Modeling the Efficiency of Sampling and Trapping Varroa destructor in the Drone Brood of Honey bees (Apis mellifera)

Article *in* American Bee Journal · March 2002

Graham C Smith
Animal and Plant Health Agency

Modeling the Efficiency of Sampling and Trapping *Varroa destructor* in the Drone Brood of Honey bees (*Apis mellifera*)

by DAVID WILKINSON and GRAHAM C. SMITH
Central Science Laboratory
Sand Hutton, York, YO41 1LZ, UK

Revised manuscript received for publication Nov. 5, 2001

Abstract

A computer model simulating varroa mite (*Varroa destructor*—previously known as *Varroa jacobsoni*) infestation in colonies of honey bees (*Apis mellifera*) confirmed that, due to the preference of mites to invade drone (male) honey bee brood to reproduce, a very high proportion of the mite reproduction could occur in a relatively small amount of drone brood. Several regimes of sampling or removing drone bee pupae to estimate or remove numbers of varroa mites were simulated to compare their effectiveness. The model indicated that regular sampling of at least 100 drone pupae could provide the beekeeper with a useful warning of when numbers of varroa were approaching damaging levels. An infestation level of 15% of drone pupae would be a conservative threshold to indicate treatment was imminently required. The model indicated that significant reduction of mite numbers could be achieved either by very regular uncapping and removal of most of the natural drone pupae, or by trapping mites in artificially high numbers of drone pupae. The numbers of drone pupae required to significantly delay the mite build-up could be reduced considerably by trapping at a time when the bee colony was otherwise broodless. However, the varroa numbers were not controlled sufficiently by drone brood removal alone in any of the regimes tested.

Introduction

The control of varroa mites (*Varroa destructor*—previously known as *Varroa jacobsoni*) has been a big problem for beekeepers ever since varroa first infested honey bee (*Apis mellifera*) colonies. Beekeepers have relied on various chemical treatments - some of them more efficient at killing varroa than others. A big danger in the use of chemical treatments is the development of resistance by the mites. Indeed, varroa developed resistance to Apistan® (fluvalinate) only a few years after it was first registered for use in Italy (Milani 1994; Lodesani *et al* 1995; Watkins 1997). This may have been due to earlier improper use of fluvalinate formulations registered for other agricultural use. Beekeepers in many countries are interested in the use of biological control methods that might delay the onset of pesticide resistance. This could be achieved by integrating a biological method so as to reduce the frequency of chemical treatments required, whilst still allowing acceptable control of the mite population. One such method of particular interest to beekeepers is the removal of varroa mites in drone brood. Drone brood is a good candidate for trapping and removing varroa mites because when the mites invade cells to reproduce, they show a strong preference for drone cells (Boot *et al* 1995). It is possible to take advantage of this in three ways:

a) As a *diagnostic test* samples of drone pupae can be uncapped and pulled out using an uncapping fork (CSL 1996). If this is done around the age when the eye pigment of the pupae is pink-purple, any adult varroa can be clearly seen against the white bodies of the pupae. By uncapping drone pupae rather than worker pupae beekeepers can increase the chance of finding the varroa infestation early, while there is still plenty of time to do something about it.

b) As a *quantitative test* a sufficiently large sample of drone pupae (at least 100) can be uncapped as described above, and the number of infested pupae counted to calculate the percentage infestation level. It has been advised that an infestation level of less than five percent indicates low enough mite numbers not to warrant treatment, but that a level of 25% or more indicates a severe infestation which will require imminent treatment (CSL 1996). It is also believed that a colony can be severely affected when a mite population rises above 2000 – 3000 (Delaplane & Hood 1997, Martin 1998, Martin 1999), although there is some debate as to whether certain viruses also need to be present for clinical damage to occur (Ritter *et al* 1984; Ball & Allen 1988; Varis *et al* 1992; Bowen-Walker *et al* 1999; Nordström *et al* 1999; Brødsgaard *et al* 2000).

c) As a *control method* the bees can be encouraged to rear quantities of drone brood which is removed from the hive before any reproducing mites within the cells emerge. The drone-trap comb can be reused if the varroa mites are removed by uncapping and shaking/ washing out the brood and mites. For some time it has been thought likely that the most efficient time to use drone traps is when there is no other brood present, but most beekeepers who use drone brood trapping, do so when there are considerable amounts of other brood present.

Since drones do not contribute directly to foraging or brood rearing tasks as worker bees do, beekeepers prefer to sacrifice drone brood to find or remove varroa mites. Calis *et al* (1999a) modelled mite-trapping methods, and confirmed that drone-brood traps should be much more efficient than worker brood traps. Calis *et al* (1999b) also tested some intensive drone-brood traps in colonies in the field, and found that they could reduce the varroa population by as much as 93% if used at times when no other brood was present.

A model of varroa mites in a honey bee colony was used here

Keywords: ***Varroa destructor*, *Apis mellifera*, population estimation, drone trap, biological control**

to assess the importance of drone brood in the natural build-up of the mite population, and to compare the efficiency of various drone-sampling and trapping methods for measuring or reducing the varroa population.

Method

The computer model detailed by Wilkinson & Smith (in press) was used to model the varroa mite population in a simulated honey bee colony. The colony simulation was based on a seasonal growth pattern typical of a prolific colony in a temperate country of Northern Europe, where honey bees have a main brood season lasting about six months, and a period in mid winter when virtually no brood is reared. Varroa mites were allowed to invade worker brood or drone brood, according to the mite invasion rates derived by Boot *et al* (1994) and Boot *et al* (1995), which include a strong preference for mites to invade drone cells. The amount of drone brood was set to a percentage of the worker brood.

To assess the importance of drone brood in the mite population growth, the percentage of drone brood was varied whilst other variables were kept static, and the daily number of live mites emerging from worker and drone cells compared. The percentage of drone brood at which equal numbers of mites are emerging from drone and worker cells, (D_e), is a useful indicator of how important the drone brood is to mite build-up. D_e was also calculated for different numbers of adult bees and varroa mites available for brood invasion.

The model was then seeded with 10, 100 or 1000 female varroa mites, and the daily mite population recorded throughout each simulation, along with the proportion of drone brood infested. Low, medium and high mite population growth rates were simulated by varying the mite reproductive rates (viable adult daughters per mother). Each simulation modelled a three-year period. From this it was possible to see whether drone uncapping to estimate the proportion of drone cells infested could be an accurate predictor of the total mite population. To determine the reliability of a sampling method, confidence limits of proportions were calculated using the methods described by Armitage & Berry (1987). These methods help show whether a sample of 100 uncapped drone-pupae is enough to reliably determine the level of infestation.

In order to see whether drone sampling or drone trapping could significantly suppress the mite population growth, the model was modified to remove varying amounts of drone brood. Removal of natural drone brood was simulated by removing the varroa mites from a variable amount of the natural drone brood before they could emerge. This included the extreme simulation of a beekeeper removing as much of the natural drone brood and the invaded mites as could be practically uncapped on a weekly basis. Uncapping was simulated rather than freezing of brood because although freezing would kill 100% of the mites in the brood, natural drone brood is often on the same comb as worker brood and difficult to separate. It was assumed that 20% of the adult mites in uncapped drone brood would be left behind inside the drone cells during the uncapping process.

Drone trapping of varroa mites was simulated by adding extra drone cells to the model, then removing all mites in that extra brood before emergence. A range of trapping frequencies and numbers of drone cells were simulated. A drone trap applied at an otherwise broodless period was also tested to simulate the effect of caging a queen, or integrating the drone trap with swarm control. Such methods are advocated for maximizing the efficiency of the drone trap by ensuring all the mites are phoretic (on adult bees) when the drone brood is at the right stage for mite invasion.

Results

The numbers of mites that emerged from drone and worker cells in the model are compared in Figure 1. The two lines cross (the D_e point) where as many mites are emerging from the drone cells as the worker cells. This occurs when the amount of drone brood comprises about 5% of the worker brood. Varying the numbers of phoretic mites or numbers of adult bees had little effect on D_e, which varied between 5% and 7%, being highest when the ratio of phoretic mites to adult bees was highest. It is relevant to note how steeply the drone line slopes, indicating that the level of drone brood is likely to be a very significant factor in mite population growth.

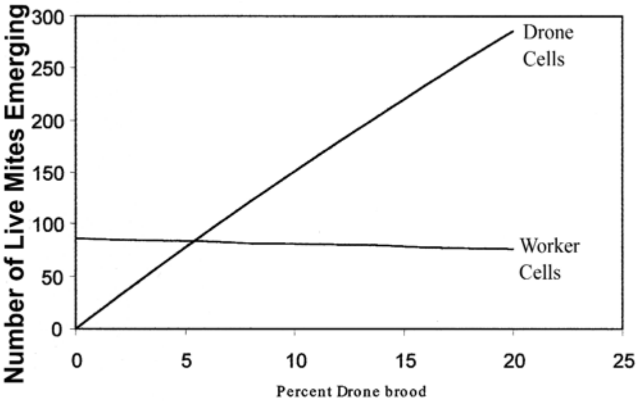

Figure 1. The number of simulated varroa mites (mothers and offspring) emerging alive from drone and worker brood cells at increasing percentages of drone brood.

In all simulations tested no simple relationship could be found between the proportion of the drone brood infested, and the total mite population. Increasing mite populations were generally accompanied by increasing proportions of drone cells infested, but early in the beekeeping season when drone brood rearing was just beginning and the initial mite to drone-cell ratio was high, an increasing mite population was sometimes accompanied by a decreasing proportion of drone-cell infestation.

The infestation level in the drone brood always reached 25% before the mite population reached 2000, so this infestation level could be used as a threshold to warn the beekeeper that treatment is necessary to avoid severe colony damage. However the time interval between these two thresholds was dependent both on the initial mite load, and on the mite's reproductive rates. With the low reproductive rates and an initial mite population of 10 or 100 this warning interval was between 6 and 9 months. With a high initial mite population or with medium or high reproductive rates the warning interval was reduced to approximately one month. The mite population at the point when the drone brood infestation level reached 25% varied between 110 and 830.

The upper 90% confidence limit for the proportions of drone brood infested when 100 cells were uncapped was approximately 8% higher than the proportion. Hence if the measured proportion in the sample were 15%, there is a 5% chance that the true level could be 23% or more.

Uncapping 100 drone cells per fortnight, and removing the mites with the pupae, slowed the mite population build up only slightly, with the 2000 mite threshold reached about one month later. Removing three quarters or more of all the drone pupae by regular uncapping delayed the build up quite effectively—the mite population reaching 2000 about one year later than it would otherwise have done.

A simulated drone trap consisting of 1500 drone cells in late May only delayed the mite numbers reaching 2000 by about one month compared with no trapping. Simulating such a mite trap once a month for the four summer months (May, June, July, and August) and increasing the size of the drone trap to 3000 drone cells delayed the 2000 threshold by three to four months. A 6000 drone cell trap given once a month for the four summer months resulted in a 2000-threshhold delay of about one year, as did a 1500 drone cell trap given once during a broodless period. The latter method reduced the mite population by 87%, which is consistent with earlier work (Calis *et al* 1999b).

Figure 2 shows the effects of two different drone brood removal methods on the mite population compared with no control. The 1500 trap during the broodless period was the most effective at suppressing the mite population growth. A 1500 trap applied in each of the summer months, but at times when other brood was present, gave moderate suppression of the mite population. The presence or absence of other brood was an important factor in how efficiently the mites were caught in the drone brood trap. A graph of total mites and mites in brood cells (Figure 3), shows that a high proportion of the mites are already in brood cells during the trapping times, and are thus unavailable for trapping unless a broodless period is induced.

Discussion

An important finding from the model is that a relatively small percentage of drone brood can contribute a large proportion of the mites emerging from the brood after reproduction. For example the model indicates that with 5% drone brood, as many mites are

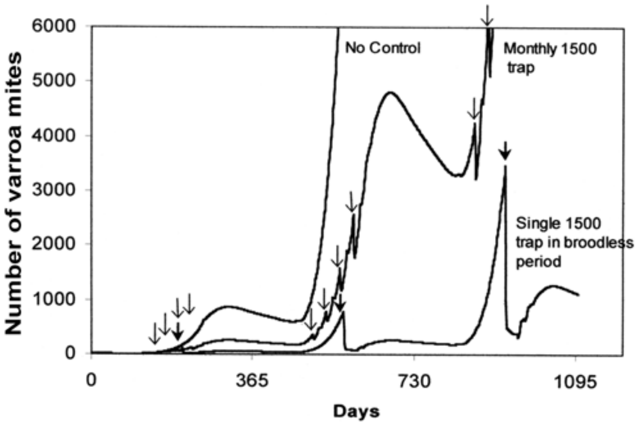

Figure 2. The number of simulated varroa mites in the colony, comparing three regimes: no control; a drone trap of 1500 pupae applied in each of the four summer months; and a single annual drone trap of 1500 pupae applied during a broodless period in late July. Day 1 is January 1st, and arrows mark the times of trapping (bold arrows mark trapping in broodless period).

emerging from 50 - 60 drone cells as from 1000 worker cells. This certainly emphasizes the importance of drone brood in mite population growth, and the need for beekeepers to prevent large quantities of drone brood being reared unnecessarily and being left to emerge in the hive. Some beekeepers rarely if ever replace old combs in their colonies, and such colonies often end up with large percentages of drone brood, perhaps more than 10%. These are literally large breeding grounds for the mites, and the model suggests this could be rapidly fatal for such colonies. A simple comb replacement program with regular and ruthless ‘culling’ of the old combs and the badly built combs should help reduce the drone brood numbers. Comb replacement programs are generally encouraged in any case for other brood health purposes (Mike Brown, personal communication, Koenig *et al* 1986, Berry & Delaplane in press)

The results also show that sampling drone brood to estimate the level of mite infestation can be a valuable warning system for beekeepers. Beekeepers however should be aware of its limitations. Firstly, due to the simple chance variation of sampling 100 pupae, the measured infestation level could be below the warning threshold, even though the mite population is already dangerously high. It may often be worthwhile to sample another 100-200 drone pupae to obtain a more accurate estimate of the overall infestation level. Secondly, the model showed there are times in the cycles of

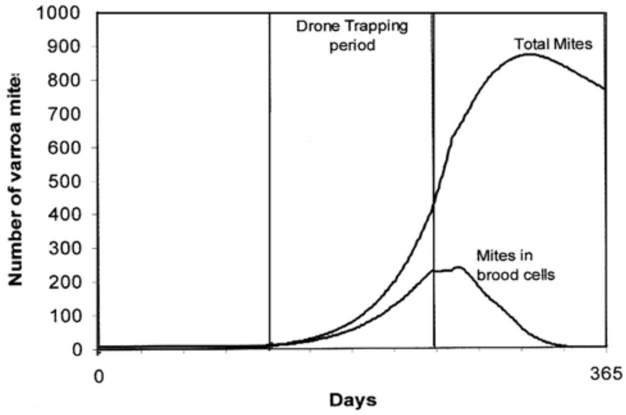

Figure 3. The number of simulated varroa mites in brood cells (worker and drone) compared with the total number of mites in the colony. Day 1 is January 1st.

the colony and mite populations when there could be only a month or two between finding 25% of the drone pupae infested, and the mite population reaching levels which require urgent treatment. The times generally recommended for treating against varroa are usually in the early spring or the autumn, outside the main honeyflow period, and when there is less brood and a higher proportion of the mites are phoretic. To err on the safe side, and to fit in with recommended treatment times, beekeepers may prefer to base the timing of treatment on a lower warning threshold—say a 15% drone infestation level. This could be particularly important with prolific colonies in areas with a long brood season.

The results of the drone-trapping simulations highlight how difficult it is to control varroa by using drone trapping alone. Regular removal of most of the natural drone brood was very effective, but would obviously require much more time input by the beekeeper than chemical treatment. The model suggests that the use of drone traps at times when large numbers of worker brood could be harboring many mites would probably not be worth the effort. However, this model demonstrated that drone trapping was much more effective if applied in a broodless period, thus confirming the previous findings of Calis *et al* (1999b). It could therefore be cost effective to combine any swarm control and/or requeening with a drone trapping campaign. The model showed that it is very important to apply these drone trapping/removal methods from year one. Waiting until a warning threshold was reached before starting the drone trapping would result in poor control.

For some beekeepers such intensive management would not be cost effective, but for others a drone trapping/removal method of controlling mites without such frequent use of chemicals has many advantages, including the delay of mite resistance to chemicals. Integrating some of the more effective methods mentioned above could offer even greater mite control without chemicals. Whatever methods are adopted however, it is very important for beekeepers to remain vigilant, as re-invasion of hives with mites from nearby colonies can quickly reverse any effective control.

REFERENCES

Armitage P, and Berry G (1987) Statistical Methods in Medical Research. Blackwell Scientific Publications, Oxford, UK: p 119.

Ball B, and Allen MF (1988) The prevalence of pathogens in honey bee (*Apis mellifera*) colonies infested with the parasitic mite *Varroa jacobsoni*. *Annals of Applied Biology* 113: 237-244.

Berry JA, and Delaplane KS (2001) Effects of comb age on honey bee colony growth and brood survivorship. *Journal of Apicultural Research* 40: 3-8.

Boot WJ, Schoenmaker J, Calis JNM, and Beetsma, J (1995) Invasion of *Varroa jacobsoni* into drone brood cells of the honey bee, *Apis mel-*

lifera. *Apidologie* 26: 109-118.

Boot WJ, Sisselaar DJA, Calis JNM, and Beetsma J (1994) Factors affecting invasion of *Varroa jacobsoni* (Acari: Varroidae) into honey bee, *Apis mellifera* (Hymenoptera: Apidae), brood cells. *Bulletin of Entomological Research* 84: 3-10.

Bowen-Walker PW, Martin SJ, and Gunn A (1999) The transmission of deformed wing virus between honey bees (*Apis mellifera* L) by the ectoparasitic mite *Varroa jacobsoni* Oud. *Journal of Invertebrate Pathology* 73: 101-106.

Brødsgaard CJ, Ritter W, Hansen H, and Brødsgaard HF (2000) Interactions among *Varroa jacobsoni* mites, acute paralysis virus, and *Paenibacillus larvae larvae* and their influence on mortality of larval honey bees in vitro. *Apidologie* 31: 543-554.

Calis JNM, Boot WJ, and Beetsma J (1999a) Model evaluation of methods for *Varroa jacobsoni* mite control based on trapping in honey bee brood. *Apidologie* 30: 197-207.

Calis JNM, Boot WJ, Beetsma J, van den Eijnde JHPM, de Ruijter A, and ven der Steen JJM (1999b) Effective biotechnical control of varroa: applying knowledge on brood cell invasion to trap honey bee parasites in drone brood. *Journal of Apicultural Research* 38: 49-61.

CSL (1996) Managing varroa. Advisory leaflet PB 2581, Ministry of Agriculture, Fisheries and Food, London, UK.

Delaplane KS, and Hood WM (1997) Effects of delayed acaricide treatment in honey bee colonies parasitized by *Varroa jacobsoni* and a late-season treatment threshold for the southeastern USA. *Journal of Apicultural Research* 36: 125-132.

Koenig JP, Boush GM, and Erickson EH Jr (1986) Effect of type of brood comb on chalk brood disease in honey bee colonies. *Journal of Apicultural Research* 25: 58-62.

Lodesani M, Colombo M, and Spreafico M (1995) Ineffectiveness of Apistan® treatment against the mite *Varroa jacobsoni* Oud in several districts of Lombardy (Italy). *Apidologie* 26: 67-72.

Martin SJ (1998) *Varroa jacobsoni*: monitoring and forecasting mite populations within honey bee colonies in Britain. Advisory leaflet PB 3611, Ministry of Agriculture, Fisheries and Food, London, UK.

Martin SJ (1999) The Virus, Mite And Model: A Useful Approach Towards Varroa Control. *Proceedings of Apimondia* Congress XXXVI: 141-142.

Milani N (1994) Possible presence of fluvalinate-resistant strains of *Varroa jacobsoni* in northern Italy. International Bee Research Association (ed. Matheson, A.), Cardiff, UK.

Nordström S, Fries I, Aarhus A, Hansen H, and Korpela S (1999) Virus infections in Nordic honey bee colonies with no, low or severe *Varroa jacobsoni* infestations. *Apidologie* 30: 475-484.

Ritter W, Leclercq E, and Koch W (1984) Observations des populations d'abeilles et de *varroa* dans les colonies à dif férents niveaux d'infestation. *Apidologie* 15: 389-400.

Varis AL, Ball BV, and Allen M (1992) The incidence of pathogens in honey bee (*Apis mellifera* L) colonies in Finland and Great Britain. *Apidologie* 23: 133-137.

Watkins M (1997) Resistance and its relevance to beekeeping. *Bee World* 78: 15-22.

Wilkinson D and Smith GC (in press) A model of the mite parasite, *Varroa destructor*, on honey bees (*Apis mellifera*) to investigate parameters important to mite population growth. *Ecological Modelling*.