood in Sussex, will allow approximately 17 per cent of the varroa to survive a treatment of oxalic acid versus only 2.4 per cent in a colony with zero sealed brood. This is a reduction from 5.3 doublings to about 2.6 (17–34, 34–68, 68–128), or a reduction from one year's control to half a year. This shows why it is important to treat broodless hives.

Annual Treatment

LASI research has also determined the effect of hygienic behaviour on varroa population growth. In 42 colonies which we monitored for one year, eight were fully hygienic and had an average one-year varroa population growth of 19.4 times (range 7.4 to 28.2) versus 45.1 times (range 21.1 to 65.4) in the 34 colonies that were not fully hygienic. This means that hygienic behaviour was worth approximately 1.2 doublings, equivalent to a quarter of a year's additional control. Putting it another way, 2.25 g oxalic acid applied via sublimation to a non-hygienic colony provides approximately one year's control but one and a quarter years to a hygienic colony.

Table 1 lists the control provided by the methods we have tested. From a

beekeeping perspective it would be good to have a method or combination of methods that provided more than one year's control. In this way, annual treatment would be enough with something to spare. We have found two combinations that provide more than one year of control. These are a single application of oxalic acid to broodless colonies with high levels of hygienic behaviour, and double application of oxalic acid, at an interval of 14 days, to broodless colonies.

Apistan® is highly effective against non-resistant varroa, when it will also provide more than one year of control. However, when varroa are resistant to fluvalinate, the active ingredient in Apistan®, the duration of control drops considerably. When we tested LASI colonies with Apistan® we found that the proportion of varroa killed averaged approximately 50 per cent, equivalent to only one fifth of a year's control. Other studies report similar figures, even as low as 30 per cent mortality.

Not all control methods are equally effective and some would seem not worth the bother. Oxalic acid can be very effective if applied to a broodless colony, but will have only very limited effectiveness if applied to a colony with normal large amounts of brood. Beekeepers sometimes ask us if it is OK to treat hives with brood with oxalic acid. Inasmuch as it is unlikely to harm the bees, it is OK, but it is rather a waste of time. If a hive with a normal amount of brood is treated, about 70 per cent of the varroa will survive. It will take only half a doubling for the varroa population to build back up to the pre-treatment level. This is equivalent to about one tenth of a year's worth of control. By contrast, treating a broodless colony provides one year's worth of control. Which would be easier and cost less: treating colonies with brood with oxalic acid ten times or treating broodless colonies once? Both will give the same level of varroa control.

Commercial Considerations

One of the challenges faced by commercial beekeepers is the time it takes to repeat the management needed for one hive on hundreds, even thousands of colonies. In this regard, having a varroa control method that can last a year would be of great value. In the case of oxalic acid, it makes sense to apply in winter when colonies naturally have small amounts of brood or are even broodless. LASI research has shown that, in Sussex, there is no month when all



Hasan al Toufailia uncapping drone cells from a trap frame to count varroa mites

Table 1. Comparing effectiveness of different methods to control varroa. The approximate number of years of control is based on a situation where varroa numbers increase 40 times (5.3 doublings) in one year without control (Reference 4). The number of doublings to build up is the number of times the varroa that survive treatment need to double in number to have the same population size (total number of adult female varroa) as before treatment

Varroa Control Method	Conditions	Varroa Survival (%)	Doublings to Build Up	Duration of Control (Years)
1. Apistan ⁵	Varroa not resistant	circa 1	6.7	1.3
2. Apistan ^{2, 6, 7}	Varroa resistant	30–60	1	0.2
3. Oxalic acid, one 2.25 g application via sublimation ^{3, 4}	Zero sealed brood	2.4	5.3	1.0 1.25 if hygienic
4. Oxalic acid, two 2.25 g applications via sublimation ¹	Zero sealed brood	0.4	8	1.5
5. Oxalic acid, one 2.25 g application via sublimation ^{1, 3}	Small patch sealed brood, 500 cells	17	2.6	0.5
6. Oxalic acid, one 2.25 g application via sublimation ^{1, 3}	Normal amount sealed brood	70	0.5	0.1
7. Trapping in drone brood, one cycle of brood ¹	First batch spring drones	54	0.9	0.17
8. Trapping in drone brood, two cycles of brood ¹	First and second batches spring drones	29	1.8	0.34

Notes

- 3. Hygienic colonies are those that remove 95 per cent or more freeze-killed brood within two days.
- 4. The second oxalic acid application was two weeks after the first application.
- 7, 8. Varroa were trapped in the first batch of drone brood to be reared in spring (7), or the first two batches (8). To do this, a frame of foundation, two-thirds drone cells and one-third worker cells, was introduced into each hive and removed one month later. This frame contained all the drone brood in the colony.

hives are broodless, but that December is the month with least brood, both in terms of the average number of cells and the proportion of colonies with sealed brood.

Winter Checks

It would be worthwhile for beekeepers to check their colonies in winter to determine the month with least brood, and also to remove or scrape out any small patches of sealed brood before treating with oxalic acid. Although checking hives in winter is not recommended, this is probably more because there has not been, until recently, any reason to do it. However, if done with care, winter inspections do not cause any harm. Of the 89 hives we inspected in December 2013 to determine if they were broodless and, if not, to scrape out any sealed brood before treating with oxalic acid, 87 survived the winter. With varroa, and

with oxalic acid, there is now a reason to check hives in winter. In different areas, the winter break in brood rearing may be more or less pronounced and it is, of course, important that beekeepers know their local conditions and how bees respond to them. □

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