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Screened bottom boards



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**Rural Industries Research and
Development Corporation**

Screened bottom boards

by Dr Doug Somerville & Dr Damian Collins

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Foreword

The role of honey bees as pollinators in the horticultural, pastoral and broad acre cropping industries is well documented and increasingly valued by the rural industries. Thus the long term viability and sustainability of the Australian beekeeping industry is of immense importance to the greater agricultural community.

The range of threats to the honey bee industry is quite considerable and global in nature. Honey bee colonies are experiencing major losses world-wide and there is a growing level of concern about the future viability of beekeeping. The one major threat to beekeeping is the parasitic varroa mite that has jumped hosts from the Asian bee to the Honey Bee. Honey bees show very little resistance to varroa mites and, as a result, their populations around the world are under immense pressure.

Although currently free of this parasitic mite, Australia will likely have to deal with it some time in the future. Any management strategy that can be adopted now by Australian beekeepers to assist with its management will help the Australian beekeeping industry become more resilient.

The use of screened bottom boards has been identified as having potential benefits in being part of an integrated pest management system. Unfortunately there is a perception that the design of these screened bottom boards may affect the productivity of the hive.

The results of this research demonstrate no difference in the productivity of honey bee colonies when using conventional bottom boards or using screened bottom boards. Thus, beekeepers should consider trialling screened bottom boards as a possible varroa mite readiness strategy without prejudice that they may affect productivity.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Pollination R&D program, which aims to improve pest and disease management (of honey bees) to ensure the ongoing supply of pollination services.

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Craig Burns

Managing Director

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Executive Summary

Background

The core purpose of this research was to test the productivity differences between a conventional bottom board and a screened bottom board on a honey bee hive. The use of screened bottom boards may provide some advantages in an integrated varroa mite pest control program. The perception that the use of screened bottom boards affects productivity due to draft is a major impediment to beekeepers considering their use and adoption.

Aims/objectives

Review existing designs and use of screened bottom boards. Design a functional screened bottom board, then measure the temperature, humidity and production differences between hives fitted with screened bottom boards and those with conventional bottom boards.

Methods used

A screened bottom board was compared to a conventional bottom board with 30 hives in each treatment (although only 20 in each treatment survived until the end). The weight gain was measured during four periods over 14 months. The temperature and humidity was measured on five hives within the two treatments for the duration of the trial. Bee strength and brood area were measured at the completion of the trial.

Results/key findings

There was a mean weight gain over the entire period of 15% for hives with the screened bottom boards compared to conventional bottom boards. This could have been dependant on the particular design of bottom board tested and the combination of climatic conditions the hives were exposed to during the 14 month period. This is a positive finding, as any benefit the modified screened bottom board design may have to assist in the control of pests of bee hives will not, according to this research, be impeding the productivity of the bee hive. The statistical analysis indicates no significant difference between the two treatments, ie the screened bottom board and the conventional bottom board, as far as key productivity data was concerned.

Implications for relevant stakeholders

All beekeepers should consider what the management of honey bees will look like when varroa mites arrive in Australia. The results of this project provide information for beekeepers to make an informed decision on the use of screened bottom boards as they may affect productivity of a bee hive. The use of screened bottom boards may also provide other benefits that beekeepers may consider testing in their own apiaries.

Recommendations

The primary purpose for the use of screened bottom boards is their positive role in the control of varroa mites. The progress of varroa tolerant honey bee breeding programs should be carefully followed on the world stage. The use of screened bottom boards is not a stand-alone strategy to economically control varroa mites but, integrated with the use of specific varroa tolerant stock, they may be of major benefit.

Introduction

Varroa mites are arguably the most serious pest currently being experienced by honey bees world-wide. They are not presently found in Australia but it is assumed that this status will eventually change. There is a range of chemical options for treating colonies of honey bees to suppress mite populations, but they are all short term in their application. The use of screened bottom boards is said to assist in discarding mites that fall to the bottom of the hive by the function of them falling through the screen onto the ground, some distance from the colony and any bees. There has been some doubt about the use of these screens, which may interrupt the colonies ability to rear brood and thus reduce the profitability of the hive.

There are a limited number of published papers on the subject of screened bottom boards. No author doubts that the boards may be useful in the management of varroa mites, although there are variations in the percentage of mites that are discarded by the bee colony with the use of these boards. Estimates vary from 10 to 30%. One of the limitations in the uptake of these devices is the belief that the bees are exposed to drafts and a greater variation in temperature within the brood area. The few papers published on this subject are not conclusive as to whether this is an issue or not.

There is one possible advantage of screened bottom boards not mentioned by any previous researcher or beekeeper. This is the option to close bees in the hive to minimise chemical pesticide spray risk if the apiary cannot be moved prior to the application of potentially toxic chemicals. The screen allows the colony not to become overheated which will likely be the case with conventional solid bottom boards. This may have major advantages to both beekeepers and crop growers in providing a workable solution to a major problem, even without any benefit from varroa mite control.

Biology of varroa mites

Some facts to consider in the management of this major problem to beekeeping world-wide:

- mites reproduce on a 10 day cycle ¹
- within 12 weeks (three months), the number of mites in a hive can multiply by a factor of 10 ¹
- high mite numbers in a hive when drone brood rearing ceases can quickly lead to the death of a colony ¹
- mites feed on both adult and brood of honey bees ²
- mites prefer to breed in drone brood (10 to 12 times more frequently) ²
- a female mite may produce a second and third generation by entering new brood cells ²
- life span of a mite can vary from 27 days to five months ²
- mite populations double every four weeks, although this is largely dependent on the amount of drone brood present ²
- at any given time in the year, while brood is present in the hive, about two-thirds of the mites are under cappings and reproducing ³
- mites are phoretic (carried by adult bees) for a minimum of four to five days. Thus, there is a potential for a 20% turnover of phoretic mites every day. Older mites re-enter a brood cell and new ones emerge ³
- varroa mites mostly mature on younger nurse or house bees, unless the mite population is very high, older field bees carry very few mites ⁴

Mite impact

- in the process of the mite feeding on the brood or adult bee, they may act as a vector for the spread of viruses ²
- colony collapse can be very rapid, taking only a few weeks ²
- symptoms of colony collapse include brood disease type symptoms associated with EFB and AFB, but without these bacteria present. The cause of the collapse is probably due to an escalation in viruses with the bees succumbing to these pathogens
- in highly infested colonies the bees are already severely damaged by the mites and the viruses, before treatment is applied. Even with extremely efficient treatments, these will not be sufficient to save the colony because the damage inflicted by the virus infections will not be removed by removing the mites ⁵

Treatments

- a colony allowed to build its own comb will produce about 17 to 20% drone cells. When mites have access to drone brood they are able to reproduce three times faster in population. In a well-managed colony using worker-sized foundation, drone cells can be kept down to about 4%. ³ Although, when conditions are favourable, drone brood is constructed under the bottom bar and between the top bar and queen excluder
- as drone brood is 10 to 12 times more attractive to mites than worker brood, it is possible to place drone brood combs in a hive with the purpose of regularly removing these combs and thus removing the contained mites. Keep in mind that old combs are four to five times more attractive to varroa than new combs. Theoretically, removing the drone brood once a month will prevent the mite population expanding. Removing drone brood comb twice a month will reduce the mite population ³
- any treatment applied to a hive that only kills phoretic mites (adults attached to adult bees) at the time of treatment, will return to its previous adult mite numbers within five days as new mites emerge each day
- Apistan® (Fluvalinate) and Bayvarol® (Flumethrin) are contact pesticides. The pesticide impregnated plastic strips are placed in the brood nest area suspended between the frames. The bees rub against the strips and the pesticide is spread around the hive by contact between the bees. The strips are left in the hive for 6 to 8 weeks
- Fumigants, including food grade mineral oil, oxalic acid, thymol and formic acid, have variable results in controlling varroa mites. Many of these products require specific environmental parameters to be effective. There is also a potential for adverse effects on the bees, brood and the beekeeper. By their mode of action, a sealed hive is more likely to be effective when using these treatments
- while not considered a treatment, many in the beekeeping fraternity believe that the long-term answer for managing the varroa problem on *Apis mellifera* is to breed a bee resistant to varroa. There are a number of breeding programs around the world that have this as their primary aim.

Two pathways by which bees behave have been identified as being effective in removing mites from the hive or stopping them from reproducing.

1. Grooming behaviour of bees has been studied in *Apis cerana* colonies and has been found to be a very effective means by which varroa mites are removed from the adult bees. The mites in most areas are damaged and injured by the grooming behaviour. There is some evidence that *Apis mellifera* also remove adult mites from each other, visibly damaging the adult mites.^{6,7} This trait would be expected to vary in its expression from colony to colony and could be a worthwhile line of research to pursue.

2. Varroa Sensitive Hygiene (VSH) is a behavioural trait of honey bees in which the house bees detect and remove developing bee pupae that are infested by developing varroa mites, thus interfering with the breeding cycle of the varroa. This trait has been found to be a hygienic behaviour of honey bees and thus heritable.⁸

Both these traits have the potential to reduce the dependence of beekeepers on chemicals to manage mite populations. Both traits may also benefit from the use of screened bottom boards in discarding infested pupae and damaged mites.

Applying powdered sugar can be an effective method of removing phoretic mites. A screened bottom board needs to be in place for this method to work. Approximately a quarter of a cup of icing sugar is applied over the bees in the brood box. The fine sugar adheres to the mites' foot pads, causing them to lose their grip on the bee. To be effective in reducing mite populations, it needs to be applied every third day for 21 days. The powdered sugar probably increases grooming behaviour of the nurse bees, thus leading to the removal of the phoretic mites.

Screened bottom boards

- about 20% of the adult mites on newly hatched adult bees will fall off the bees to the bottom of the hive in the first three days after emergence⁹
- the mesh or screen size should offer a 3 mm opening.⁹ As the adult mite is a flat shape and measures about 1.1 mm long by 1.7 mm across, they will pass through the screen with little difficulty¹⁰
- screened bottom boards are not a stand-alone treatment to control mite populations, they must be used in conjunction with other mite control treatments
- hives are said to be drier during the winter. The hive can be put down in any position and water will not accumulate on the bottom board. Also, the open mesh screened bottom board may help to reduce humidity and condensation effects in a hive
- in extremely high humid environments a screened bottom board may make it difficult for the colony to control the humidity in a hive and ripen the nectar
- ants entering the hive through a screened bottom board may be impossible for a colony of bees to manage. There are a range of ant species and their impacts on bee hives is also variable
- screened bottom boards used with tray inserts under the mesh covered with either a substance such as petroleum jelly or a sticky mat are an excellent means of monitoring natural mite fall. With highly efficient treatments such as Apistan® and Bayvarol®, one can expect a 95 to 99% reduction of mites before resistance to these chemicals emerges. Once the mites are resistant to these two pesticides, all the other treatments available are variable in the numbers of mites killed. It thus becomes a vital management activity to regularly measure mite populations in an apiary to ensure mite levels do not become critical and un-expectantly kill colonies
- there is a mixture of views on leaving tray inserts under a screen during the cooler periods of the year. Some advocate a human analogy whereby 'would you leave your front and back door open all winter' and others have commented on their observations that open screens during winter have no noticeable effect on the productivity of a hive
- with screened bottom boards the colony can be locked in using an entrance shutter and the hive can be safely moved during the day, with reduced risk of the colony overheating and dying
- the use of a screened bottom board is reported to extend the period between a mite emerging from a brood cell and re-entering another brood cell to reproduce from 4.4 days to 9.4 days¹¹

- those who advocate the use of screened bottom boards very clearly indicated that one of the main benefits is the lack of build up of debris on the bottom board. This frass is an ideal haven for wax moth larvae, plus small hive beetle larvae and adults. There is also no opportunity for the bottom board to flood by the inundation of storm water if the hive is tilted with the entrance higher than the back of the hive.

Mite monitoring

It is vital for effective management of varroa mites to continually monitor the levels of mite infestation in a hive. As the mite population may vary from one hive to another and between apiaries, it is important to also measure the mite population in each apiary. A common method used to access mite levels in a colony is to count all the mites that fall onto a mat placed on the bottom board.

The boards are either sticky or covered in a substance such as petroleum jelly to ensure the live mites stay put to allow an accurate count. The number of mites are counted and divided by the days the board has been in place to determine mites dropped by the colony per day.¹²

How often is 'continually monitor' for mite populations? This will vary from season to season and location to location. If your bees are located in a traditional temperate zone with cool to cold winter temperatures with little or no brood present, a spring build up period, followed by a reduction in brood area over summer and autumn, then perhaps at least four tests should be conducted – early spring, late spring, mid to late summer and late autumn. This would be regarded a minimum number of mite counts.²

The mite counts per day on the sticky mats provide a guide to the levels of infestation within that colony. While researching this project, the author came across a few published guides as to what the mite drop numbers mean. The following is an example only, and it would be good advice to conduct multiple tests using different techniques to determine what levels of infestation the mite drop counts equate to in your own geographic locations.

In the United Kingdom mite counts on sticky mats above eight per day through most of the year are considered extreme and immediate mite controls are required. Levels above two mites per day in the middle of winter are also considered very high. Mite levels at one per day or lower are considered safe, with no immediate treatments necessary.²

Other authors provide some guide to what they regard as an acceptable number of mites or what level of mite drop should trigger action from the beekeeper;

< 5 mites per day	=	low infestation levels
5-10 mites per day	=	medium infestation levels
> 10 mites per day	=	high infestation levels ¹³
30 or more mites per day	=	imminent colony collapse ¹⁴

Greater than 9 mites per day at the end of spring treat hive

Greater than 12 mites per day at the end of summer treat hive¹⁵

Must reduce mite fall to 0.5 to 1 mite per day prior to winter¹⁶

The average natural mite fall of 0.2 mites just before bees overwinter corresponds to a total population of mites of about 100 to 200 mites. Therefore the natural mite fall of one varroa per day corresponds to approximately 500 varroa mites in a colony¹⁷

The figures for natural mite fall are variable and no doubt are strongly correlated to the population of the colony and age of the mites and the area of brood.

Screened bottom boards can be an effective means by which mite drop levels can be monitored without the need to interfere with the colony. This provides very good outcomes by not accidentally squashing bees inadvertently, not increasing nosema levels in the hive and not promoting aggressive behaviour of the bees regarding the defence of their hive.

A tray can be constructed to slide under the screened bottom board with the sticky paper of petroleum jelly attached to catch the falling mites. Continually monitoring the effectiveness of the various treatment methods is vital, as a control program that was effective one year may not be effective the next year.²

Objectives

1. Review existing designs and use of screened bottom boards.
2. Design a functional screened bottom board.
3. Measure the temperature and humidity differential in the brood nest between hives fitted with screened and non-screened bottom boards.
4. Measure the production differences between hives fitted with screened and non-screened bottom boards.

Methodology

Bottom board design

Several screened bottom board designs were appraised. A loose bottom board with a removable screen was the bottom board of choice. This design demonstrated considerable ventilation, which would assist in testing the temperature, humidity and production performance of hives fitted with screened bottom boards as opposed to solid bottom boards.

A fixed screen or removable screen is irrelevant for the purposes of the comparison between conventional and screened bottom boards but the idea of a removable screen allows damaged screens to be quickly replaced and or the screen to be removed for cleaning.



Figure 1: Screened bottom board on left and conventional bottom board on right

The screened bottom board could be fitted with a removable tray to assist in mite counts if or when required. The gap in the screens is 3mm, allowing debris and frass to pass through the screen but preventing bees from passing through.

Temperature and humidity

Five hives in each group (5 screened bottom boards, 5 solid floor bottom boards) had a Tinytag View 2 data logger installed. The probes on the end of a flexible cord were placed into empty queen cages and anchored 50mm from the bottom bar in one of the middle frames. In all cases this was in an active brood rearing area.

The Tinytags were programmed to record the temperature and humidity every hour for the duration of the project. There were four distinct measurement periods during the trial period based on the need to transport the apiary to different geographic locations based on flowering events for the purpose of honey gathering or the provision of pollination services.

Measurement periods:

- 27th November 2011 10th April 2012
- 10th April 2012 30th July 2012
- 30th July 2012 18th September 2012
- 18th September 2012 23rd January 2013

Of the sub-group of hives with Tinytags installed, one hive from the conventional bottom board group and two hives from the screened bottom board group were removed from the trial for the last measurement period (18/09/2012-23/01/2013) due to queen failure and general demise of the colony.

Background to analysis

A screened bottom board was compared to a conventional bottom board with 30 hives in each treatment (although only 20 hives in each treatment survived until the end). A timeline is shown in Table one showing five periods of weighing corresponding to moves of the hives. Bee strength, brood were also measured at completion.

Table 1: Timeline of events

Weighing Date	Event	Duration	Removals
27/11/2011	Start: Young (cherry orchard)	15 weeks	2 C + 1 S (queen failure?)
10/4/2012	→ Bermagui (spotted gum)	15 weeks	
29/7/2012	→ Narrandera (almond pollination)	7 weeks	
18/9/2012	→ Young (cherry orchard)	18 weeks	8 C + 9 S (swarming?)
23/1/2013	Completion		

Five of the 30 hives in each treatment were fitted with temperature and relative humidity (RH) data loggers which took hourly measurements. Raw data is plotted in Appendix B3.

Statistical analysis

A repeated measures analysis of weight gains at the four timepoints was carried out, with treatment, time and their interaction as fixed and an unstructured covariance matrix for the four timepoints within each hive.

The software ASReml¹⁸ was used to fit the mixed model.

In addition, a generalised linear model with normal errors and log link was used for total aggregated weight gain with treatment as the factor. The coefficient for treatment difference was exponentiated to provide an estimate (and confidence interval) for proportional difference in weight gain.

The other responses took discrete values (i.e. not on a continuous scale), and so an ordinal model was fitted using polr function in the MASS library ¹⁹ in the R statistical software environment ²⁰. The odds ratio presented is the relative odds of obtaining a higher value for the screened bottom boards versus conventional. All other calculations were performed in the R statistical software environment ²⁰.

For the temperature and RH data, daily minimum and maximum values were calculated. Each of these four series were analysed as repeated measures in a mixed model smoothing spline framework ²¹, comprising fixed treatment, linear time and treatment by linear time interactions, and random spline time, treatment by spline time, and hive, hive by linear time (with a correlation between these two effects) and hive by spline time effects.

Diary of activities

September 2011 – Hives were moved to a cherry orchard near Young (South West Slopes of NSW).

Early October 2011 – Hives were moved to an adjoining site. Major swarming occurred through late September and October. Estimated 90% + swarmed.

17th November 2011 – All hives in the apiary were re-queened with young queens. Thirty hives had screened bottom boards installed.

27th December 2011 – Based on consistency of hive strength, sixty hives were selected from an apiary of approximately 80 hives. All sixty hives were weighed. Five hives in each group (5 screened bottom boards, 5 solid floor bottom boards) had a Tinytag View 2 data logger installed. The probes on the end of a flexible cord were placed into empty queen cages and anchored 50mm from the bottom bar in one of the middle frames. This, in all cases, was in an active brood rearing area.

The floral conditions were highly favourable for honey bee foraging with yellow box (*Eucalyptus melliodora*); Blakely's red gum (*E. blakelyi*); lucerne (*Medicago sativa*); scotch thistle (*Onopordum acanthium*) and flatweed (*Hypochoeris radicata*) all flowering and providing pollen and/or nectar to the hives.

10th January 2012 – Hives were assessed for honey storage capacity and those hives identified as requiring more comb space were provided additional supers.

Floral conditions were diminishing compared to the previous date visited, with scotch thistle towards the end of its flowering, and flatweed, lucerne and volunteer canola (*Brassica napus*) available to foraging bees in limited amounts. Small hive beetles were observed in large numbers throughout all hives in the apiary.

25th January 2012 – Hives were assessed for honey storage capacity and those hives identified as requiring more comb space were provided additional supers.

Full supers, or those deemed near to capacity for storing honey, were removed for extraction.

15th February 2012 – Hives were checked for activity and honey storage. Long-leaved box (*Eucalyptus goniocalyx*) was in flower.

13th March 2012 – Hives were assessed for honey storage capacity and those hives identified as requiring more comb space were provided additional supers.

Two hives were slimed by small hive beetle larvae, one hive from each treatment, both hives were side by side. Chalkbrood was common through the apiary.

Floral conditions poor with long-leaved box and flatweed in flower. Large loads of pollen were being gathered and evidence of a shake of nectar, although some robbing activity was observed.

10th April 2012 – Hives were moved from Young to Bermagui on the Far South Coast of NSW. All hives were weighed as they were loaded onto the truck. Long-leaved box and flat weed were still in flower at the Young site. Spotted gum (*Corymbia maculata*) was starting to flower at Bermagui.

4th May 2012 – Hives were checked for activity and honey storage. Hives had stored worthwhile honey and were continuing to collect and ripen nectar.

16th May 2012 – Hives were assessed for honey storage capacity and those hives identified as requiring more comb space were provided additional supers. High numbers of small hive beetles were observed in hives across the apiary. Large loads of pollen were being collected from spotted gum, with a steady flow of nectar.

6th June 2012 – Hives were checked for activity and honey storage. Field bees observed to be collecting good supplies of pollen.

25th July 2012 – Removed full or nearly full supers of honey and weighed boxes as they were loaded onto truck for extraction. Small hive beetle numbers were less than previous inspection, but still common throughout apiary. Spotted gum and dillwynia (*Dillwynia spp.*) were in flower, white stringybark (*E. globoidea*) close to flowering.

29th July 2012 – Hives were moved from Bermagui to Narrandera in the Riverina onto almond pollination. No blossom was apparent when the hives were delivered to the orchard. All hives were weighed.

17th August 2012 – Hives were checked for general condition.

18th September 2012 – Hives were moved from almond orchard near Narrandera to cherry orchard near Young.

27th September 2012 – Hives were checked for activity and honey storage. Measurements were recorded of bee strength (frames of bees), disease and pest status and frames of brood. If evidence of swarming was apparent, this was also noted. Dry supers were weighed and added to hives requiring room to store honey.

Small hive beetles common, some hives exhibiting chalkbrood disease and three hives exhibiting symptoms of AFB. Swam cells in most of the test hives, although evidence of only a few having swarmed at this date. Cherries (*Prunus spp.*), Paterson's curse (*Echium plantagineum*) and canola in flower and being worked by the field bees.

10th October 2012 – Full or nearly full honey supers removed and weighed.

18th October 2012 – Hives in cherry orchard were transported to new locality within same area.

21st October 2012 – Hives were checked for activity and honey storage. Weighed and added supers to hives requiring room to store honey.

27th November 2012 – Hives were checked for activity and honey storage. Weighed and added supers to hives requiring room to store honey. Inspected all hives for disease status and queen condition. Re-queened all hives. A few hives exhibiting signs of chalkbrood disease. A number of hives had poor performing queens or the queen had become a drone layer.

7th December 2012 – Hives were checked for activity and general conditions.

23rd January 2013 – Final measurements including total weight of each hive unit, disease and pest status, frames of bees, frames of brood and overall rating from 1 to 5.

Scoring

(based on bees and brood in an eight frame double hive with a migratory lid and queen excluder)

1. 2-4 frames of bees, 2 frames of brood
2. 6-8 frames of bees, 4 frames of brood
3. 10-12 frames of bees, 4 + frames of brood
4. 14+ frames of bees, 6 frames of brood
5. 16 frames of bees +, 6 + frames of brood (bees clustered in the lid)

Small loads of orange and purple pollen were being collected. Nothing obvious was in flower. Atmospheric temperature was 40°C with humidity less than 20%.

Screened bottom board design

There are a range of different screened bottom board designs around the world, primarily for the management and counting of varroa mite populations. By inserting a collection tray under the screen covered with a substance such as petroleum jelly or sticky paper, any mites falling through the screen are held fast. By counting natural mite fall over a set period of time, it is then possible to estimate the resident varroa mite population and make a decision whether to apply a treatment to suppress the mite population in the event that the population has reached an economic critical threshold. This method of monitoring mite populations avoids the need to remove bees from the hive to process them to determine mite populations.

The screened bottom board for this research was designed so the screen could be removed and the bottom board could be easily cleaned if the need arose. The appearance of the screen was similar to that of a conventional queen excluder but with a 3mm gap instead of a 4.1mm gap.



Figure 2: Screened bottom board used in the trial on left next to conventional bottom board



Figure 3: A varroa screen to fit into the base of a bottom board on left compared to a wire queen excluder



Figure 4: A screened bottom board designed and constructed by Ray Geale and Niall Keane, Wagga Wagga



Figure 5: American screened bottom board with gridded mat removed



Figure 6: American screened bottom board with gridded measuring mat inserted



Figure 7: English screened bottom board with ridged plastic closure removed



Figure 8: English screened bottom board with ridged plastic tray inserted

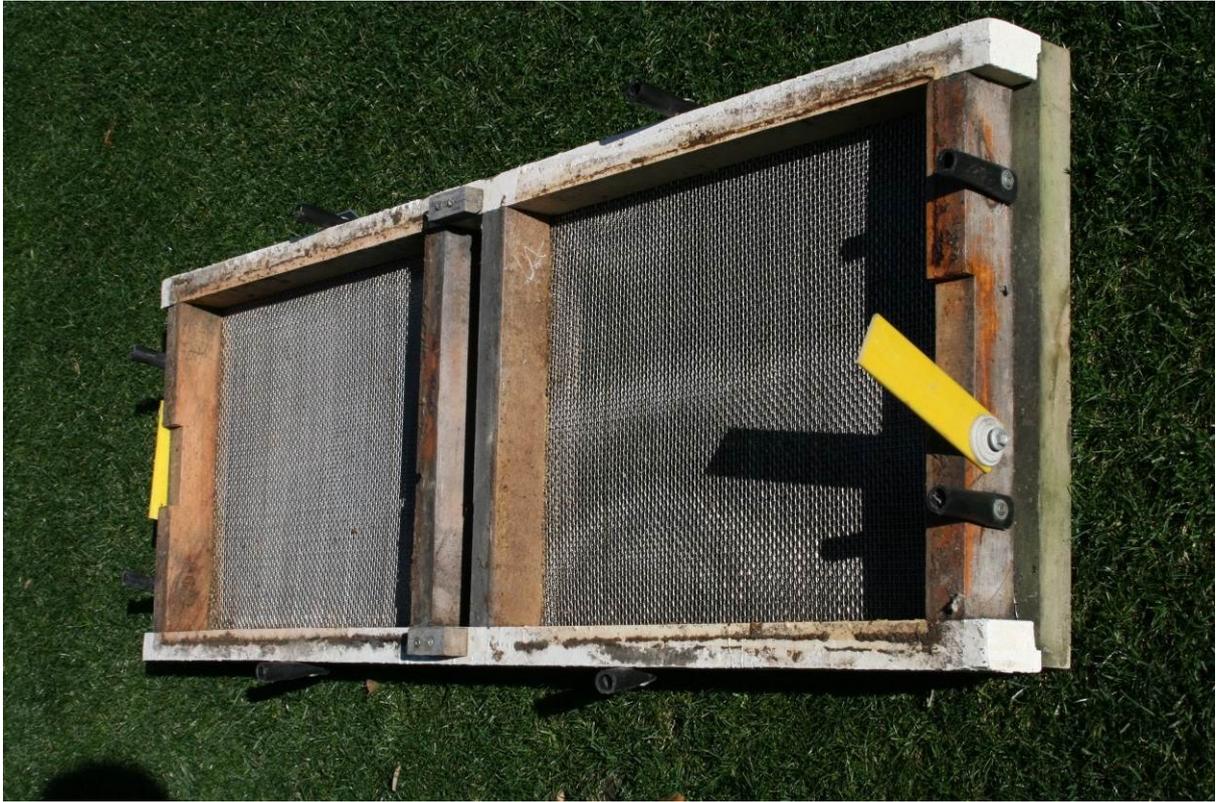


Figure 9: A New Zealand designed screened bottom board for two hives



Figure 10: A New Zealand designed screened bottom board with tray removed



Figure 11: A very robust screened bottom board designed and constructed by Barry Pobke from South Australia

Varroa and screened bottom boards survey

NZ Beekeepers' Conference 2012

Summary

New Zealand beekeepers were surveyed for their use of screened bottom boards at their National Beekeeping Conference held at Napier in June 2012. A total of 46 responses were received, with a high number (65%) indicating that they use screened bottom boards on at least some, if not all, their bee hives.

This is possibly a bias survey as the very nature of surveys is that they are voluntary and as such, if you are not using screened bottom boards, you may not feel inclined to take part. Recorded advantages of using screened bottom boards included eliminating natural varroa mite drop throughout the year, providing ventilation, reducing humidity and moulds in the hive and assisting with the movement of bee hives during daylight hours.

Varroa mite management was reasonably stable with many beekeepers using more than one treatment class (different chemical families) though the year. This practice is likely to slow down mite resistance to one or more chemicals even though mite resistance to the synthetic chemicals has been confirmed in NZ. The use of screened bottom boards is not seen as a major management tool in varroa mite control, but rather as a useful addition to an integrated pest management strategy.

Aim

To determine the extent of the use of screened bottom boards within New Zealand.

Objective

Survey beekeepers attending the New Zealand Beekeeping Industry Annual Conference, 2012.

Materials/Method

200 copies of a survey form were distributed at the annual 2012 New Zealand Beekeeping Conference held at Napier on the North Island in June. Incentive to complete the survey was a random draw prize of a few publications and sugar shake kit for varroa – all products of NSW DPI bee team members. Copy of the survey in Appendix A.

Results

There were 46 responses received from the attendees, with 42 responses indicating they would like a copy of the final results of the survey. Most of the surveys were collected during the conference. There were approximately 300 people in attendance at the conference. Many of the returned surveys represented beekeeping operations with more than one person attending the conference, thus the sample size is greater than the number of surveys returned.

Table 2: Do you use screened bottom boards

No	16
Yes	20
Some hives	10

Table 3: Seasonal use of varroa mite treatments

Spring		Winter		Autumn	
Bayvarol®	5	Oxalic acid	3	Apivar®	8
Apistan®	4			Apiguard®	2
Apivar®	5			Bayvarol®	6
Formic acid	1				

Table 4: Preference for varroa mite treatments

Treatment	
Screened bottoms	1
Apistan®	11
Apivar®	20
Bayvarol®	19
Apilife Var®	3
Oxalic acid	3
Food grade mineral oil	2
Resistant bees	1
Thymovar®	2
Drone removal	3
Thymol	1
Fluvic Acid	1
Icing sugar shake	1
Apiguard®	1
Formic Acid	1

Table 5: Number of treatments per annum for varroa

Nil	2
One	4
Two	27
Three	7
Four	3
Five	2

Screened bottom boards – reasons why not used

- not practical on 4 way pallets
- undecided, not enough time to monitor other uses of screened bottom boards
- cool the bottom brood chamber too much in spring, autumn and winter; removing them all from my hives (Waikato)
- we have both and get the same control of mite and healthier hives on solid bottoms
- no noticeable difference (have both bottoms).

Six beekeepers insert plastic corflute blocking off the screens in the bottom boards during the cooler winter period.

Comments on screened bottom boards

- bees seem to be happier, bee hive drier and cleaner inside all year round
- evidence of amount of hive debris being cleaned out and varroa natural drop
- mites supposedly fall through mesh and are unable to re-enter hive when miticide is used
- unsure of benefit
- mites are falling all the time, the mites fall out through the mesh boards onto the ground; hives stay clean and dry all year
- less condensation in our climate (North Island)
- useful due to natural drop of mites (four survey responses)
- when strips lose efficiency varroa may still drop off and fall through screens
- good ventilation in hive
- better ventilation, healthier bees, can be a problem in winter after heavy snow
- stops mites getting back up on the bees again; natural organic treatments tend to knock down mites rather than kill them
- not a significant advantage regarding varroa, but neither are they a disadvantage

- monitoring mite drops
- provided the hive is at least 10cm off the ground, live mites cannot climb back into the hive
- if long grass is under the bottom the mites may climb back up into the hive
- any natural mite fall is removed, ease of monitoring NMF [natural mite fall]
- very handy to use for shifting bee hives during the day; must help, certain amount of mite drops
- the main benefit is ventilation for shifting. The disadvantage is hive too cold during winter causing loss of queens because queens trapped by excluder. Hive stays drier with less build up of moisture during winter – possible nosema advantage. I would feel varroa screens may assist SHB in Australia
- hives shut down earlier and quicker with mesh bottom boards, a little slower to start up in spring, but once away, go like rockets. I use breeding cords and fogging most of the year. Autumn I treat with Apivar or Bayvarol with good results. All the rubbish from the hive falls out through the mesh and onto the ground.
- I do find bees get cold and build up slower during winter
- have tried screened bottom boards; don't see advantage with varroa treatments. Can cause a draft autumn/winter. Gives more honey in supers but then hard to get honey into hive in autumn for winter
- screened bottom boards need protection from wind
- don't get moulds growing in hives, as hives are much drier
- get wax moth under mesh with slides in place, need to be cleaned regularly
- improved shifting, ventilation. Beneficial for health and hygiene. Very significant reduction in dampness inside the hive
- good for moving hives. Good for summer ventilation. Block for winter
- don't use screens on four frame nucs. Like screened bottoms which allows us to move bees during the day onto and off kiwifruit pollination
- we like mesh boards for ventilation of our hives. We have had solid bottoms underneath, but are now moving to open as the crud just sits there. Will block off in winter for warmth.

Table 6: New Zealand beekeepers believe their treatments for varroa mites were

Very effective	16
Effective	22
Ok	9
Reduced effectiveness	5
Looking for other treatments	5

General comments on varroa treatments

- Apistan® proving less effective over time; organics are high labour inputs and variable results; Apivar® slightly better than organics
- screened bottom boards are good for improved hive ventilation and to keep the bottom board clean from debris. In terms of varroa control, type of bottom board does not make a difference unless you are using essential oils or formic acid. If varroa treatments release vapour, mesh bottom boards reduce their effectiveness
- problem – treatments come in from Europe with instructions that work in that region. The efficacy of treatments varies if done according to the label, they don't work
- research into more organic treatments would be great
- the organic treatment in the winter is for control of mite resistance to the strips (Apistan)
- we have trialled a range of organic treatments and some have poor to moderate effectiveness, most are straight snake oil. Resistant bees are our only hope for a decent future in keeping bees
- do some alcohol wash to measure mite populations
- Apivar® is a slow acting treatment, needs to be put in before mite numbers get too high. If mite numbers are high when putting strips in use a thymol treatment at the start to reduce mite numbers. Organic treatments need a minimum of two treatments in spring and three treatments in autumn. Also need to do much more monitoring of mite numbers. Organic treatments do not cope well with high mite levels
- waiting
- looking for improved treatments to meet resistance issues
- find that Apistan® still effective. Apiguard® is very variable. Apivar® needs at least 10 weeks in hive, good for autumn but not spring (Auckland)
- very effective – Bayvarol®. Effective – Apivar®. Reduced effectiveness – Oxalic, I do not have a broodless period
- last year was the first time we have treated the hives three times, twice with Bayvarol® and lastly with Apiguard®/Thymovar®.

Discussion

Reports of failing varroa mite treatments were not evident in the responses. It has been confirmed by Dr Mark Goodwin, based at the Horticulture Research facility at Hamilton in New Zealand, that resistance to Bayvarol® and Apistan® has now occurred within the northern areas of the North Island of New Zealand. This is not unexpected as varroa mites were first discovered in 2000 in Auckland and 2006 in Nelson (South Island), so bee colonies have had sufficient exposure to chemical treatments for over a decade in some parts of the country.

The initial thought process was that the use of screened bottom boards would assist in an integrated management system to suppress varroa mite populations. Neither in this survey, nor other studies/reports published, is it suggested that the use of screened bottom boards is a stand alone method for controlling varroa mite populations.

Quite a high proportion of the responses to the survey indicated that they use screened bottom boards on all or some of their hives (65%), although given the title of the survey some participants at the NZ

conference may have thought that if they do not use screened bottom boards that the survey was not applicable to them, thus the use of screened bottom boards in NZ is likely to be less than 65%.

One encouraging result for the NZ beekeeping industry is the high number of beekeepers who use more than one treatment in any one year (87%). This occurs with a rotation of chemical classes, mainly the synthetics (Bayvarol® and Apistan®) with the organics, primarily thymol based products. The effectiveness of the organic treatments was questioned by a number of beekeepers, with variable control results experienced. The variable response by the organic treatments killing mites was put down to climatic issues, rather than any suggestion of developing resistance to the treatments by varroa mites.

Apistan®, Bayvarol® and Apivar® were the most popular treatments of choice. Responses such as Apistan® becoming less effective over time and the organics requiring high labour inputs suggest a movement in treatment choices, be they reluctant ones by beekeepers. The thought process seems to be that the days of relatively easy management of varroa mites are coming to an end and a more detailed strategy will be required.

Although the question was not specifically asked in the survey about monitoring mite populations, some of the responses indicate that this may be happening, but I get the impression that monitoring is still at a low level. There was particular interest in the sugar shake kit I took to the conference as a mite monitoring tool. Natural mite fall on screened bottom boards could also be a means of monitoring varroa mite populations.

The use of screened bottom boards was believed by many users to reduce rubbish build up on the bottom boards and, as such, result in a healthier environment for the colony. The hive seems to have less moisture build up and less mould. A few beekeepers expressed the positive feature of being able to move bee hives during the day if a screened bottom board was fitted. This was particularly apparent during kiwifruit pollination when work loads were high. Presumably hives were closed up very early in the morning before bees fly and then loaded on trucks to move into and out of orchards during daylight. Kiwifruit flowers in October and November, so the potential for warmer weather conditions is present. With a solid bottom in place and a colony closed up there is a risk of the colony overheating and dying, or becoming heat stressed with the result of some of the brood dying.

Some beekeepers stated that they inactivate the screen by sliding a sheet of corflute across the screen during winter whilst others did not indicate they did anything. It appears from the responses that screened bottom board use in NZ is well established but there is not a strong belief that they play a major role in varroa mite control. Rather, the impression is that they help with varroa mite control. Some beekeepers have clearly identified other benefits for their incorporation into their beekeeping operation, such as the reduction of rubbish and humidity within the hive and the advantage of being able to close bee hives up for transporting during daylight hours.

Results

First measurement period

Hive numbers start: 30 conventional bottom boards and 30 screened bottom boards.

Hive start weight was measured on 27th November 2011 and hive finish weight was measured on 10th April 2012. This period represents the peak of a hot summer until the middle autumn, representing a time gap of 105 days (15 weeks).

On three separate occasions, supers were added to the hives which required storage room for surplus honey. Full honey supers were removed once for extraction. One hive with a screened bottom board and two hives with conventional bottom boards died before the end of this measurement period, possibly due to queen failure.

The brood disease chalkbrood was prevalent in hives in both screened and conventional bottom boards (7 in screened and 5 in conventional).

Hive numbers finish: 28 conventional bottom boards and 29 screened bottom boards

Second measurement period

Hive numbers start: 28 conventional bottom boards and 29 screened bottom boards

Hive start weight measured on 10th April 2012 and hive finish weight measured on 30th July 2012. This period is from mid autumn to mid winter, experiencing cooler coastal conditions on the Far South Coast of NSW. The bees were primarily foraging on spotted gum blossom. The time period was days (15 weeks).

Hive numbers finish: 28 conventional bottom boards and 29 screened bottom boards

Third measurement period

Hive numbers start: 28 conventional bottom boards and 29 screened bottom boards

Hive start weight measured on 30th July 2012 and hive finish weight measured on 18th September 2012. This period is from the end of winter on almond pollination until early spring when the hives were moved to cherry pollination. The time period was 51 days (7 weeks).

Hive numbers finish: 28 conventional bottom boards and 29 screened bottom boards

Fourth measurement period

Hive numbers start: 28 conventional bottom boards and 29 screened bottom boards

Hive start weight measured on 18th September 2012 and hive finish weight measured 23rd January 2013. This period is from mid spring to mid summer, experiencing warm to very hot dry conditions, representing a time period of 127 days (18 weeks).

At the beginning of the period, the majority of hives were observed with swarm cells in the brood area. Small hive beetles were also in consistent numbers across all hives in the trial. A few hives in both treatments were observed to exhibit signs of chalkbrood disease. By the 27th November 2012, there was evidence that a significant number of hives had not recovered from the swarming activity with either broodless conditions or evidence of drone laying queens. As a result a further nine hives with screened bottom boards and eight hives with conventional bottom boards were removed from the trial for this measurement period.

At the completion of the data collection (23rd January 2013) the numbers of small hive beetles in the hives had declined from mid spring. Ten out of the twenty hives with screened bottom boards and eight of the twenty hives with conventional bottom boards were observed to have low numbers of beetles.

Chalkbrood disease was more prevalent than in the mid spring period with six out of twenty in the screened bottom board hives and seven out of twenty in the conventional bottom board hives.

Hive numbers at finish: 20 conventional bottom boards and 20 screened bottom boards

Weight gain

For the repeated measures analysis, there were no significant treatment nor treatment by period interactions (Table 7).

Table 7: Repeated measures analysis of weight gains: Table of Wald-type F statistics

	DF	F-stat.	P-val
Treatment	1,52.4	2.166	0.15
Period	3,49.9	127.9	<0.001
Treatment × Period	3,49.8	0.7015	0.56

Note: DF=degrees of freedom (numerator, denominator), F-stat.=Wald F-statistic, P-val=P-value

For the aggregate analysis, the difference was almost significant (P<0.1): the estimate of relative treatment difference was ~15% (95% CI: -2% – 34%).

Table 8: Aggregate analysis of weight gain (log link): coefficients and ses

	Coefficients				Backtransformed (with 95% CI)		
	Coef	SE	t-stat	P-val	Effect	Lower	Upper
Conventional	4.426	0.059	75.296	<0.001	83.6	74.2	94.2
Screened vs Conventional	0.14	0.077	1.823	0.076	1.151	0.984	1.345

Note: Coef=estimated coefficient, SE=its SE, t-stat=t-statistic (est/SE), P-val=P-value, Effect=back-transformed coefficient, Lower=Lower 95% CI, Upper=Upper 95% CI

Other variables

There were no significant differences in the other production functions (Table 9). The odds ratios were between 0.5 and 1.5, indicating little difference.

Table 9: Analyses of other production functions: coefficient estimate (est), SE (and t-value) along with odds ratio (OR) and its 95% confidence interval.

	Coef	SE	t-stat	OR	95% CI	
					Lower	Upper
Bee strength 27/9/12	0.111	0.5	0.223	1.12	0.41	3.05
Frames of brood 27/9/12	0.331	0.493	0.672	1.39	0.52	3.76
Frames of bees 23/1/13	-0.579	0.804	-0.72	0.56	0.11	2.86
Bee strength 23/1/13	-0.232	0.594	-0.39	0.79	0.24	2.64
Frames of brood 23/1/13	0.297	0.6	0.495	1.35	0.40	4.55

Note: Coef=estimated coefficient, SE=its SE, t-stat=t-statistic (est/SE), OR=Odds ratio, Lower=Lower 95% CI for OR, Upper=Upper 95% CI for OR

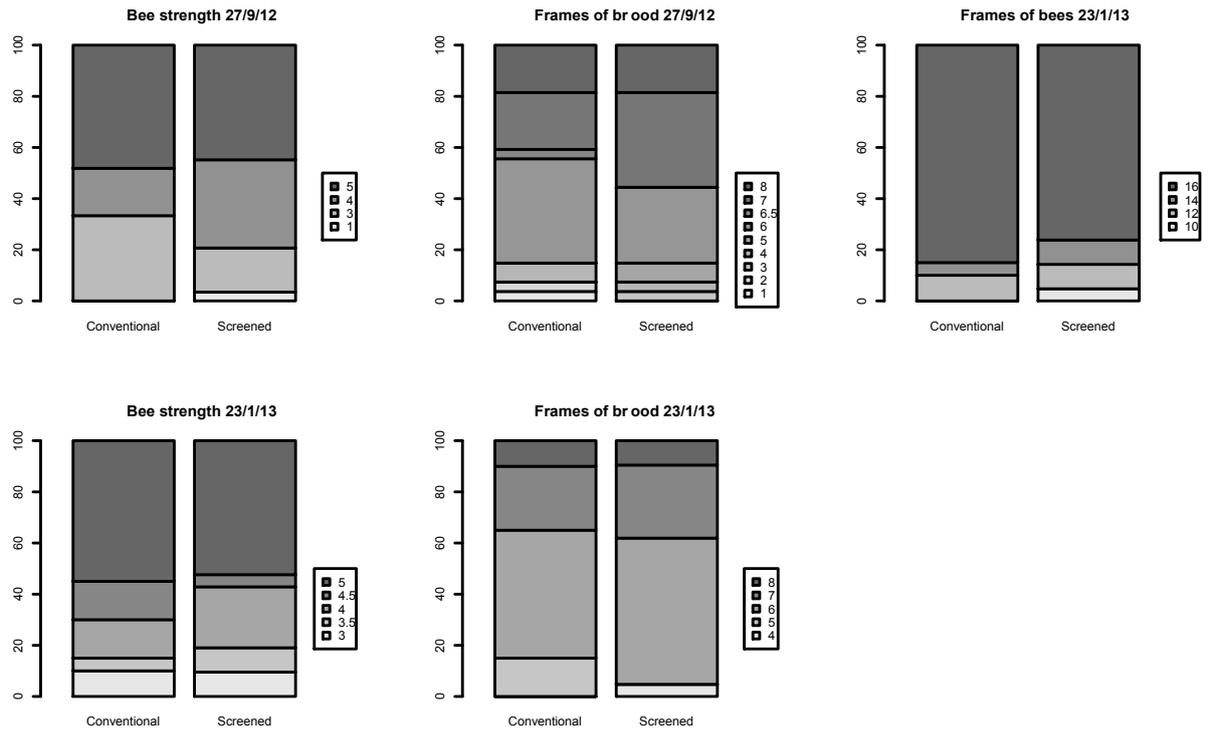


Figure 12: Barcharts of proportions in each class for the other variables collected.

Temperature and humidity (See appendix C for detailed tables.)

For temperature, there were significant treatment by time interactions on both minimum and maximum temperatures. Close examination of the fitted trends (Figure 13) suggests that there are certain time intervals when temperatures were lower in the screened bottom board relative to the conventional, such as in late August (min temp. only), mid October and January 2013 (min temp. only). However, any differences in mean temperatures were never greater than about 0.5 C°.

For RH, there were significant average treatment differences for both max and min RH, and significant treatment by time interactions for minimum RH. Examination of the fitted trends (Figure 14) indicates that RH is generally higher for the screened bottom boards. However, like temperature, though statistically significant, the mean difference is very modest practically, never more than a few percent (%) difference.

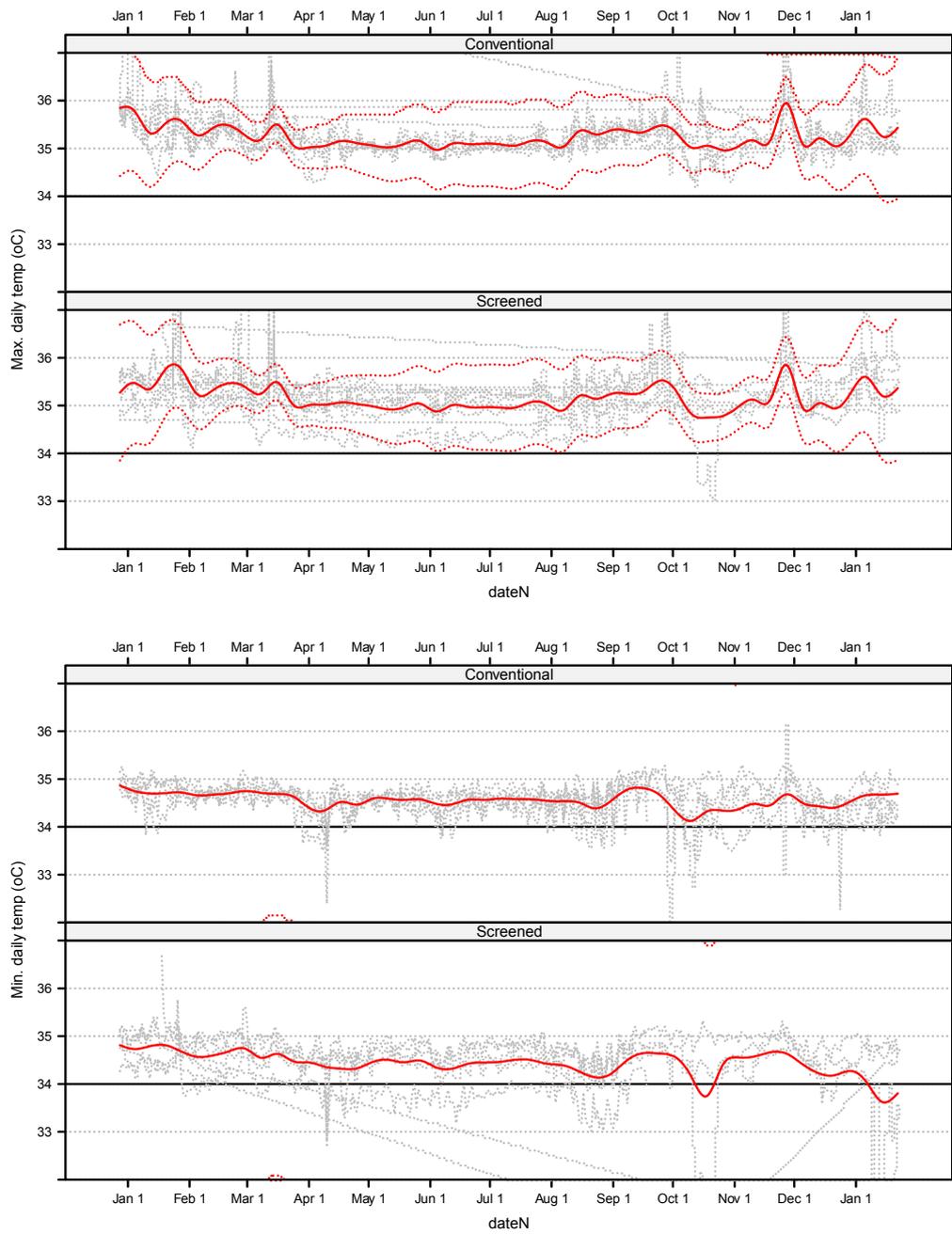


Figure 13: Analysis of minimum and maximum temperatures: fitted trends overlaid on raw data (gray).

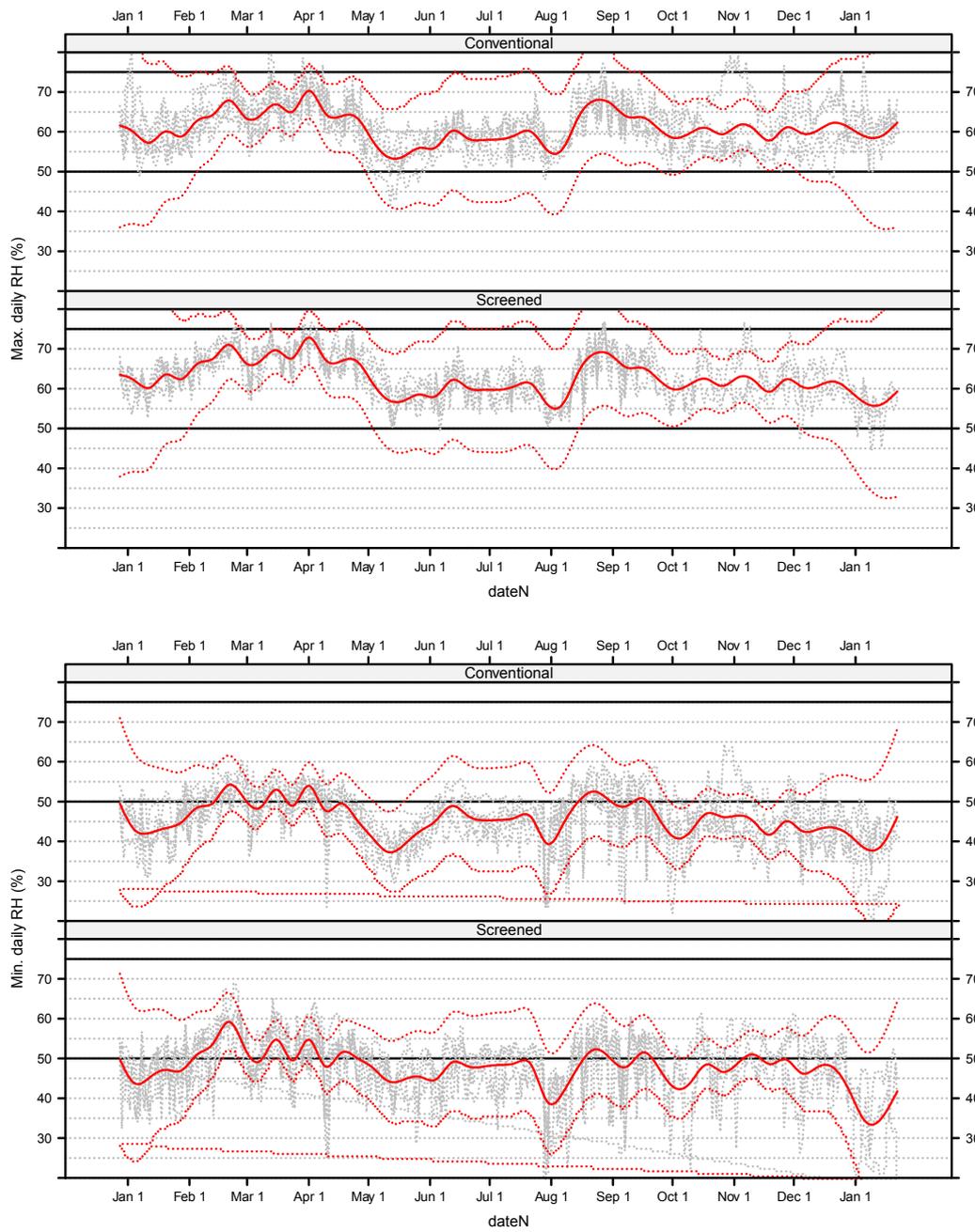


Figure 14: Analysis of min and maximum RH: fitted trends overlaid on raw data (gray).

Implications

The main question is - *are screened bottom boards a useful tool to help manage varroa in bee hives ?* As Australia does not currently have varroa mites, the efficiency of screened bottom boards in the control of mites was not the focus of this research, rather the question was whether the use of screened bottom boards in their own right affects the productivity of the hive.

One of the impediments to adopting screened bottom boards is their perceived impact on the productivity of the hive. This research project investigates their impact over a fourteen month period covering a range of seasonal conditions.

The results of this study suggest that there is no significant difference in productivity of bee hives with the use of screened bottom boards compared to conventional bottom boards. Thus any conversation on the use of screened bottom boards should be focused on their impact on varroa mite populations.

The results provide encouragement to the Australian beekeeping industry to trial screened bottom boards within their own apiaries, with reduced prejudice that they may reduce or affect the productivity of a hive due to the opportunity of greater ventilation.

Various studies suggest a variation as to the effectiveness of screened bottom boards in this regard but they do not provide a rating for the resident bees ability to demonstrate Varroa Sensitive Hygiene (VSH) or any grooming behaviour. While these two factors have been discussed in this report they are the fundamental basis of research programs world-wide to develop a varroa tolerant honey bee.

The screened bottom boards used in this research were purpose constructed and at the time there were few commercial alternatives available to the beekeeping industry. The conventional material screened bottom boards are constructed from woven stainless steel 3mm mesh, is not cheap. Beekeepers manufacturing their own screened bottom boards would be advised to shop around for the cheapest raw materials. A screened bottom board will be more technically difficult to construct and could be at least twice the price of conventional solid bottom boards.

The value of screened bottom boards to beekeepers will be enhanced if used in combination with strains of honey bees selected to demonstrate grooming behaviour and VSH behaviour. If used with conventional honey bee stock which does not show any propensity to control varroa in the hive, their value for varroa management will be questionable.

The survey of New Zealand beekeepers at their 2012 conference revealed a high level of use of screened bottom boards, although the belief was that their role in varroa mite control was minor. The main strategy in New Zealand at the time seemed to be treating hives twice a year for varroa with alternative treatment types. This rotation of treatments will invariably delay the onset of mite resistance to any specific treatment.

A few beekeepers in New Zealand regarded the main benefit of screened bottom boards as being able to move bee hives into and out of kiwifruit orchards during the day rather than of a night time which is usually the case. This was achieved by closing the front entrance before field bees begin to fly for the day, giving the beekeeper the rest of the day to pick the hive up and transport it to its new location.

Recommendations

There is an increasing diversity of designed 'ventilated' bottom boards based on the screened bottom board principle. There are also some significant claims as to what some of these modified commercially available bottom boards will do for the resident honey bee colony. The individual should weigh up these claims and test them in their own apiaries. Keep in mind that the research findings in this report indicate that they do not create a negative environment as far as productivity is concerned.

Other areas of research that could be considered to determine the benefits or weaknesses of this particular design strategy could include:-

- A trial to determine if the use of screened bottom boards reduces the incidence or damage of the bee hive pest, the small hive beetle.
- A trial to determine if the use of screened bottom boards is feasible in areas where there are heavy ant densities.
- The benefits of using screened bottom boards to facilitate the movement of bee hives into and out of orchards during day light hours. Also the feasibility of locking honey bee colonies within their hive in cropping or orchard situations to protect the bees from the application of toxic pesticide applications.

The primary purpose for the use of screened bottom boards is their positive role in their use in the management of varroa mites. The progress of varroa tolerant honey bee breeding programs should be carefully followed on the world stage

Appendix A

Copy of the survey form provided to the New Zealand beekeeping conference in Napier 2012



SURVEY: Varroa & Screened bottom Boards

This is a brief questionnaire enquiring into the use of screened bottom board use in the New Zealand Beekeeping Industry, and the management of Varroa mites in general.

1. Are you using screened bottom boards?

- No. *Go to Question 6*
- Some hives – to test Varroa populations
- All hives

2. How long have you been using screened bottom boards?

_____ years

3. What area of NZ are your bee hives?

4. Do you believe screened bottom boards are useful for Varroa mite control/management?

- Yes
- No

Why?

5. Are your screened bottom boards in use all year?

- Yes
- No

Comment:

Please TURN OVER →

6. What are your main treatments for Varroa mites?

7. Do you believe your treatments for Varroa mites are:

- Very effective
- Effective
- Okay
- Reduced effectiveness
- I'm looking for other treatments

8. Other comments on screened bottom boards and Varroa mite treatments you wish to provide:

OPTIONAL:

Name: _____

Email Address: _____

THANK YOU FOR YOUR COMMENTS

If you have provided your email address, I will endeavour to send you a copy of the results of this survey.

Regards
DOUG SOMERVILLE
PhD, Technical Specialist Honey Bees
NSW Department of Primary Industries

Appendix B

B.1 Weight gain

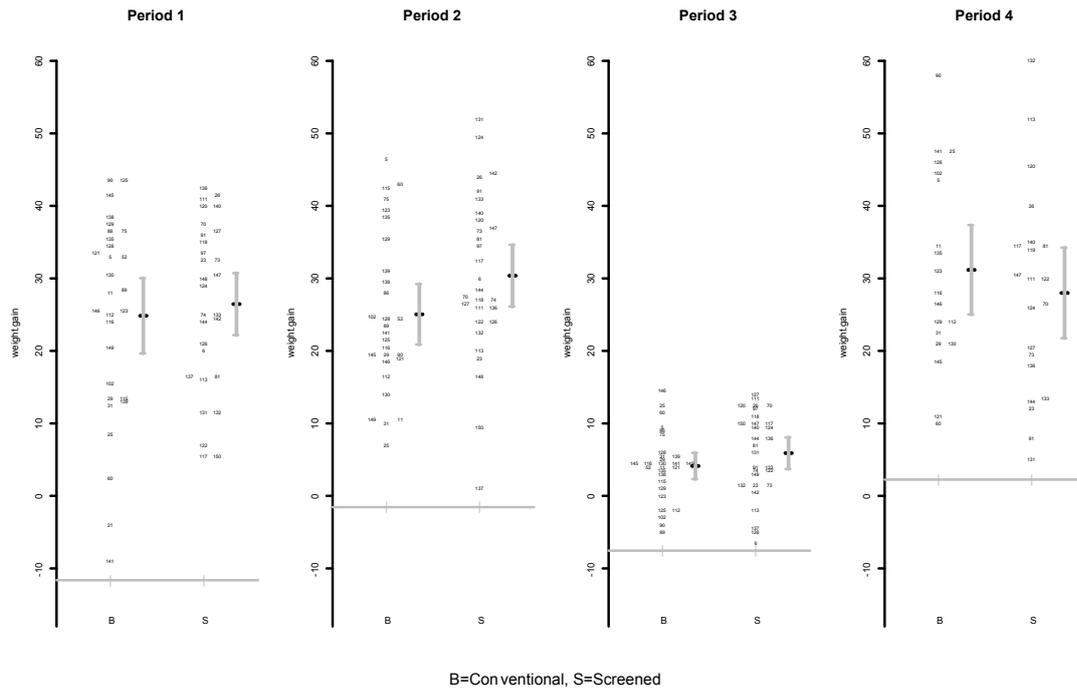


Figure 15: Weight gains in each of the 4 periods

B 2 Other production variables

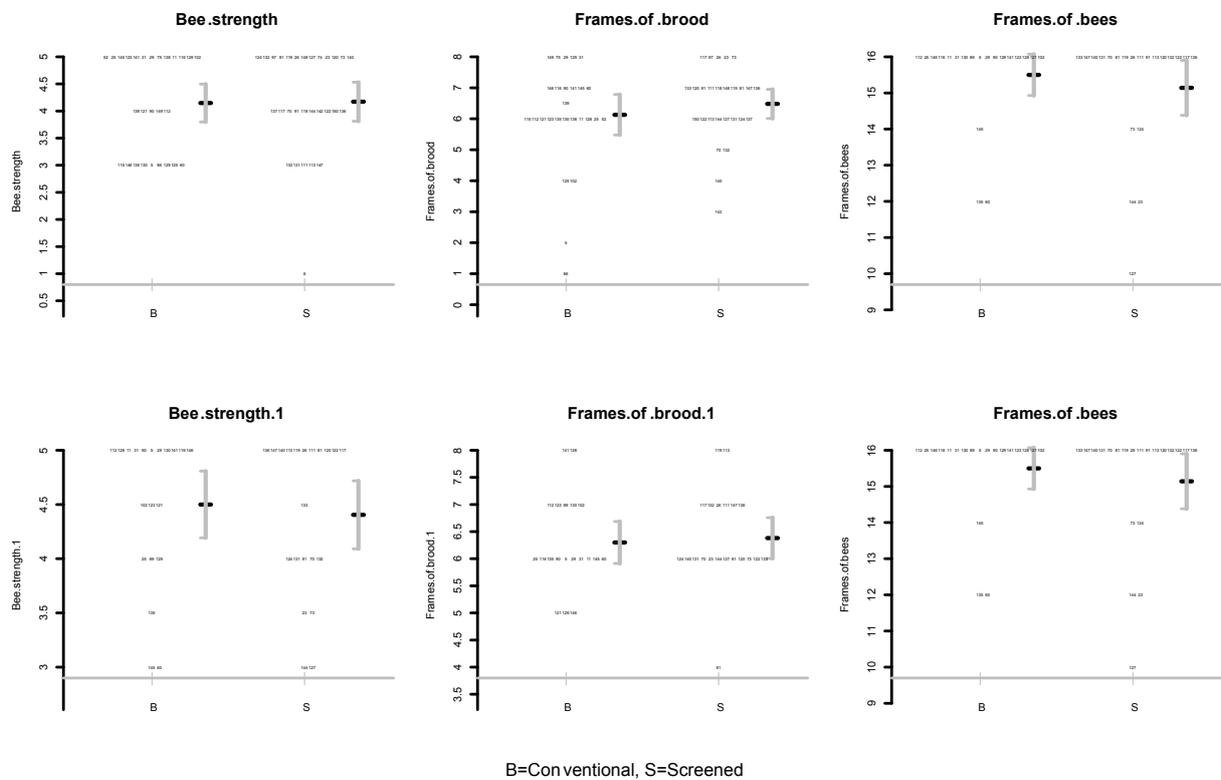


Figure 16: Bee strength, brood, frames of bees at final time points

B.3 Temperature and humidity

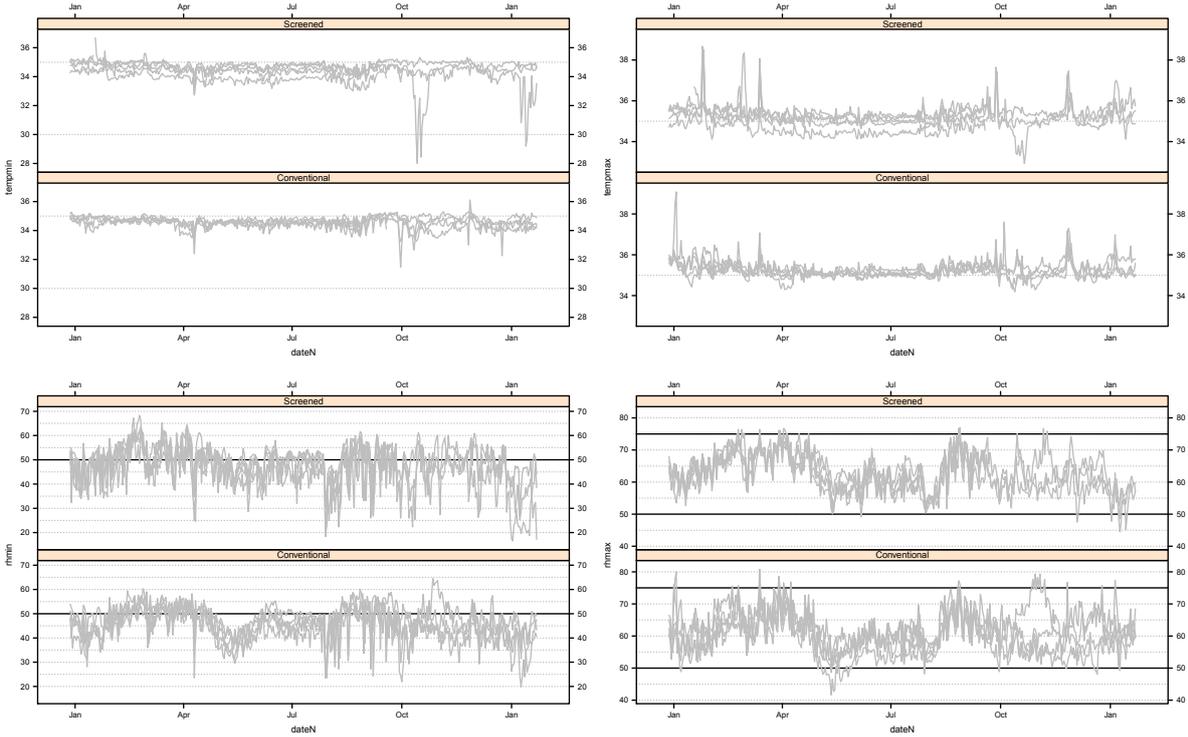


Figure 17: Raw temperature and humidity data

Appendix C

Further detail on the temperature and humidity modeling

As indicated in the methods, each of these four derived response variables (min/max temp and RH) were analyzed as repeated measures in a mixed model smoothing spline framework ²¹, comprising fixed treatment, linear time and treatment by linear time interactions, and random spline time, treatment by spline time, and hive, hive by linear time (with a correlation between these two effects) and hive by spline time effects.

Table 10 shows the detailed output from the maximum and minimum temperature models. The Wald statistics for the fixed terms in each (Tables 10a and c) show that there are no significant treatment or treatment by linear time effects. In other words, there is no evidence of a consistent difference in min or max temperature between treatments, or an increasing or decreasing difference over time. However, the variance components for the random terms (Tables 10b and d) show that the interaction of treatment by spline time is significant in each model. That is, there is statistical evidence that the non-linear trends differ between treatments. The other variance components relate to the repeated measures nature of the data, and comprise hive effects, and interactions of hive with linear and spline time, to allow for the correlations between successive measurements on the same set of hives.

Table 10: Analysis of maximum and minimum daily temperatures: Wald F-statistics (fixed terms) and variance components (random terms)

a) Max temp: Wald F-statistics and coefficients for fixed terms

	DF	F-stat	P-val	Coef	SE	t-stat
(Intercept)	1,7.9	1.686e+05	0.000	35.26	0.1211	291
treatment	1,5.6	1.750e-01	0.692	-0.08348	0.1715	-0.4868
lin(time)	1,5.8	3.842e+00	0.099	-0.0003192	0.0002584	-1.235
treat×lin(time)	1,5.8	8.500e-02	0.781	-0.0001104	0.0003782	-0.2917

b) Max temp: Variance components for random terms.

	component	SE	t-value	REMLRT (χ_1^2)
spl(time)	6.66e+01	1.54e+01	4.34	
Trt×spl(time)	1.77e+00	7.15e-01	2.47	21.9 (P<0.001)
hive	7.29e-02	3.70e-02	1.97	
cor(hive,hive×lin(time))	8.64e-01	5.52e-01	1.57	
hive×lin(time)	2.85e-07	1.95e-07	1.46	
hive×spl(time)	3.88e-01	9.40e-02	4.13	
Residual variance	9.00e-02	2.23e-03	40.40	

c) Min temp: Wald statistics and coefficients for fixed terms

	DF	F-stat	P-val	Coef	SE	t-stat
(Intercept)	1,7.3	1.309e+05	0.000	34.57	0.1333	259.4
treatment	1,5.1	9.290e-01	0.379	-0.1223	0.1908	-0.6411
time	1,5.6	7.873e+00	0.033	-0.0005202	0.0004378	-1.188
treat×time	1,5.6	1.576e+00	0.259	-0.0008037	0.00064	-1.256

d) Min temp: Variance components for random terms.

	component	SE	t-stat	REMLLRT (χ_1^2)
spl(time)	1.35e-05	3.45e-07	39.00	
Trt×spl(time)	1.96e+01	5.27e+00	3.71	10.4 (P=0.001)
hive	8.56e-02	4.71e-02	1.82	
cor(hive,hive×lin(time))	9.12e-01	5.74e-01	1.59	
hive×lin(time)	8.63e-07	5.68e-07	1.52	
hive×spl(time)	3.63e+01	4.15e+00	8.76	
Residual variance	6.22e-02	1.59e-03	39.00	

Table 11 shows the detailed output from the maximum and minimum RH models. The Wald statistics for the fixed terms in each (Tables 11a and c) show that there is a significant treatment difference in each case at the 5% level but no significant treatment by linear time effects (although almost significant for max RH). In other words, there is some evidence of a consistent difference in min or max RH between treatments, and little or no evidence that this difference either increases or decreases over time. The variance components for the random terms (Tables 11b and d) show that the interaction of treatment by spline time is significant only for min RH. That is, for min RH, there is statistical evidence that the non-linear component of the trend over time differ between treatments. As for temperature, the other variance components relate to the repeated measures nature of the data, and comprise hive effects, and interactions of hive with linear and spline time, to allow for the correlations between successive measurements on the same set of hives.

Table 11: Analysis of maximum and minimum RH: Wald F-statistics (fixed terms) and variance components (random terms).

a) max RH: Wald F-statistics

	DF	F-stat.	P-val	Coef	SE	t-stat
(Intercept)	1,8.2	8966.00	0.000	61.02	0.9189	66.41
treatment	1,8.2	11.10	0.010	1.792	1.307	1.372
time	1,5.8	14.50	0.010	-0.004895	0.003395	-1.442
treatment × time	1,5.8	4.54	0.079	-0.0109	0.005117	-2.131

b) max RH: Variance components for random terms.

	component	SE	t-stat	REMLLRT (χ_1^2)
spl(time)	6.27e+03	1.41e+03	4.430	
Trt×spl(time)	2.83e+01	3.20e+01	0.883	0.608 (P=0.436)
hive	4.13e+00	2.11e+00	1.960	
cor(hive,hive×lin(time))	6.43e-01	4.68e-01	1.380	
hive×lin(time)	4.60e-05	2.89e-05	1.590	
hive×spl(time)	1.73e+02	3.35e+01	5.170	
Residual variance	9.47e+00	2.36e-01	40.000	

c) min RH: Wald statistics and coefficients for fixed terms

	DF	F-stat	P-val	Coef	SE	t-stat
(Intercept)	1,8.0	10730.000	0.000	45.91	0.6258	73.37
treatment	1,8.1	7.215	0.027	1.872	0.9042	2.071
time	1,5.2	18.010	0.007	-0.01224	0.004485	-2.73
treatment × time	1,5.2	0.526	0.500	-0.004953	0.006833	-0.725

d) min RH: Variance components for random terms.

	component	SE	t-stat	REMLLRT (χ^2)
spl(time)	1.00e+04	2.47e+03	4.050	
Trt×spl(time)	8.68e+02	3.43e+02	2.530	28.3 (P<0.001)
hive	1.79e+00	9.85e-01	1.820	
cor(hive,hive×lin(time))	3.92e-01	4.68e-01	0.837	
hive×lin(time)	7.57e-05	5.06e-05	1.500	
hive×spl(time)	8.83e+01	2.01e+01	4.390	
Residual variance	2.44e+01	6.02e-01	40.500	

Notes on Tables 10 and 11

For the fixed effects sub-tables (Tables 10a, 10c, 11a, 11c) the columns are:

1. DF: Degrees of freedom (numerator, denominator)
2. F-stat: F-statistics
3. P-val: P-value
4. Coef: the estimated coefficient. For treatment, this refers to the difference between screened minus conventional bottom boards (and similarly for treatment by time)
5. SE: its SE
6. t-stat: t-statistic (Coef/SE)

For the variance component sub-tables, the columns are:

1. component: the estimated variance component
2. SE: its estimated SE
3. t-stat: t-statistic (component/SE). (A rule of thumb is that t-stat>1 usually indicates statistical significance for variance components using a REML LRT.)
4. REMLRT: REML likelihood ratio test (LRT) for testing treatment by spline time

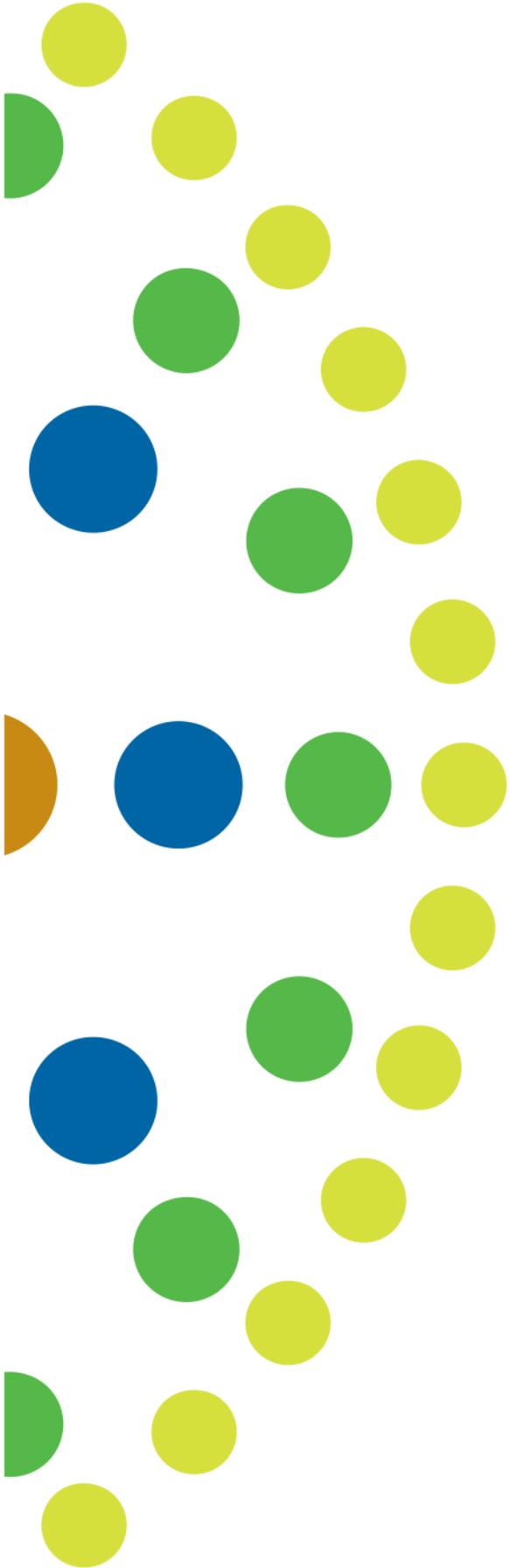
For the variance component sub-tables, the rows are:

5. spl(time): spline time
6. Trt×spl(time): treatment by spline time
7. hive, cor(hive, hive×lin(time)), hive×lin(time), hive×spl(time): components of variation relating to hives
8. residual variation: residual variation

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Screened bottom boards

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