Enhancing pollination efficiency

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Photo: Rob Manning, Cherry flowers, Stoneville, Western Australia.

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Statement

The report should enable orchardists and agriculturalists to take a closer look at the way honey bees could be used in pollination to maximise yields of crops. Manipulation of hive entrances with particular device attachments to enable bees to exit hives with increased abundance of pollen on their bodies should increase pollination efficiency from beehives that are normally leased from beekeepers.

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Summary

Langstroth hives fitted with a modified lid with an entrance lined with soft felt or steel or plastic pollen traps or hives fitted with plastic pollen traps and sugar-fed significantly increased the pollen count on the bodies of exiting honey bees. In terms of utilising the research findings in contract pollination service where costs can determine profitability, the recommendation is for a trial in a commercial orchard (e.g. almond, apple, avocado, plum) of sugar-fed single hives fitted with plastic pollen traps. Despite the bees' destruction of the felts lining the modified lid entrances, the soft felt liner might be a worthwhile inclusion into any field trial.

This will require some changes in how beehives are managed by beekeepers and because of that, the implementation of the recommendation may encounter some initial resistance.

This research was peer-reviewed and published in the Australian Journal of Entomology:

Rob Manning, Hana Sakai and Linda Eaton (2010) Methods and modifications to enhance the abundance of pollen on forager honey bees (*Apis mellifera* L.) exiting from beehives: implications for contract pollination services. *Australian Journal of Entomology* **49**, 278-285.

Introduction

Honey bee pollination services in Australia are dominated and generally determined by a single plant species, the almond, though the pollination of other crops such as lucerne, melons, canola and sunflower can use substantial numbers of beehives. The expansion of the Australian almond industry which is emerging as the second largest exporter of almonds in the world has been huge and along with its development, thousands of beehives are contracted to pollinate the crop. In recent times the almond crop has expanded at about 6,000 ha/year where honey bee pollination service now requires 7.5 bee hives/ha.

The unprecedented demand as the Australian almond industry expands is putting pressure on the supply of beehives for the pollination service and as a consequence the almond industry has experienced increased pollination service fees. In the background of all this development is the threat of the honey bee parasite *Varroa destructor* which has invaded most of the world's beehives causing considerable destruction of bee colonies and a subsequent dependence on the use of pesticides. Australia, a major exporter of honey currently remains varroa-free even though near-neighbouring countries such as New Zealand and Papua New Guinea are endemic with the parasite.

It is in the industry's best interests to attempt to increase pollination efficiency. The focus on the pollination side in this aspect could be to potentially reduce the number of hives required per ha, reduce orchard costs, decrease the demand on pollination services which can at times be limiting (and perhaps more so in the future) at the same time to try and maximise orchard yields.

Researchers (Hatjina *et al.* 1998, Hatjina *et al.* 1999) have used materials such as fine and coarse bristles, wool, sponges, felt in devices that attach to beehives which wipe pollen from bees entering the hive. The materials coat the bees (enpollinate) as they leave the hive, thus potentially increasing pollination efficiency when beehives are employed in orchards. The authors found that woollen fabric and felt showed promise as liners for hive-entrance pollen transfer devices.

It is not known whether well-established equipment like plastic pollen traps or plastic corrals (used to prevent the entry of mice) fitted to the front entrance of beehives can enpollinate bees like the fabrics do or whether there would be differences just because plastics have a capacity to be electrostatically charged. Static electricity may play a role in pollen transfer as bees are positively charged when entering a hive from foraging, whereas bees are slightly negatively charged when they leave a hive early in the day (Erickson 1975).

The experiment tested a series of grades of felt, as one grade performed well for previous researchers a decade ago. This material was tested alongside other standard forms of machinery that are known to increase pollen foraging such as pollen traps and orchard practises such as feeding sugar syrup to bees.

The development of the devices using felt were carefully considered taking into account that it had to be simple, of cheap construction, not be restrictive on foraging bees and developed so as not to interfere in current configurations of hive placement in orchards where hives are normally placed close together upon pallets.

The aim of the experiment was to test a range of devices that can strip and enpollinate bees and to test the hypothesis that by forcing bees through enpollination devices increased honey bee pollination efficiency would occur – determined through measurements of pollen abundance on bees exiting beehives.

Method and activities

Apiary

A total of thirty-six hives were tested comprising of three replicate hives for each of the 12 devices (Table 1). Three replicate experiments were performed so that the thirty-six hives were tested over three time intervals, each of 10 days duration (Table 2). The experiment commenced in late June 2007 and corresponded with the time that beekeepers would normally prepare and place hives for almond pollination. Thirty-six single Langstroth hives were used in a randomised design (Fig. 1). A few weeks prior to the experiment, each of the 36 colonies used in the experiments were adjusted to contain similar numbers of bees and frames of brood and honey. Queen bees in each hive were derived from the same genetic line.

On day zero, each of the experiment hives had standard lids. After sampling the lids were replaced with the modified lids for the rest of the 10 days.

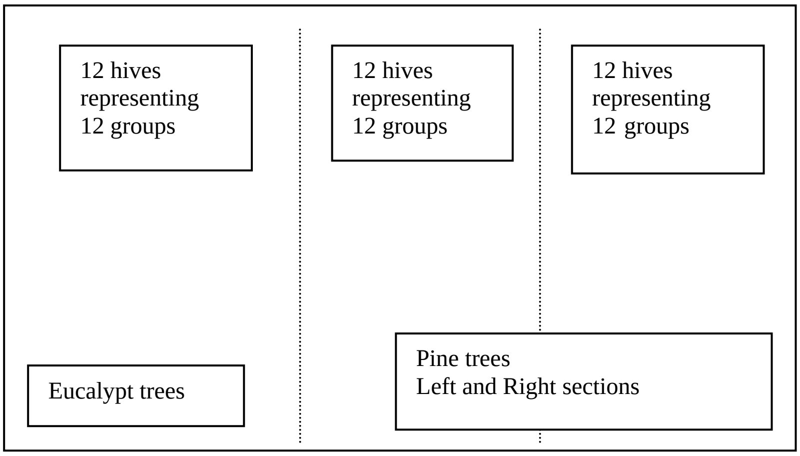

Fig. 1. Apiary site layout – a standard randomised blocked design was used where the apiary site area was divided into three sections and where in a group replicate a device was randomly assigned.

Devices

Modified lids

Lids that normally fit Langstroth hives were modified to have a front entrance that was lined top and bottom by felt. Three types of white coloured industrial felt – hard, medium and soft labelled AE 1.6 mm, FWF 1.6 mm & BE 3.2 mm respectively were obtained from Felt Fabricating Pty Ltd, Unit 10, 5 Tooronga Ave, Edwardstown, South Australia 5039. The black decorative felt was obtained from a craft shop. The modified lids which housed the felt had an entrance where the 6 mm distance between the two felt layers was identical to that used by Hatjina *et al.* (1998, 1999).

Table 1 The different devices used in the experiments (see also appendicies).

Device modification group	**Hive number**	**Hive replicate No.**	**Comment**
1. No device	1	1	No device, normal hive Control for devices 8 to 12
	2	2	
	3	3	
2. Modified lid	4	1	Modified lid (no felt) Control for devices 3 to 7
	5	2	
	6	3	
3. Hard felt	7	1	Modified lid (AE 1.6 mm)
	8	2	
	9	3	
4. Medium felt	10	1	Modified lid (FWF 1.6 mm)
	11	2	
	12	3	
5. Soft felt	13	1	Modified lid (BE 3.2 mm)
	14	2	
	15	3	
6. Decorative felt	16	1	Modified lid (Black craft felt)
	17	2	
	18	3	
7. Queen Excluder	19	1	Modified lid (Plastic insert)
	20	2	
	21	3	
8. Pollen trap	22	1	Steel
	23	2	
	24	3	
9. Pollen trap	25	1	Plastic
	26	2	
	27	3	
10. Sugar fed	28	1	Two frame plastic sugar feeder (Internal). No pollen trap.
	29	2	
	30	3	
11. Sugar fed with pollen trap	31	1	Two frame plastic sugar feeder (Internal) & same plastic pollen trap as device 9.
	32	2	
	33	3	
12. Entrance corral	34	1	Plastic entrance barrier use to keep out pests such as mice.
	35	2	
	36	3	

A modified lid with no felt inserted was used as one of the controls. Another modified lid contained a strip from a plastic queen excluder which is normally used to separate the bottom brood box from the honey boxes (supers) above, restricting the queen to the brood chamber.

Pollen traps and corral

Both steel and plastic pollen traps were trialled. These traps are commercially available to beekeepers in Australia. The Corral device was made of plastic and used in parts of Europe normally to cover the hive entrance to prevent the entry of small rodents.

Sugar

Sugar was fed as a 50 % solution (1 L water with 1 kg sugar) to one of groups fitted with a plastic pollen trap. Plastic 'frame' feeders were inserted into the brood box (replacing two frames) were topped up every two days with one or two litres (see Fig. 4).

Honey bee activity

Honey bee activity for each hive was measured for a one minute interval each morning (10 am – 12 noon) and afternoon (2 pm – 4 pm) for each of the sampling days (Table 2). Only exiting bees were counted leaving the hive. A timer and a hand-held thumb counter were used. Two temperature data recorders placed at the same height as the hive entrance were located at either end of the apiary and recorded ambient temperatures in the apiary every 20 minutes from June to August. Temperature recordings were matched with the times the bee activity measurements were taken.

Table 2 Sampling regime, dates and duration of experiment. R = rain.

	Sample times					
Experiment replicate	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
1	26 June	28 June	30 June	2 July (R)	4 July	6 July
2	10 July	12 July	14 July	16 July	18 July	20 July
3	31 July (R)	2 August	4 August	6 August	8 August	11 August*

*sampling on the 10^{th} was prevented by heavy rain.

Sampling

Five bees exiting each hive were collected from each hive following the morning (10 am) and afternoon (2 pm) bee activity measurements. Each bee was placed into a 5 ml plastic vial containing 3 ml of 70 % alcohol for each of the sampling days in Table 2, so that: 18 sample days x 2 times (am & pm) x 36 hives x 5 bees gave 6,480 individual samples that were processed in a laboratory.

Laboratory analysis

Each bee sample preserved in 3 ml alcohol was given two drops of Triton-X detergent and then sonicated for 1 minute using an ultrasonic cleaner (Unisonics FXP8M) followed by a rapid 30 second vibration on a Sentra vibrator/mixer (Hatjina 1996 & Hatjina *et al.* 1998 settled on using one sonication and one wash treatment for each of their samples). Prior to its use the ultrasonic cleaner was left on for 20 min and tested with aluminium foil for 20-30 secs which would perforate indicating it was functioning. The bee sample was then removed from the alcohol which was then subsequently centrifuged (Beckman J2-21 M/E with JA 20.1 rotor) for 6 minutes at 12,000 g (10,460 rpm). Supernatants were carefully discharged and 30 µL of distilled water added to each sample and re-sonicated for one minute to ensure homogenous distribution of pollen in solution.

15 µL of the pollen solution from each tube was placed on a haemocytometer (Hycor Kova glasstic slides; Hycor Biomedical Inc. California, USA) where the number of

pollen grains on the slide grid was counted. The total number of grains in the original pollen precipitate of each tube was derived under the assumption that the volume (0.9 μL) within the 3 mm x 3 mm x 0.1 mm grid examined in the haemocytometer was representative of the whole sample. For each sample, the number of pollen grains was multiplied by dividing the 30 μL volume by 0.9 μL and multiplying that figure (33.33) by the pollen count from all the grids.

Statistical analysis

A linear mixed model using the natural log of the raw pollen count was used. In order to deal with the log of a large number of zero counts in the data set, a shift of 0.1 was added to each pollen count. Other non-linear models that were tested but considered to provide poorer fits to the data included Poisson and quasi-Poisson generalised linear models. Hive_no was included as a random effect term to account for the natural variation that would be expected between different hives. It is reasonable to expect that observations from the same hive are correlated. Rep and day, with day nested within rep were also included as random effects to account for the variation in the 6 days from each of the three replicates. The inclusion of a hive_no:rep:day term takes into consideration that readings on a particular day and from the same hive are also likely to be correlated with each other. Preliminary exploratory models tested the hypothesis that as the bees try to remove the felt over time and the felt deteriorates, less pollen may be retained on the bees. The fixed effects bee count and temperature were also included in preliminary models but were not found to be significant and were excluded from the final model. The description of the parameters tested is shown in Table 3. The final model can be expressed as follows:

ln(count 0.1)= I +group+ampm with random effects of hive_no, rep, rep:day and hive_no:day:rep.

A number of different parameterisations of this model were examined to make it possible to compare different modification groups with each other. Specifically these were:

1 Reference Model A: where reference levels are modification Group 1 and morning (am).

2 Reference Model B: where references levels are modification Group 2 and morning (am).

3 Reference Model C: where reference levels are modification Group 9 and morning (am).

All values are ± Standard Error.

Table 3 Model parameter descriptions.

Parameter	**Description**	**Parameter type**
count	Pollen count	Continuous
I	Constant (intercept)	Continuous
group	Modification group	Factor
rep	Replicate number of the experiment	Factor
day	Day number as described in Table 2	Continuous
pm	Afternoon pollen count	Factor
lid	0 if no modified lid; 1 if there is a modified lid (equal to 1 for groups 2 to 7 see Table 1)	Binary
felt	0 if no felt in modified lid; 1 if modified lid has felt (equal to 1 for groups 3 to 6 see Table 1)	Binary
trap	0 if no pollen trap; 1 if pollen trap fitted to hive (equal to 1 for groups 8, 9 & 11 see Table 1)	Binary
bee_count	Count of the number of bees leaving the hive per minute used to represent bee activity	Continuous
temp	Temperature recorded in the apiary both at morning and afternoon	Continuous
rep:hive_no	Interaction between replicate and hive number used to isolate the variation between individual hives. 36 hives in each replicate x 3 replicates = 108 unique hives across the experiment.	Factor
day:felt	Interaction between day and felt	Factor
day: group	Interaction between day and group	Factor

Evaluation

Reference Model A: No modified lid; no pollen trap

The results show the following modification groups had significantly higher pollen counts than the Group 1 hives without a modified lid. Ordered by size of effect against Group 1 controls they were: Bees exiting the plastic pollen trap sugar fed hive (Group 11) carried 3.5 times more pollen; plastic pollen trap (Group 9) carried 3.2 times more pollen; modified lid with soft felt (Group 5) carried 3.1 times more pollen; steel pollen trap (Group 8) carried 2.7 times more pollen and modified lid decorative felt (Group 6) carried 1.7 times more pollen than Group 1 bees.

All other hives with modified lids (felt and non-felt alike) were not found to be statistically different from hives with no modifications fitted. Hives with a plastic corral entrance (Group 12) also did not show a significant difference in pollen counts when compared with hives with no modifications.

Reference Model B: Modified lid, no pollen trap

In order to compare the effect of the different modification types to a hive with only modified lid and no other device, the same model was re-parameterised with modification Group 2 as the reference group. This means that all modification groups were compared with Group 2 – the hives with a modified lid and no pollen collection device. The results show that four of the modification groups had significantly higher pollen counts than the Group 2 modified lids. From largest to smallest increase in pollen counts these were: Bees exiting the plastic pollen trap, sugar-fed (Group 11) carried 2.7 times more pollen; plastic pollen trap (Group 9) carried 2.4 times more pollen; modified lids with soft felt (Group 5) carried 2.4 times more pollen and the steel pollen trap (Group 8) carried 2.1 times more pollen than bees exiting from Group 2 controls. These results confirm those seen from the Reference Group 1 Model. The only difference being that while the decorative felt modified lid (Group 6) was significantly higher than no modifications (Group 1), it is not significantly different to the modified lids in Group 2 ($P = 0.3796$).

Reference Model C: Plastic pollen trap

One of the modification groups had a plastic pollen trap and was sugar-fed (Group 11). In order to test whether the addition of the sugar feed to the hive fitted with the plastic pollen trap affects pollen counts, the model was rerun using hives with a plastic pollen trap as the reference modification group (Group 9).

The results of the model showed that the addition of sugar syrup into hives with a plastic pollen trap (Group 11) does not significantly change pollen counts from hives with a plastic pollen collection device and no sugar feed. Although the positive sign of the parameter estimate (0.99 – which equates to a factor increase of 2.7) indicates that if anything feeding sugar syrup slightly increases pollen counts. The results also showed that there was no significant difference between the plastic and steel pollen traps. Furthermore, the results show that the bees exiting the soft felt modified lids (Group 5) do not result in significantly higher pollen counts when compared with the pollen traps.

Pollen deposition on surfaces of devices with entrance barriers

Approximately 12 cm^2 surface of the plastic entrance barriers the bees entered through in modification groups 7, 9, 11 and 12 were tested for pollen deposition along with the steel surface of Group 8 by wiping a designated area with a cotton bud and proceeding through the same methodology as for the bee samples. The results showed the surface pollen count (in the above order) was 2,215 ± 721 (queen excluder), 122,872 ± 36,009 (plastic pollen trap), 127,132 ± 39,564 (plastic pollen trap + sugar fed), 1,774 ± 621 (corral) and 2,796 ± 1,103 on the steel pollen trap surface.

Implications

Lid modifications with soft felt inserts increased the pollen count on bees by 309% while decorative felt increased the bees' pollen count at a lesser level of 167% when compared with hives where no devices were attached. Our pollen counts using felt are higher than that measured by Hatjina *et al*. (1999) who showed average increases of 113% from their control but are relatively similar to one trial of Hatjina *et al*. (1998) where an increase of >200% was found. The modified lid (Group 2) did not significantly increase pollen counts compared with no modifications, implying that it is the material used to line the lid that has the potential to increase pollen counts.

Hatjina *et al*. (1998, 1999) also showed that their 2-mm thick felt significantly ($P < 0.001$ and $P < 0.01$, respectively) increased pollen richness (number of pollen types) on bees – hinting that some improvement in cross-pollination might be expected in orchards when different varieties are in flower. Hatjina (1998) acknowledges that these types of pollination transfer devices do in fact enable cross-pollination with subsequent fruit set in cropping cultivars and is helped by the fact that body-hair of bees is adapted to collect and retain pollen (Free & Williams 1972).

One of the problems with utilising felt as hive-entrance transfer device is that bees have a habit of chewing and removing its fibres (Hatjina *et al*. 1998). In our experiments the bees readily chewed (in order of destruction) the decorative felt, soft, medium and hard felts. The hard felt remained relatively intact over the 10-day experiment. Despite the visual evidence of bees removing felt, there was no statistical evidence to suggest that this was having a negative effect on pollen counts on bees over the 10-day experiments. However, given a longer experimental period of time the removal of felt may adversely affect the pollen count on bees. Where felt devices were used in Hatjina *et al*. (1998) work they found much variation between hives in the ability for the devices to increase amounts of pollen on departing foragers.

The statistical analyses suggest that pollen traps (Groups 8, 9 and 11) or a soft felt modified lid are more effective than no device at increasing pollen counts on bees. However, there was no significant difference between the soft felt modified lid and the use of pollen traps. Compared with hives that would normally be employed in orchards for pollination, the addition of a pollen trap clipped to the hives' front entrance would increase the pollen on bees by 278–352% than if no device was used (the current situation in orchards).

Of the pollen traps, the sugar-fed plastic pollen trap showed the largest increase in pollen counts on bees when compared with Group 1 hives (Reference Model A). In fact, bees from these hives had over three times as much pollen on them compared with those from Group 1. However, the sugar-fed hives with no pollen traps (Group

10) were not significantly different from hives with no modifications, indicating that feeding sugar syrup alone does not significantly increase pollen counts on bees. Hives fitted with a pollen trap but without being sugar-fed showed very similar pollen counts to each other, implying little difference between the plastic and steel devices. Of the hives with modified lids, only the soft felt (Group 5) and decorative felt (Group 6) devices showed significantly higher pollen counts when compared with no modifications.

There is also the dual role that a pollen trap plays apart from its ability to increase the bees' pollen count that an amount of pollen is trapped in them and because of that, theoretically a calculation of the numbers of flowers that bees have visited can be made. In Hill *et al*. (1985) they found that for every 100 almond flowers there was 65 ± 4 mg of pollen (averaged from their presented data). Therefore if the experimental data were transposed as coming from an almond crop and where bees collected all of the pollen from those flowers, the bees in Group 9 (plastic pollen trap) would have visited some 137,000 flowers. The addition of 1–2 L of sugar every 2 days would cause the bees from hives fitted with the same pollen trap (Group 11) to visit 238,500 flowers (an additional 101,500 flowers). Group 11 bees either foraged more flowers or switched to pollen foraging (as opposed to nectar foraging) or both given that the average bee activity was 87 bees/min/hive for hives fitted with a pollen trap which was within other published measured bee activity (52–267 bees/min) (e.g. Langridge and Goodman 1985).

Pollen traps, particularly those made of plastic, perhaps had an inherent advantage. Honey bees are positively charged as they fly through the air and plants are negatively charged because they are grounded (Vaknin *et al*. 2000) and as plastics are known to carry electrostatic charge, bees entering and leaving modification Groups 7, 9, 11 and 12 could benefit from this action. Only the surface of the barrier that bees pass through inside the plastic pollen traps (Groups 9 and 11) had substantial amounts of pollen adhering to it and is perhaps why bees exiting those hives (and those sugar-fed) tended to have higher total body pollen counts than most of the other groups tested.

Even though pollen count on bees was similar for modification Groups 8 and 9 (Figs 2, 3) the amount of pollen collected in the traps was significantly different. Pollen collected by Group 9 bees was on average 63 g more than Group 8 bees. Even for Group 11 bees where sugar feeding was not effective at significantly increasing pollen count on bees, there was significantly more pollen collected by the bees in the traps. A similar effect was found by Goodwin and Ten Houten (1991) when they fed beehives 1 L sugar syrup daily in a 10 ha kiwifruit orchard. However, when hives were fed just sugar syrup (Group 10) body pollen counts were no different from controls. It might be that sugar feeding and the subsequent increase in pollen foraging (via increased pollen collection) is only specific to kiwifruit because of the lack of nectar produced by its flowers (Goodwin 1986). During our experiment there was a nectar flow which was evident by the burr-comb built under the lid during each 10-day experiment (see Fig. 4) and therefore the addition of sugar syrup into the hive made no difference to foraging behaviour. It is interesting to note however that hives fitted with a pollen trap and sugar-fed would show such a difference in bee pollen count on bees and the amount of pollen trapped than those just sugar-fed.

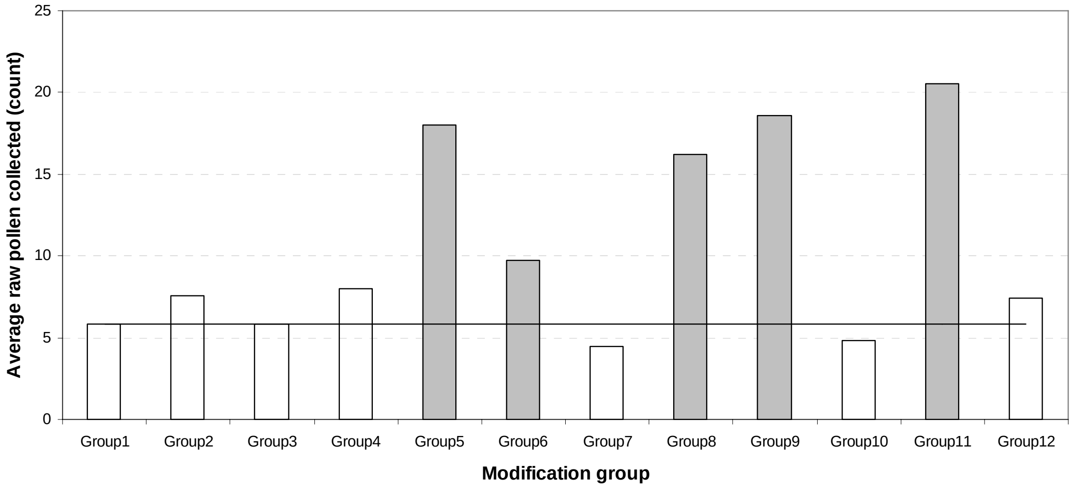

Fig. 2. Average raw pollen count on bees leaving each modified group. Reference level: group 1, am, replicate = 1, bee activity = 1 and bee per minute. Raw pollen count = actual count from the haemocytometer. Coloured group indicates the significant difference to group 1 and white is not significantly different.

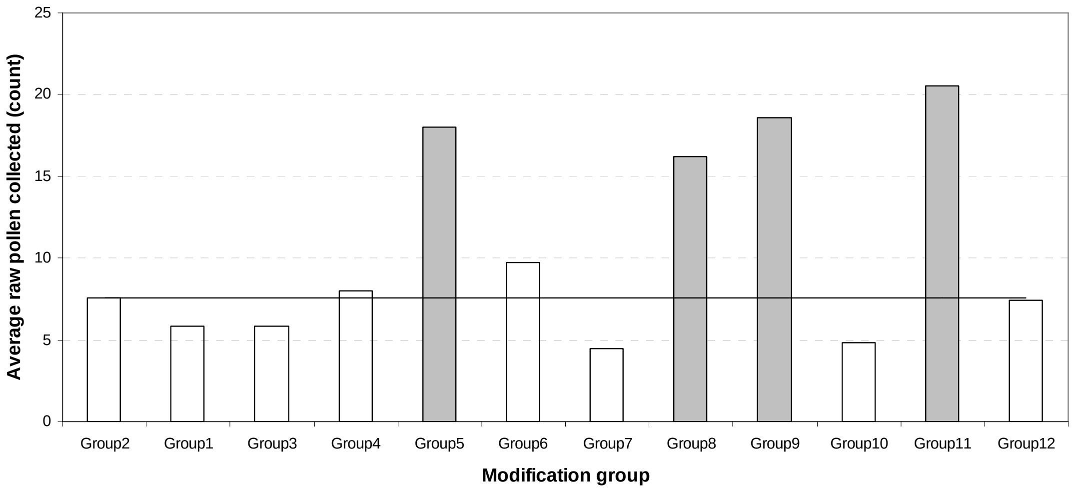

Fig. 3. Average raw pollen count on bees leaving each modified group. Reference level: group 2, am, replicate = 1, bee activity = 1 and bee per minute. Raw pollen count = actual count from the haemocytometer. Coloured group indicates the significant difference to group 1 and white is not significantly different.

Hatjina (1996) showed that after one sonication and a single wash treatment that the percentage (± standard error) of small pollen grains removed from bees averaged 77.8 ± 2.29 % and large pollen grains averaged 91.1 ± 1.8 %. Her overall average was that 82.2 ± 2.13 % of all pollen grains were removed from bees. Further sonication and washes found those bees had an average total pollen count of 29,300 ± 13,200 grains (see Table 4). That value is higher than the average total counts from all groups in our experiment (Table 5) perhaps because ours was conducted over winter (same period that almond orchards flower) but nevertheless the project data is similar to other values published (Table 4).

Although pollen viability was not addressed in this experiment, Free & Durrant (1966) have found that bees leaving their hive can carry viable pollen and that pollen germination *(in vitro)* can differ significantly within cultivars of the same species and pollen production from flowers between cultivars can be consistently different (Hill *et al.* 1985). Hatjina *et al.* (1999) found the average germination of pollen collected on felt was 39.5 % and was similar to that germinated from corbicular (leg) pollen from returning pollen foragers (36.3 %) and again illustrates the need to maximise the pollen carrying capacity of foragers (and forager numbers) when bees are used in pollination contracts.

Table 4 Comparative pollen abundance on bees foraging on different plant species.

Reference	Ave number pollen grains/bee ± SE	Predominant pollen species	Common name
Free & Williams (1972)	20,756 ± 11,385	*Pyrus malus/communis*	Pear
Free & Williams (1972)	9,574 ± 3,784	*Prunus avium*	Cherry
Free & Williams (1972)	1,879 ± 272	*Prunus domestica*	Plum
Free & Williams (1972)	12,225 ± 1,209	*Fragaria x ananassa*	Strawberry
Free & Williams (1972)	8,823 ± 1,502	*Rubus ideaus*	Raspberry
Free & Williams (1972)	9,845 ± 1,579	*Helianthus annuus*	Sunflower
Free & Williams (1972)	1,602	*Trifolium pratense*	Clover
Free & Williams (1972)	50,735 ± 3,176	*Taraxacum officinale*	Dandelion
Hatjina (1996)	29,300 ± 13,200		
Hatjina *et al.* (1998)	700 ± 300 to 19,700 ± 5,700		
Vaissiere & Froissart (1996)	205 to 2,500	*Cucumis melo*	Cantaloupe/ rockmelon
www.agric.wa.gov.au – search pollination: avocado	1,575 – 4,090	*Persea americana*	Avocado

Table 5 Average total pollen counts on honey bees exiting experimental devices foraging on urban flora from Day 2 to Day 10.

Device modification group	Mean pollen count	Standard Error	N
1. Control – no modifications	862	116	450
2. Control – modified lid only	1,443	209	450
3. Hard felt	1,124	184	450
4. Medium felt	1,567	236	450
5. Soft felt	2,283	315	450
6. Decorative felt	2,287	527	450
7. Queen excluder	971	195	450
8. Steel pollen trap	1,934	204	450
9. Plastic pollen trap	2,745	291	450
10. Sugar fed	934	237	450
11. Plastic pollen trap + sugar	2,800	744	450
12. Corral	1143	151	450

It is recommended to further trial the use of pollen traps on hives (see Fig. 4) in orchards and to measure yields. Over many years of researching honey bee pollination the author has yet to see where pollen trap use has been trialled and tested specifically for that purpose. The traps are relatively cheap (AUD$9.96 - 2006) and reuseable but would require emptying of pollen every three days if it where to be harvested for further processing for a bee-feed or human consumption (health food). The cost of manufacture of the modified lids even with the most effective transfer mechanism of soft felt would be high (Fig. 5).

Fig. 4. The plastic pollen trap which produced foraging bees with the highest pollen count. Top-left: pollen trap, Top-right: pollen trap with sugar feeder, Lower-left: pollen trap in-situ and lower-right: trapped pollen collected in tray under pollen trap.

Fig. 5. Top: A modified hive lid in-situ. Bottom: underside view of a modified lid with the bottom half of the entrance lifted back to show the layer of soft felt (BE 3.2 mm) which was the best of the felts. Note the area of felt chewed by bees. Perspex covers block the left and right sides of the front entrance forcing the bees to mix (pile-up) before finding their way along and through the central open area (arrowed).

The use of felts would attract further expense because of the devices' shorter lifespan which would require regular replacement during a pollination contracts.

The potential benefit of fitting pollen traps to hives when they are used in pollination contracts is obvious for a relatively simple procedure albeit an initial one-off expense. This was the first time that commercial pollen traps have been examined for their potential to increase pollination efficiency in agriculture and its implementation could find some resistance by beekeepers because of their current management styles of shifting and placing hives into orchards, i.e. the external pollen trap might be a hinderance.

Recommendations

In terms of utilising the research findings in contract pollination service where costs can determine profitability, the recommendation is for a trial in a commercial orchard (e.g. almond, apple, avocado, plum) of sugar-fed single box beehives fitted with plastic pollen traps.

Acknowledgements

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Appendices

Hard felt: AE 1.6 mm thickness.

Rep1 Hive 7 AE

Rep2 Hive 7 AE


Rep3 Hive 7 AE


Rep1 Hive 8 AE


Rep2 Hive 8 AE


Rep3 Hive 8 AE

Rep1 Hive 9 AE

Rep2 Hive 9 AE

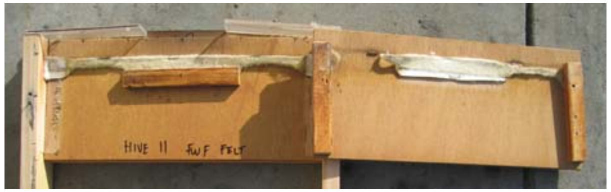

Rep3 Hive 9 AE

Medium felt: FWF 1.6 mm thickness.


Rep1 Hive 10 FWF

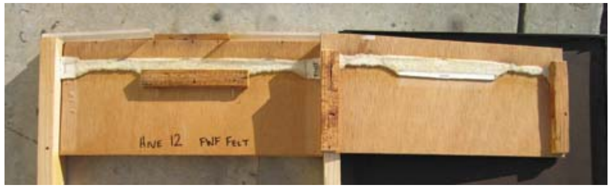

Rep2 Hive 10 FWF


Rep3 Hive 10 FWF


Rep1 Hive 11 FWF


Rep2 Hive 11 FWF


Rep3 Hive 11 FWF


Rep1 Hive 12 FWF


Rep2 Hive 12 FWF


Rep3 Hive 12 FWF

Soft felt: BE 3.2 mm thickness.


Rep1 Hive 13 BE


Rep2 Hive 13 BE


Rep3 Hive 13 BE


Rep1 Hive 14 BE


Rep2 Hive 14 BE


Rep3 Hive 14 BE


Rep1 Hive 15 BE


Rep2 Hive 15 BE


Rep3 Hive 15 BE

Décor (black decorative) felt.

Rep1 Hive 16 Décor

Rep2 Hive 16 Décor


Rep3 Hive 16 Décor

Not taken

Not taken


Rep3 Hive 17 Décor

Not taken

Not taken

Rep3 Hive 18 Décor

Décor felt being removed by bees

Device types


Control no devices

Modified lid (no felt)

Plastic pollen trap only


Sugar fed only

Sugar fed with pollen trap

Steel pollen trap

Modified lid with felt inserts

Corral

Laboratory

Sampling hives in the apiary

Coolroom storage of 6,480 of samples

Detergent added to samples and manual vibration

Ultrasonication of samples

Centrifugation (16 samples/time)

Ultrasonication again

Microscope analysis of samples