Journal of Apicultural Research 43(3): 114–117 (2004)

ORIGINAL ARTICLE

Effect of screen floors on populations of honey bees and parasitic mites (*Varroa destructor*)

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Received 30 January 2004, accepted subject to revision 5 March 2004, accepted for publication 25 June 2004

SUMMARY

This study compared brood production, honey consumption (in winter only), population growth of honey bees (*Apis mellifera*), and population growth of parasitic mites (*Varroa destructor*) in hives with open screen or wood as floor material. Two experiments were conducted in Baton Rouge, Louisiana, USA, one in winter (19 colonies) and one in summer (22 colonies). In both experiments, we established uniform colonies of honey bees by subdividing 30 kg of mite-infested bees. Each colony began with about 11 000 bees, no brood, and uniform populations of mites (127 and 480 mites per colony in winter and summer, respectively). The summer test included a third treatment (8 colonies) where a wooden tray (5 cm deep) closed the space beneath a screen floor. After the first 20 days of the experiments, when no adult bees or mites had yet been produced in any of the colonies, the treatments showed no differences in brood production, honey consumption, or survival of adult bees. At nine weeks, colonies with screen floors had fewer mites, a lower percentage of their mite population residing in brood cells (open screen only), and more cells of capped brood. These results suggest that colonies with open-screen floors may hold back the growth of mite populations by decreasing the rate at which mites invade brood cells.

Keywords: *Apis mellifera*, *Varroa destructor*, screen bottom board, parasitic mites, honey bees, brood invasion

INTRODUCTION

Screen instead of wood on the floor of a bee hive has been tested over the years for various reasons. Most recently, screen floors have been employed to monitor populations of *Varroa destructor* (PAM, 1993) or reduce varroa populations (Pettis & Shimanuki, 1999; Ostiguy *et al.*, 2000; Ellis *et al.*, 2001; Sammataro *et al.*, 2004). Others have tested the effects of screen floors on overwintering (Horn, 1990; Skowronek & Skubida, 1995), moisture content of honey (Liebig, 1992), and brood production (Skubida & Skowronek, 1995; Pettis & Shimanuki, 1999; Ellis *et al.*, 2003).

Overall, there seem to be some benefits and few negative effects associated with screen floors on bee hives. Therefore, some beekeepers have begun to include screen floors with other control measures to create an integrated procedure for controlling varroa mites (Ellis *et al.*, 2001; Ostiguy *et al.*, 2000; Sammataro *et al.*, 2004), and some beekeepers throughout the world have been using screen floors on their hives for decades (Spear, 2002).

Our objectives were to determine if screen floors could have a measurable effect on bees and varroa mites during a nine-week field test. We compared the effect of screen floors on honey consumption, brood production, the growth of bee populations, the growth of mite populations, and the distribution of a mite population within a colony (the number of mites in brood cells as compared to the number on adult bees). Our findings were consistent with earlier reports but also showed that colonies with open-screen floors had a lower percentage of their mite population in brood cells (P-MIB).

MATERIALS AND METHODS

The effects of screen floors on bee colonies were evaluated in two experiments in Baton Rouge, Louisiana, USA. Experiment 1 was conducted in the winter; experiment 2 was conducted in the summer. Both experiments had a nine-week duration, and all test colonies began with no brood and uniform mixtures of mites and bees.

Experiment 1

Nineteen colonies were established from a miscellaneous population of bees and mites that had been collected into a large cage (Harbo, 1986). We established uniform populations of 10 900 ± 100 (mean ± s.d.) bees per colony by producing 38 cages of bees, weighing the bees in each cage, and then pairing the cages to obtain uniform weights of bees among the 19 colonies. Each colony began with five standard Langstroth combs (43 × 20 cm), no brood, caged bees, about 127 varroa mites (bees in the source cage contained 89 mites per kg of bees), and a free-mated queen of unknown parentage. During the distribution of bees from the large cage, we collected four samples that each contained about 150 g of bees. We counted bees and mites in these samples and could then estimate the initial number of bees and mites in each colony. Colonies were established 23 January 2002; queens were released two days later.

Ten of the colonies were established in five-frame boxes with screen (3.2 mm) instead of wood on the floor. Each colony was placed on two cement blocks (20 × 20 × 40 cm) that were spaced about 24 cm apart. Therefore, block material (about 2 cm below the screen near the front and back of the colony) and earth (*c.* 20 cm below the remainder of the colony) were directly beneath the screen floors. The other nine colonies were established in hives of equal size but with traditional wood floors. Each hive had a volume of 25 litres before adding combs that consisted of worker-sized cells only. The two treatments were randomly arranged in the test apiary. Hive volume was doubled in late February by adding a super containing four combs and a

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TABLE 1. Experiment 1, comparing populations of bees and mites that were installed into hives having either a screen or a traditional wooden floor. Each colony began in Baton Rouge, LA with no brood, about 10 900 bees, a free-mated queen, and about 127 varroa mites.

Variable	Open screen floor (*n* = 10)	Wood floor[a] (*n* = 9)	*F*	*df*	*P*
20th day of exper. (12 Feb)[b]					
Cells of capped brood	4050 ± 825[c]	4306 ± 625	0.57	1, 17	0.46
Mite population on adult bees	50 ±14	40 ± 22	1.61	1, 17	0.22
Adult bee population	9467 ± 392	9267 ± 490	0.98	1, 17	0.34
Honey loss/bee/day (mg)	7.2 ± 2.6	6.0 ± 2.1	1.45	1, 17	0.25
62nd day of exper. (26 Mar)					
Cells of capped brood	14 283 ± 1 398	12 166 ± 2146	6.39	1, 16	0.02
Total mite population	207 ± 77	268 ± 128	1.42	1, 16	0.25
Percentage of mites in brood	54 ± 13%	75 ± 15%	9.86	1, 16	0.006
Adult bee population	22 168 ± 2469	21 179 ± 3511	0.49	1, 16	0.49

a. One colony became queenless in early March, so March analyses contained 8 colonies in this group
b. Bees installed on 23 January; queens released on 25 January
c. Data are means ± s.d.

feeder (about the size and in the position of a fifth comb) to all colonies. The food consumption portion of the experiment was finished by this time, and colonies were all fed sugar syrup.

Measuring populations of bees and mites

Brood was measured in all colonies on 11 February and 25 March (17 days after the onset of egg-laying and again at the end of the test). We measured both the area of total brood and the area of capped brood by using a wire grid having squares of 2.5 cm on a side. Cells of brood were estimated for each colony by multiplying sq. cm of brood by 3.7.

Populations of adult bees and mites were measured on the morning after measuring brood, 12 February and 26 March. We confined all bees to their hives by closing hive entrances the previous night. In the morning, we weighed each hive with and without bees. Before reuniting the bees with their equipment, we sampled bees and later weighed each sample (*c.* 130 g) and counted the number of mites and bees in each. From these data, we estimated the number of adult bees and the number of mites on adult bees in each colony.

The number of mites in brood was estimated in each colony at the end of the experiment by counting the number of mites per 200 cells of capped brood. We included various stages of capped brood by counting a horizontal line of 50 cells on each side of two combs. Mite progeny were not included in the counts; only adult foundress mites were counted when estimating mite populations in brood cells. The percentage of mites in brood cells (P-MIB) was calculated for each colony by dividing the number of mites in brood cells by the total mite population in that colony (Harbo & Harris, 1999b).

Honey consumption was estimated only for the first 20 days of the experiment because (1) bee populations become complex when adult bees begin emerging in the colonies (colonies are no longer genetically uniform and birth rate would need to be considered in each bee population), and (2) plants usually begin to produce nectar in the field after mid February in Louisiana (incoming nectar would add another variable). To compare honey loss among colonies, all combs were weighed before the experiment and on 12 February. Colonies had brood in February, so we removed the weight of the brood by subtracting 93 mg/cell of all stages (Nelson & Sturtevant, 1924). Recognizing that bees store variable amounts of honey in their foreguts, we included foregut weights in the estimates. At the beginning of the experiment, the average foregut weight was 29.5 mg/bee. On the 20th day of the test, we estimated foregut contents in each colony. Total mg weight of foregut contents of a colony equals $n(0.76\mathbf{x} - 70.4)$ where n equals the number of bees in each colony on 12 February and $\mathbf{x}$ equals the average weight of a bee in mg (Harbo, 1993). Honey consumption for the 20-d period is presented in mg per bee per day (mg/bee/d) where the number of adult bees consists of the midpoint between the 23 January and the 12 February populations. Anti-robbing devices were fastened at the entrance of each colony to prevent robbing among the colonies (Harbo 1993).

Experiment 2

This experiment consisted of 22 colonies that were set up in the summer (26 June). The design was similar to that of experiment 1 except that colonies were in standard 10-frame hives, honey consumption was not measured, and there were three treatments instead of two. Each colony in the test began with 11 600 bees, no brood, a caged queen, and about 480 mites. Queens were released on 28 June.

The third treatment consisted of a screen floor that was identical to the screened treatment but with a wooden tray beneath the screen. Space existed under the screen (5 cm to the wood floor), but colonies had no airflow from the bottom. The airflow in the closed-screen treatment was only from the front entrance and was therefore similar to the control colonies in that respect. The other two treatments were similar to treatments in experiment 1.

Data were analysed with SAS (2000) software (version 8) using analysis of variance. The analyses of experiments 1 and 2 are presented separately (tables 1 and 2) and also combined (table 3). Analyses of the combined data consisted of a complete randomized block design that omitted data from the closed-screen treatment of experiment 2. Data for final mite populations were normalized with a $\log_{10}$ transformation.

RESULTS

Effect on bees

Open screened floors did not have a significant effect on honey consumption in winter (table 1). Comparable data for populations of 10 000 bees in winter in Louisiana (Harbo, 1993) showed that crowded bees (550 bees per litre of hive space) consumed about 6.2 mg of honey per bee per day, whereas bees with more hive space (150 bees per litre) consumed much more (11.9 mg/bee/d). In this test, open-screen and control treatments were both at 400 bees per litre and they consumed 6.0 and 7.2 mg/bee/d (table 1). Similarly, Horn (1990) reported that colonies with screen floors consumed 10–15% more honey during winter

than colonies with wood floors. If screen floors affected honey consumption in this experiment, the effect was minimal.

Colonies with open-screen floors produced significantly more brood than colonies with wood floors (table 3). In March, the number of cells of brood was 17% greater in colonies with open-screen floors (table 1); it was 10% greater in September (table 2). These results are similar to the 14% reported by Pettis & Shimanuki (1999) in June in Maryland. Screen floors appeared to have no effect on brood production during the first brood cycle in either experiment (tables 1 and 2).

Effect on varroa

We found a relationship between the presence of screen floors and a lower percentage of the mite population residing in brood cells. This relationship was suggested on the 20th day and confirmed at the end of the experiment. On the 20th day of the experiment, we found more mites on adult bees in the colonies with open-screen floors (table 3). We did not measure the mite population in the brood cells at that time, but because the colonies had not yet produced one cycle of brood (queens caged for 2 days followed by 18 days of egg laying), the population of adult mites could not have increased from mite reproduction within the colonies. On week 9 (the end of the experiment), mite populations were measured on adult bees as well as in brood cells, and colonies with open-screen floors had a lower P-MIB than colonies with wood floors (table 3). Mean differences were 21% in experiment 1 and 13% in experiment 2 (tables 1 and 2).

On the ninth week of the experiment, mite populations in colonies with open-screen floors had significantly fewer mites than colonies with solid floors (table 3). The trends were similar in both experiments (Tables 1 and 2), but differences were significant ($\alpha < 0.05$) only when the data were combined.

DISCUSSION

The data suggest that mites were controlled to a significant degree by open-screen floors in hives. Furthermore, the open-screen treatment was associated with the percentage of the mite population in brood cells, and lower P-MIB has been related to lower mite populations (Harris *et al.*, 2003). Therefore, a lower P-MIB may be the mechanism that reduces mite populations in colonies with open-screen floors.

In contrast, the closed-screen treatment had no apparent effect on P-MIB and was similar to controls in this respect. The open- and closed-screen treatments were significantly different on day 20 when we compared the number of mites found on adult bees (table 2).

Our eight observations with closed screens were insufficient to prove that a closed-screen floor lowers mite populations. However, other experimenters used closed-screen designs very similar to ours (Pettis & Shimanuki, 1999; Ostiguy *et al.*, 2000; Ellis *et al.* 2001; Sammataro *et al.*, 2004), and their results showed the same trend as ours, that hives with closed-screen floors tended to have fewer mites than hives with traditional wood floors. Therefore, we think there is good evidence to conclude that

TABLE 2. Experiment 2, similar in design to experiment 1 but conducted in summer and containing a third treatment group, closed-screen floor. Each colony began in Baton Rouge, LA with no brood, about 11 600 bees, a free-mated queen, and about 480 varroa mites.

Variable	Open screen floor (n = 7)	Closed screen floor (n = 8)	Wood floor (n = 7)	*F*	*df*	*P*
20th day of exper. (16 Jul)[a]						
Cells of capped brood	5549 ± 748[b]	5711 ± 1462	5974 ± 1336	0.21	2, 19	0.81
Mite population on adult bees	65 ± 25	33 ± 25	43 ± 19	3.55	2, 19	0.05
Adult bee population	5775 ± 339	5504 ± 463	5480 ± 338	1.26	2, 19	0.31
68th day of exper. (3 Sept)						
Cells of capped brood[c]	6242 ± 1291	5991 ± 1240	5684 ± 1792	0.23	2, 17	0.80
Total mite population	239 ± 262	197 ± 139	391 ± 250	2.03	2, 19	0.16
Percentage of mites in brood[c]	60 ± 18%	70 ± 20%[d]	73 ± 14%	0.97	2, 16	0.40
Adult bee population	10 982 ± 1412	11 313 ± 1745	10 096 ± 1957	0.98	2, 19	0.39

a. Bees installed on 26 June; queens released on 28 June
b. Data are means ± s.d.
c. Because of failing queens, the number of capped brood cells was < 2000 cells in two colonies. Since the number of brood cells affects P-MIB (Boot *et al.*, 1994), the screen and wood floor treatments each lost one colony and therefore each had an n = 6 for these variables on 3 Sept
d. One of the colonies was omitted from analysis of P-MIB because we found no mites per 400 cells of brood and only 2 mites in the sample of adult bees.

TABLE 3. Complete randomized block analyses of the combined data from experiments 1 and 2 (tables 1 and 2). The closed-screen treatment was excluded from these analyses because it was present only in experiment 2. There were no significant interactions.

Variable	LS means ± s.e.		*F*	*df*	*P*
	open screen	wood floor			
Mite population on adult bees (day 20)[a]	58 ± 5	42 ± 5	5.11	1,29	0.03
Percent mites in brood	57 ± 4%	74 ± 4%	9.76	1, 26	0.004
Total mite population	2.23 ± 0.07[b]	2.46 ± 0.07[b]	5.28	1, 28	0.03
Adult bee population	16 575 ± 609	15 572 ± 623	1.32	1, 29	0.26
Cells of capped brood	10 262 ± 436	8 925 ± 456	4.49	1, 26	0.04

a. All other variables were measured at the end of the experiments
b. Data for this variable were normalized with a log transformation. Although data from the other variables were not transformed, all means in this table were generated from statistical analyses in SAS software. Consequently, tables 1 and 2 are better sources for actual means

both open- and closed-screens floors will reduce mite populations.

A lower P-MIB in hives with open-screen floors means that mites in those hives are remaining on adult bees for a longer time. We assume that mites in a colony are either in brood cells or on adult bees, and P-MIB describes the percentage of the mite population that is in the reproductive mode (in a brood cell). Because there is very little variation in how long a mite remains in a brood cell (mites must leave a cell when the host bee emerges as an adult or possibly sooner if a cell is prematurely uncapped by an adult bee), P-MIB is largely controlled by how soon after leaving a cell that a mite returns to a brood cell (the length of time that mites remain on adult bees). The best case for beekeepers would be if mites never entered brood cells (P-MIB = 0). At 0% MIB, mite populations would disappear with the natural mortality of the adults. If the average mite remained on adult bees for only 3 days before entering a brood cell, we would observe P-MIB = 81% (see Otten, 1991, Harbo & Harris, 1999b). In the combined data from both experiments (table 3), P-MIB averaged 57% for the open-screen floor and 74% for controls. This means that for the average varroa mite, the time span between leaving a brood cell and entering another cell (the time spent on adult bees) was 9.4 days in hives with an open-screen floor and 4.4 days in control hives.

This study focused on screen floors on hives, an environmental condition that affects P-MIB. However, colony variation for P-MIB also has a strong heritable component in the honey bee (Harbo & Harris, 1999a). It is likely, therefore, that selective breeding of bees could reduce P-MIB. Understanding the environmental conditions that may affect P-MIB, such as open-screen floors, the size of the brood cell (Goetz & Koeniger, 1993; Message & Gonçalves, 1995) and the ratio of adult bees to brood (Boot *et al*., 1994), is helpful in selective breeding for low P-MIB because a bee breeder then has the opportunity to control these environmental conditions. In addition, beekeepers may be able to reduce the rate of growth of mite populations by having screen floors on their hives.

Acknowledgements

Daniel Winfrey and David Dodge (ARS-USDA, Baton Rouge) provided technical support for this project. Deborah Boykin (ARS-USDA, Stoneville, MS) provided statistical guidance. The work was done in cooperation with the Louisiana Agricultural Experiment Station.

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