

# **Development of native bees as pollinators of vegetable seed crops**

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The University of Adelaide

Project Number: VG08179

## **VG08179**

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**Final Report: VG08179**  
**Development of native bees as pollinators of vegetable seed**  
**crops**

1 July 2009 – 9 September 2011



Katja Hogendoorn  
Mike Keller

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## HAL Project VG08179

### Development of native bees as pollinators of vegetable seed crops

1 July 2009 – 9 September 2011

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*This report details the research and extension delivery undertaken in the above project aimed at identification of the native bees that contribute to the pollination of hybrid carrot and leek, and at the development of methods to enhance the presence of these bees on the crops and at enabling their use inside greenhouses.*

Front: A female *Leioproctus clarkii* foraging for pollen on leek

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## MEDIA SUMMARY

Approximately 30% of our diet is produced as a result of the activity of pollinators. Good pollination can substantially increase set, weight and quality of seeds and fruit. Although much crop pollination is done by honeybees, several of Australia's 3,000 native bee species also contribute. Their contribution becomes particularly important when honeybees are scarce, and when crops are not optimally serviced by honeybees alone. Examples of such crops are lucerne, tomato, blueberry and passion fruit.

Compared to enclosed pollination with honeybees, hybrid seed production of carrot and leek is greatly improved when they are grown outside, indicating a role for additional pollinators. This project explored:

- the native bee species involved in the pollination of leek and carrot outside
- ways to enhance the presence of native bees on crops grown outside
- possibilities to use these pollinators inside enclosures

Of the 36 native bee species that visited the crops, ground-nesting furrow bees were the most important visitors of carrots. Unlike honeybees, they did not have a preference for the pollen producing flowers. Leek was visited by a suite of ground-nesting and some wood nesting native bees of different families.

Methods to enhance ground-nesting native bees include:

- Provision of food plants when the crop is not in flower (e.g. a Canola crop)
- Provision of areas of bare soil for nesting in close proximity to the crops.
- Limited or no till cultivation
- Selective and considerate use of pesticides

Greenhouse trials indicated that wood-nesting resin and leaf-cutter bees may be useful pollinators of leek in greenhouses. Outside, the activity of these bees only partly coincided with the flowering time of leek.

Provision of woodblocks with suitably sized holes substantially increased densities of resin bees. Their emergence can be manipulated in the following year to coincide with the flowering times of the crops, and they can be moved into greenhouses.

Future research should

- Further quantify pollination efficacy of resin bees on leek outside and in greenhouses.
- Further investigate methods to enhance and maintain native bees in and around crops
- Investigate how ground-nesting bees can be used in greenhouses
- Investigate potential to manipulate emergence times of resin bees to suit crop flowering times

## TECHNICAL SUMMARY

The production of hybrid seed using male sterile lines is often hampered by pollination deficiency. Open pollination of carrot and leek leads to greatly improved yields, compared to pollination in enclosures with honeybees. This indicates a role for other pollinators, but the species involved are largely unknown. This project explored the native bee species that are possible pollen vectors in the production of hybrid seed of carrot and leek, investigates ways to enhance their presence on outside crops, and explored the potential to use suitable native bees inside enclosed greenhouses.

### **The Science Undertaken**

Standardized crop scans, trapping and hand-netting were used to assess the visitors of male sterile and fertile leek flowers. Blue-vane and malaise trapping was performed to further assess the presence of native bees around the crops. Pollination experiments in enclosures were performed to test the potential of a number of wood and twig nesting bee species for crop pollination. Species tested included *Exoneura robusta*, *Amegilla murrayensis* and 5 *Megachile* species. Artificial nesting blocks of various types of wood, with holes of different sizes were placed at 9 farms to obtain bees for the experiments. Their uptake by bees, phenology of the species, and presence of parasitic wasps were documented.

### **Major research findings and industry outcomes**

Over two years, 36 species of native bees were caught, and 26 species were observed on the crops. Carrot was visited by 22 species of native bees, the dominant species were medium-sized *Lasioglossum* (Halictinae) species. These ground-nesting species nested in and around the crops. Unlike *Apis mellifera*, *Lasioglossum* did not have a preference for pollen-bearing carrot flowers. Leek was visited by a range of native bees, including several species of ground-nesting Colletidae, Halictidae and Apidae. After an initial period without spraying, the crops were sprayed regularly with synthetic pyrethroid to eradicate Rutherglen bug. This decimated the densities of all visitors, including native bees. Overall, the densities did not seem to recover to the original level within a week.

The experiments inside greenhouses showed good visitation of Megachilid bees to leek. However, yield data were not convincing, partly due to humid conditions and crop diseases, and partly because there was only a limited overlap between the flowering time of the crop and the activity of the bees. Flower visitation by *Exoneura* and *Amegilla* did not result in significant seed production of male sterile leek.

The wood nesting-blocks were predominantly taken up by resin bees. The bees had a preference for dense wood (eucalypt, blackwood), and for holes of 5-6 mm in diameter. Uptake was only successful when the nestboxes were protected from ants. Uptake in the first year leads to large increases in the next. The nests attracted large numbers of parasitic wasps, particularly in the second year.

### **Recommendations**

Artificial nesting substrate for wood nesting bees may increase the presence of pollinators on crops, but they need to be maintained: remove access by ants, clean cobwebs and use nest blocks that can be opened during winter so parasitic wasp brood can be removed.

Native bees that visit carrot and leek are predominately ground-nesting. There are several strategies that will contribute to their presence in the crop:

- Provide bee food for when the crop is not in flower (e.g. plant Canola before the carrots flower).

- Maintain an area of bare, slightly compacted, untilled unmulched, at most lightly trafficked, soil that is not flooded during winter. Herbicide can be used during winter to keep the patch from becoming overly vegetated.
- Use diligence with spraying insecticides. Use options that are soft for bees, prevent spray into neighbouring vegetation, spray on still nights, when the bees are inside their nests.

# INTRODUCTION

## Historical background to the project

Seed growers and plant breeders often develop plants with desirable characters for growers, processors and consumers. In many crops it is technically possible to produce hybrids by crossing different inbred parent lines. When the plant is not wind-pollinated, this process requires the activity of pollen vectors (Free 1993). Bees are eminent pollen vectors (Kevan and Baker 1983), because they rely solely on pollen and nectar for the nutrition of themselves and their offspring.

Honeybees (*Apis mellifera*) are often used for pollination, as they are easy to manage in large numbers. However, on occasion, honeybees do not perform optimally (Westerkamp and Gottsberger 2000). Suboptimal pollination by honeybees can be related to morphology and behaviour of the bees, or to lack of attractivity, either of the crop as a whole or, in hybrid seed production, of one of the parent lines, often the male sterile line (Delaplane and Mayer 2000). Furthermore, small enclosures, used by plant breeders, are often not amenable for the use of honeybees as their numbers can be very high relative to the numbers of plants.

In several instances where pollination by honeybees does not provide optimal yields, other pollinators, including native bees, can help (Winfree et al. 2007; Winfree et al. 2008). These bees occur naturally in the crops (Kremen 2008), and about a dozen species are managed for crop pollination (Batra 2001). Examples are mason bees (*Osmia*), used for cherry pollination (Bosch and Kemp 2001), leafcutter bees and (Delaplane and Mayer 2000) and halictine bees (Bosch 2005) for lucerne bumblebees for tomato (Velthuis and van Doorn 2006) and blueberry pollination, and carpenter bees in passionfruit (Freitas and Oliveira Filho 2003). Overseas, breeders use a large range of solitary bees in enclosures (e.g. *Megachile rotundata*, *M. rufitarsus*, *Osmia cornuta*, *O. cornifrons*, *O. rufa* and several *Bombus* species (e.g. (Strickler and Cane 2004), R. Driessen, pers. com.). In Australia, only a limited number of species are maintained for pollination, notably *Apis mellifera*, *M. rotundata* and some stingless bee species (Heard 1999). There are more than 3000 species of native bees in Australia (Batley and Hogendoorn 2009). These bees are a largely untapped, but potentially highly valuable group of ecosystem service providers (Cunningham et al. 2002).

## Why the project was undertaken

A number of studies have demonstrated that carrots (e.g. (Abrol 1997; Gaffney et al. 2011) and references therein) and *Allium* species (Williams and Free 1974; Parker 1982; Howlett et al. 2009) are attractive to a large range of insect visitors. Among native bees that have been reported to visit carrots and leek are halictine (Abrol 1997) leafcutter and colletid bees (Howlett et al. 2009; Davidson et al.), (Gaffney et al. 2011). Furthermore, in enclosures, carrot pollination by alfalfa leafcutter bees provided the same yield as with honeybees (Davidson et al. 2010). In support of this role of pollinators, production trials with carrots at Rijk Zwaan showed an average yield increase of 73% in two varieties of carrots when the crop was exposed to “ambient” native bee pollination in addition to honeybee pollination. In leeks a similar trial showed a yield gain of 30% when native bees were part of the mix of pollinating insects (Baelde & Hannah pers. com.). However, the identity of the species that are useful pollinators is unknown. Identification of the useful species can lead to development of methods to enhance these species in and around the crops.

Identification of useful pollinators could also open the road to deploy these species inside enclosures. This can be useful in particular when the use of honeybees leads to suboptimal pollination, as is observed in enclosed leek (A. Baelde, pers. com.).

The aims of this project were threefold:

**1. Identify possible pollinators of leek and carrot in hybrid seed production.**

The presence of native bees was investigated using standardised crop scans, hand netting and trapping. The results are presented in Chapter 1.

Furthermore, the presence of other visitors and potential pollinators were assessed against their propensity to visit male sterile flowers. The results are presented in Chapter 2. The effects of spraying on insect densities are briefly addressed in Chapter 3.

**2. Investigate possibilities to increase local densities of native bees.** The effects of providing various nesting substrates around the crops was analysed for their ability to enhance the presence of native bees. The results are presented in Chapter 4.

**3. Investigate life cycle and main brood parasites of suitable pollinators**

Suitable pollinators need to be active when the crop is in flower. The presence of pollinators of summer flowering crops can depend on the maintenance of these bees before the crop is in flower. Furthermore, when propagated in artificial nesting material, the phenology of a pollinator can often be manipulated to coincide with the flowering of the crop, and strategies can be developed to keep the main parasites and diseases under control. Therefore, we investigated the phenology of pollinators in relation to crop phenology. The results are presented in Chapter 5.

**Significance for the industry**

Identification and development of native bees as crop pollinators is not only of value to seed growers, but also to the horticultural industry in general, and for other large pollination dependent primary industries, such as cotton, canola and lucerne (Cunningham et al. 2002 Cook, 2007 #958 Gallai, 2009 #1012; Keogh et al. 2010). There are three main reasons for this.

First, as indicated above, compared to the effects of honeybees, pollination by native bees can improve yield and quality of several vegetables and fruit (Delaplane and Mayer 2000; Batra 2001). Second, maintenance of a diverse community of pollinators can improve pollination services through synergistic effects, and provide a more stable service (Kremen et al. 2002b; Klein et al. 2003; Kremen et al. 2007; Winfree and Kremen 2009). Third, with increasing concern about a worldwide decline in honey bee numbers due to a variety of diseases, the horticultural world is becoming aware of the fact that reliance on a single pollinator species can leave one in a vulnerable position (Allen-Wardell et al. 1998; Klein et al. 2007; Winfree et al. 2007; Aizen et al. 2009; Gallai et al. 2009). World-wide, the incursion of the Varroa mite has substantially increased interest in alternative pollinators, and it is prudent for Australia to identify other potential crop pollinators before an incursion of the Varroa mite causes a foreseen shortage of honeybee pollination (Cunningham et al. 2002; Cook et al. 2007; Gaffney et al. 2011). Investment in R&D to identify and manage native bees that contribute to the pollination of a range of horticultural crops will help to partially curb the expected negative effects of insufficient pollination (Cook et al. 2007), that will be the result of the incursion of the Varroa mite.

**Implications for Industry of the R&D**

The crop scans identified a wide range of largely ground-nesting bees as visitors of both crops. The presence of these bees depends on conditions in and around the crops, not

only when the crop is in flower, but also at other times. As a consequence, we have formulated advice for farmers on how to maintain and increase native bees in and around the crops (Appendix 3), and advice on how to build and maintain nest substrate for Australian native bees (Appendix 4). Actions taken according to these recommendations are likely to see yield increases in pollinator-dependent crops. This is important, in particular in the case of the foreseen shortage of honeybees.

## **CHAPTER 1: THE NATIVE BEE VISITORS OF LEEK AND CARROT**

### **BACKGROUND**

Assessment of the native bee visitors of a crop in the field is a first step towards identifying the species that could be useful pollinators (Bosch and Kemp 2002). Hence, carrot and leek, grown for hybrid seed production, were surveyed for native bee visitors.

### **MATERIALS AND METHODS**

Standardized surveys of leek and carrot crops were performed at five locations in 2009/2010, and a further six locations in 2010/11 (Appendix 1). There was an overlap of 2 locations (locations 3 and 8) between the years. Each location was visited at least four days during the flowering period of the crop (Appendix 1), at approximately 10-day intervals, at times and on days that the temperature exceeded 20 °C to ensure that native pollinators could be flying. The latter requirement precluded absolute regularity in the timing of the visits. On these days, the crops were visited twice, once in the morning and once in the afternoon.

Assessment of the presence of native bees at the crop sites was done by collecting bees by hand net or aspirator on nearby plant species, and by using malaise traps and blue-vane traps. Traps were placed in the crop before 10 am, and removed after 3 pm. After an initial trial, the use of malaise traps was abandoned for two reasons. First, their ability to collect bees depends narrowly on their position. Second, when placed well, they had the potential to trap very large numbers of the same species, and it was feared that they would have a significant influence on bee densities. Combined with the variable and unpredictable impact on the presence of naïve bees in consecutive visits, this method did not seem to serve our purpose of documenting potential crop visitors.

To assess the native bees that were visiting the crops, scans were performed at each location, during each visit. This involved walking through the crop for 20 minutes, between 10 am and 3 pm, at temperatures above 20 °C, taking note of all native bee species present on the flowers, and whether they were present on male sterile or fertile flowers. Several of the bees seen were collected by hand net or aspirator for identification. However, to preclude potential significant negative impact of the research on the bee numbers during consecutive visits, bees were not collected when they could be identified with some certainty to the species level on the basis of positive recognition or sufficient similarity to earlier collected, common species. In those cases the bees were recorded as “seen”, otherwise as “caught”. If the bees were not caught and could not be identified to species, they were identified to genus. For *Lasioglossum*, it was recorded whether they were small, medium or large in size according to arbitrary standards.

Over the two years a total of 94 scans of eleven carrot crops were performed at a total of nine farms.. For leek, a total of 18 scans were performed at location 3, 8 and 9 in the first year and at locations 3 and p in the second year. However, in the second year sampling effort on leek at location 9 was limited to two days with a single scan per day and no trapping was performed. This was due to time constraints.

For the analysis, the bees were classified into small, medium and large halictine, colletid, nomine and megachilids bees, and “others” (a variety of species caught in very low numbers). To assess potential preferences for specific crops, the frequencies of crop visitors in these classes were compared to what was caught in traps and around the crops, using chi-square tests

All bees that had been collected were killed by freezing, and pinned and identified to the species whenever possible. The majority of the specimens collected are kept in the Waite Entomological Collection of The University of Adelaide, but a small representative collection is at the premises of Rijk Zwaan Australia in Musk VIC.

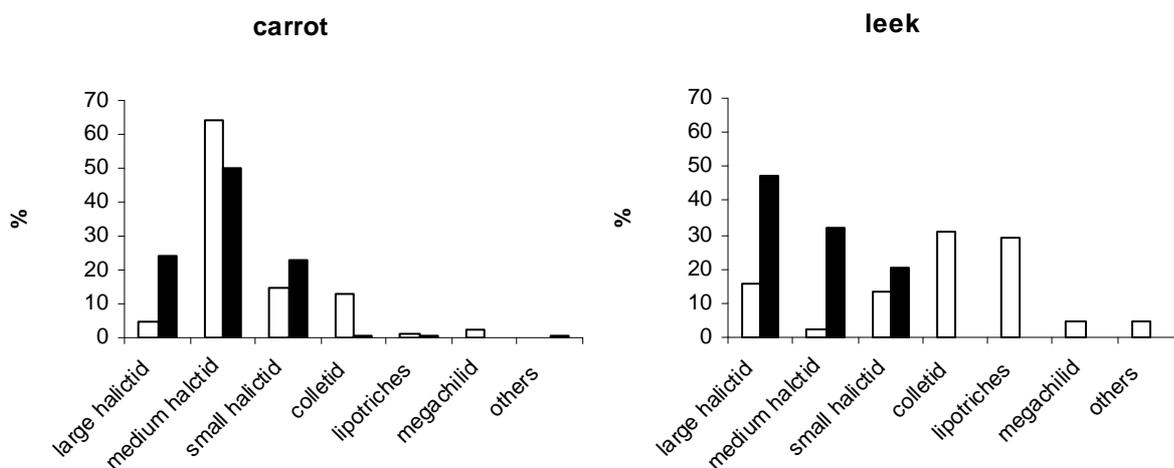
## RESULTS

Combined, a total number of 587 of native bees specimens were caught at the carrot and leek, and 71 on other plants (Appendix 2). Of these specimens 140 were caught in the first year of the project, and 356 in the second year. The remaining 71 specimens had been caught during occasional visits in earlier years, and by staff at Rijk Zwaan. The latter specimens are included in analyses to investigate the species that visit the crops, but not in quantitative analyses of visitation rates, as they were collected in non-standardised ways.

### *Carrot*

A total of 501 specimens of native bees were seen or collected in or around carrot crops and a majority of these (90%) were halictine species.

It is important to distinguish between the bees caught in the traps and the bees that were actually observed to visit the crops. Of the 501 specimens, 200 were seen or caught on the carrot flowers and of these, 79% were halictine bees. Thus, the proportion of halictines caught in traps was significantly higher than the proportion observed on the flowers (Chi-square = 51.14,  $p < 0.001$ ). Therefore, compared to other species, halictine bees were more attracted to the traps than to the carrots. Nevertheless, halictine bees were the dominant native bee visitors observed on carrot flowers (Fig 1.1).



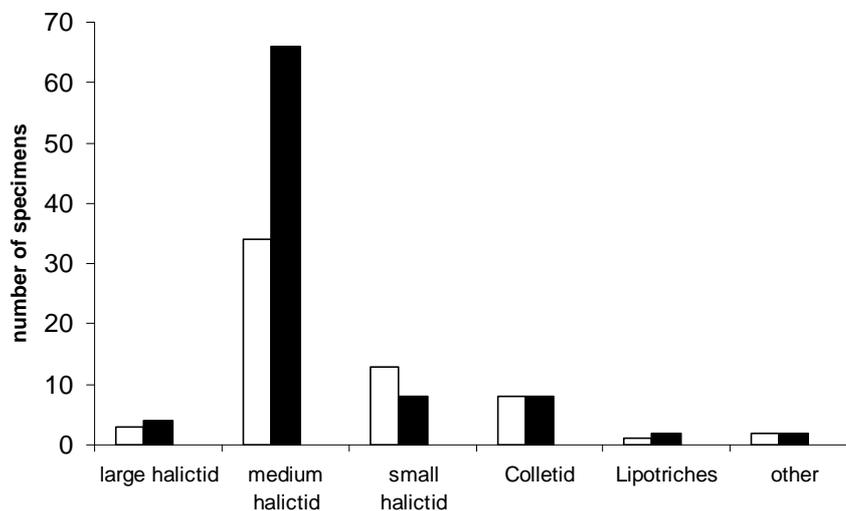
**Figure 1.1.** The frequencies of bees caught or seen on the crops (white bars) and caught using blue-vane traps (black bars) in (a) carrot and (b) leek.

Of the 53 halictine bees caught by hand-net while foraging on carrot, and thus identified with certainty as carrot pollinators, 61% were identified as *Lasioglossum (Chilalictus) clelandi*. This species was caught at all farms. There was no difference in the frequency of capture of *L. clelandi* by hand-net and in the blue-vane traps (Chi-square = 1.56,  $p = 0.46$ ). Thus, *L. clelandi* is the most predominant bee on carrot. The other halictine bees belonged to 12 species. Well represented species were *L. lanarium*, *L. gilesi* and *L. cognatum*, but these species were more frequently observed at some than at other locations. Other non-halictine bees observed on carrot were: *Leioproctus clarki* ( $n = 24$ ), *Lipotriches australica* ( $n = 4$ ), *Exoneura* species ( $n = 4$ ), and two species of each of Hylaeini and Megachilini (resin bees).

#### Visitation of fertile and male sterile carrot

The medium halictine species seem to favour the male sterile flowers (binomial test, but for the other species there was no significant difference in visitation rates (Fig 1.2).

#### native bees seen and caught on carrot



**Figure 1.2** The native bees observed (seen and/or caught by hand) and on fertile (white bars) and male sterile (black bars) carrot flowers during two years and 94 scans of eleven carrot crops at a total of nine farms.

#### Leek

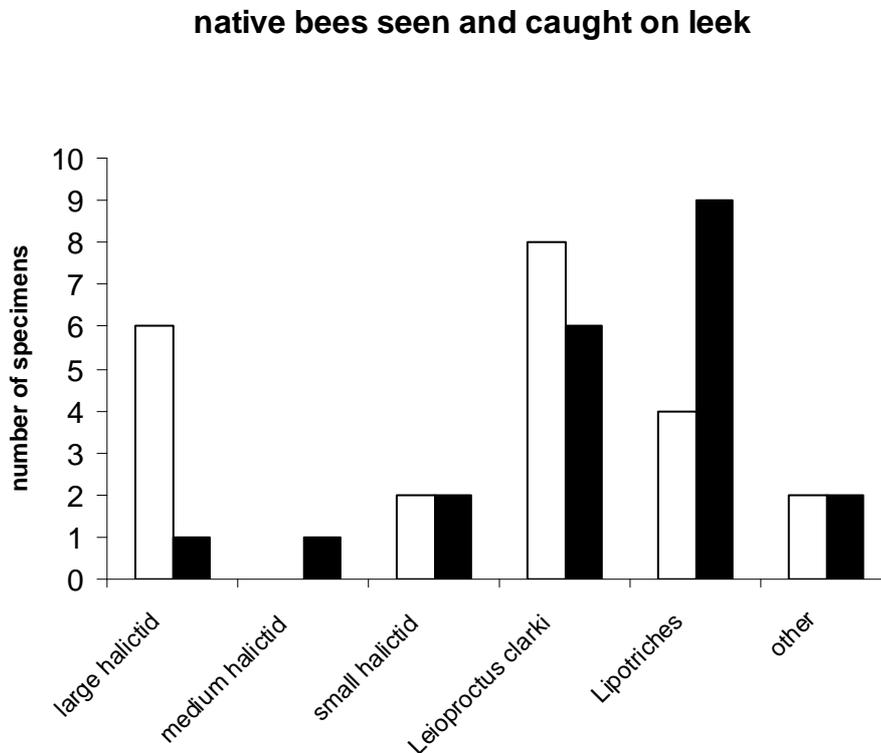
A total of 70 native bee specimens were caught or seen at the leek sites. The number of bees caught on leek was smaller than on carrot, which is mainly due to a smaller number of available locations (three in the first year, and two in the second year), and undersampling at location 9 in the second year. Nevertheless, there are striking differences in the visitors of the two crops (Fig 1.1).

Leek obtained more visits from colletid (*Leioproctus*) and nomiine bees (*Lipotriches*) than from halictine bees. Among the other species visiting leek were a small number of leafcutter and resin bees (*Megachile*)

As in carrot, the blue-vane traps in leek attracted significantly more halictines (84% of all species caught in the traps) than were observed on the crops (18% of observed bees were halictines; Fig 1.1). This shows that halictine bees were present in the area, but not attracted to the leek during the study.

*Visitation of fertile and male sterile leek*

Both sterile and fertile flowers were visited by *Leioproctus* and *Lipotriches*, and females of these species were observed collecting pollen. The large halictids collected on sterile leek were a mix of *Lasioglossum gilesi*, *L. lanarium* and *L. hiltacum*.



**Figure 1.3** The native bees observed (seen and/or caught by hand) and on fertile (white bars) and male sterile (black bars) leek flowers during two years and 18 scans of five carrot crops at a total of three farms.

**Discussion**

The main native bee visitors of both carrot and leek are clearly ground-nesting bees. A total of 13 species of *Lasioglossum*, of various sizes, were found to visit carrot. Unlike honeybees (Chapter 2), the halictine bees did not differentiate between male sterile and fertile flowers. The other bee species were observed in lower numbers. On leek, medium sized *Lasioglossum* species were largely absent during the two years. However, they had been observed and caught on leek during earlier years at location 8, and their absence during the study may have been due to a combination of relative low numbers of *Lasioglossum* at the locations when the leek was grown (Hogendoorn pers. obs.) and timing of spraying. Parker (1982) compared the halictine bee *Halictus farinosus* to honeybees for the pollination of onion, which has similar flowers to leek. *H. farinosus* was five times as abundant as *Apis mellifera*, and twice as effective in pollination.

In our study, the predominant bees visiting the flowers and collecting pollen were *Lipotriches* and *Leioproctus*. Resin bees (*Megachile*) were also observed on leek outside. This is interesting because this is the only species so far that does not nest in the ground, and is therefore more amenable to propagation and deployment in the crop. However, if leek would have been a preferred food source for these bees, these species should have been abundant at location 3 during both years of the project, as they actively used nestboxes that were positioned adjacent to the leek. This was not the case.

Therefore, it seems that, in the presence of alternative flowering plants, *Megachile* species will not forage on leek outside.

Although sampling effort was similar during the two years of the project, the locations were partly different and the weather was very different, with an extremely hot period in November 2009, and an exceptionally wet and cold spring in 2010. The effect of the weather can be gauged by comparison on the bees caught at location 3, the only location that had similar crops and similar collection effort over the two years. At this location, the blue-vane traps captured twice as many bees ( $n = 41$ ) during the second year of the project than during the first year ( $n = 20$ ;  $P = 0.001$ ). Therefore, the increase in the number of species caught seems at least in part a result of the differences between the years.

It was demonstrated that blue-vane traps do not give a reliable indication of the species that visit the crops or that are present in an area, as they are specifically attractive to halictine bees.

## **CONCLUSIONS AND RECOMMENDATIONS**

The aim of this part of the study was to establish which native bees visit leek and carrot. Carrot was mainly visited by *Lasioglossum* species, and by *Leioproctus*. Leek was visited by a range of species. The most dominant were *Leioproctus clarki* and *Lipotriches australica*. It is clear that the crops were mainly visited by ground-nesting bees. Improved pollination by native bees would therefore require improving the conditions for ground-nesting bees in the crop area.

Areas could be created that allow ground-nesting bees to nest near the crops.

These areas should be in a sunny spot. They should have compacted loamy soil, and not be mulched, flooded or frequently trafficked. Such measures have been successful to attract *Nomia melanderi* (Cane 2008), and are used to maintain a ground-nesting halictine for alfalfa pollination (Bosch 2005). They have been observed to work in a garden setting in Australia (Hogendoorn pers. obs). However, the evidence is circumstantial, and has not been experimentally tested.

Further recommendations for the maintenance of ground-nesting bees on the crops have been formulated in relation to spraying (see Chapter 3) and provision of floral resources for when the crops are not in flower (Chapter 6).

## **CHAPTER 2: OTHER INSECTS THAT VISIT LEEK AND CARROT**

### **BACKGROUND**

Apart from native bees, there are many other insects that visit and potentially pollinate leek and carrot. Assessment of the presence of these visitors on the crop is a first step towards identifying the species that could be useful pollinators (Bosch and Kemp 2004). Hence, carrot and leek, grown for hybrid seed production, were surveyed for other insect visitors, and their visitation frequency of fertile and male sterile flowers.

### **MATERIALS AND METHODS**

The locations and visiting dates of the crops at different locations are given in Chapter 1 and Appendix 1.

Standardized crop scans were done twice a day, more than one hour apart, between 10 am and 3 pm. The scans involved walking the length of the crops twice at a steady pace and scoring all visitors on a single row of flowering crop plants, which had either male fertile or male-sterile flowers. The visitors to each type of flower were classified into the following, broad groups:

Flies:	:	Eristalinae Syrphinae Other flies
Beetles:		Cantharidae (Soldier beetles) Coccinellidae (Ladybirds)
Wasps:		
Bees:		<i>Apis mellifera</i> Native bees (Chapter 1)

In 2009/10 the total length of carrot scanned was equal for male and male sterile flowers: 5550 m over five locations in 2009/10, and 9940 m at six locations in 2010/11.

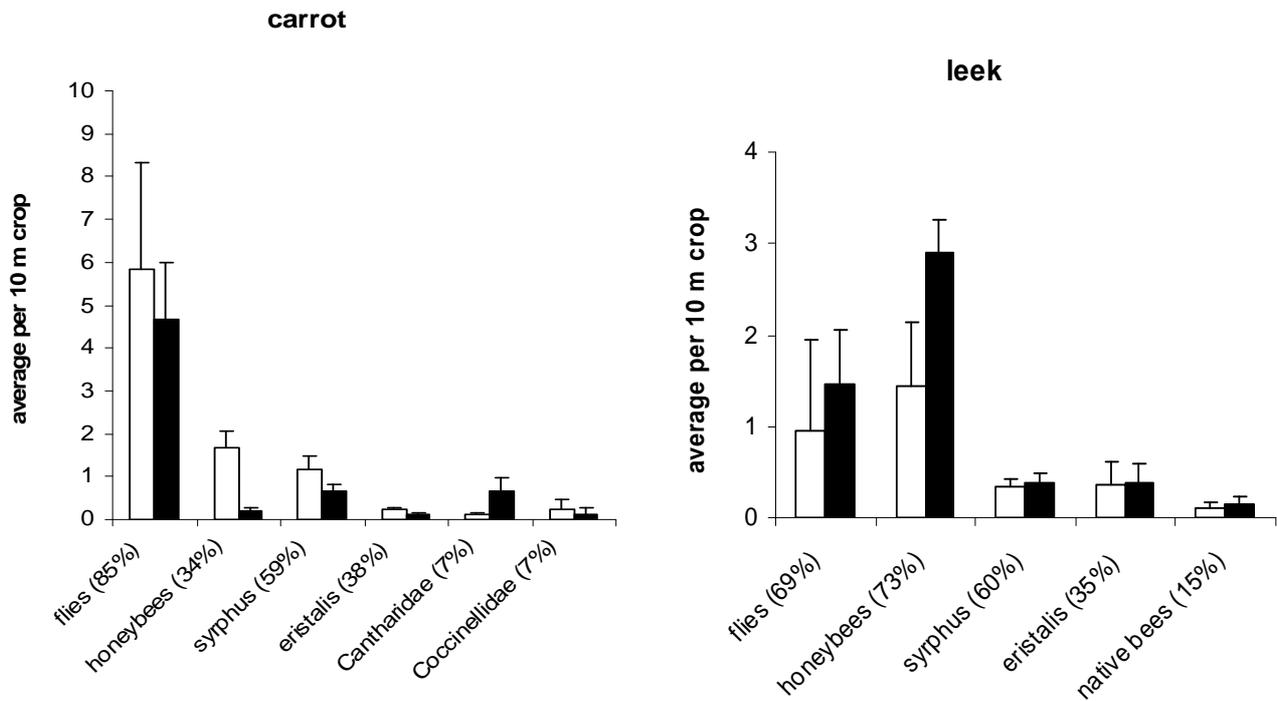
For leek, the total lengths of crop scanned was 2250 m in the first year, but, due to a combination of a short flowering season and small numbers of farms (n=2), the scans were limited to 660 m during the second year. Furthermore, during the second year, the crops at location 9 received only a single scan per day, as a second visit did not fit in the time-frame.

To allow comparisons to be made between locations and to achieve homoscedasticity of variances, the number of visitors was averaged per 10m of crop.

To assess how visitation was affected by years, locations and “sex” of crop (fertile versus male-sterile), a multivariate ANOVA was performed for each crop using sex, year and location as factors.

### **RESULTS**

The average number of visitors per 10 m of carrot was highest for flies, and lowest for native bees (Fig 2.1). Furthermore, as indicated by the high standard errors and by the high percentage of scans where no insects were observed (Fig 2.1), the presence of insects from all groups was highly variable. Soldier beetles and ladybirds are deemed unreliable pollinators, due to extreme variation (Fig 2.1) and are left out of consideration in further analyses.



**Figure 2.1.** The average number of floral visitors ( $\pm$  s.e.) observed on 10 m of fertile (white) and male-sterile (black) crops, during a total of 94 crops scans on 9 farms over two years (carrot) and . Between brackets: the percentage of scans in which the visitors were present. No ladybirds or soldier beetles have been scored on leek.

The number of visitors per 10 m of carrot (Fig 2.1) was significantly influenced by sex, year and farm (Table 2.1). Post-hoc analysis with Bonferroni correction showed a significant effect of sex on carrot visitation by honeybees ( $F = 7.00$ ,  $p = 0.009$ ; Fig 1). The flies, syrphids and *Eristalis* showed no significant preference.

**Table 2.1.** Effects of year, sterility (“sex”), and location on the number of visitors of different species observed per 10 m crop scans, assessed by multivariate ANOVA.

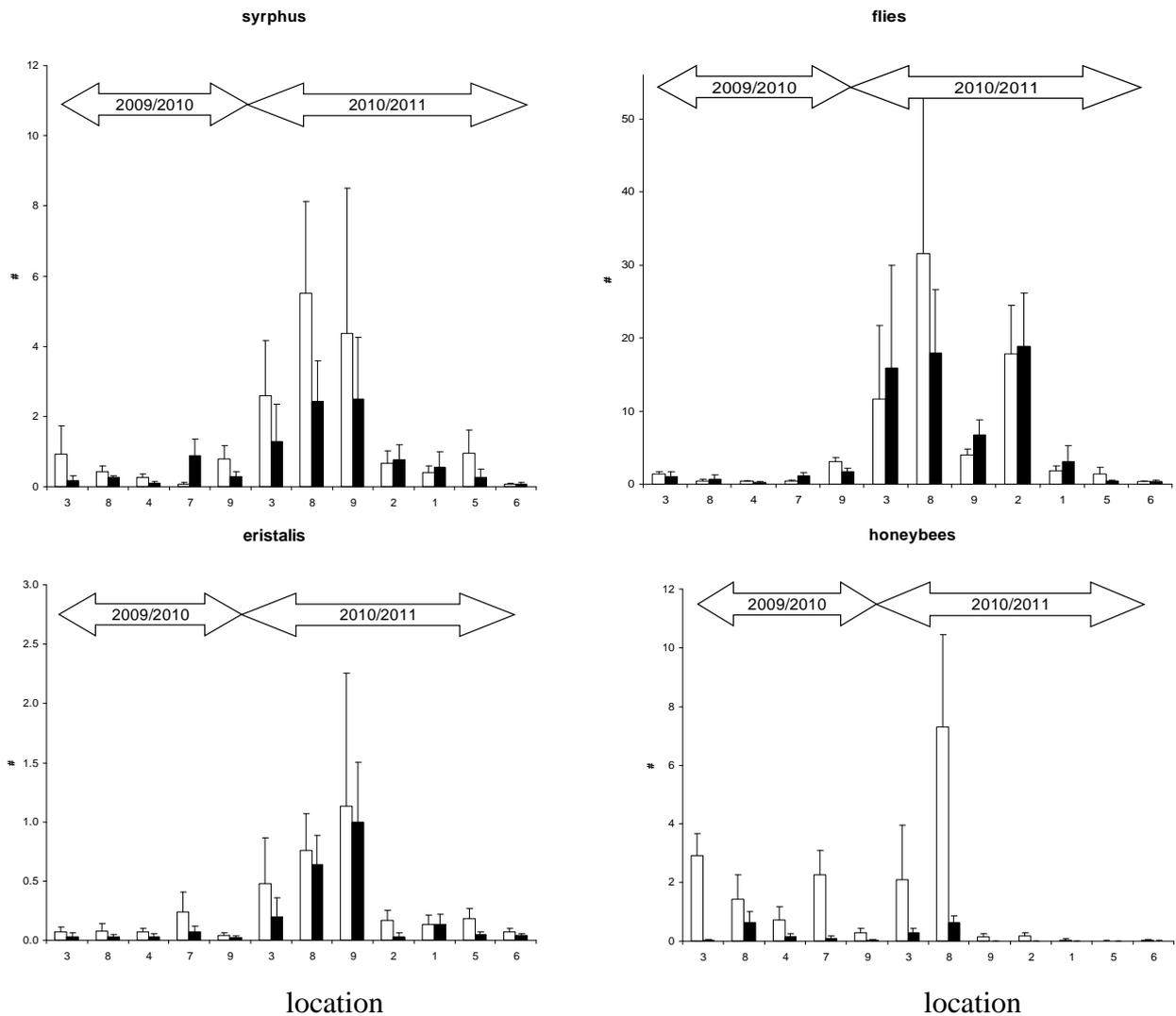
	carrot			leek		
	Pillai’s Trace	F	p	Pillai’s Trace	F	p
year	0.29	16.07	< 0.001	0.60	5.08	< 0.001
sex	0.06	2.49	0.05	0.06	0.69	0.60
farm	0.54	3.14	< 0.001	0.43	8.79	<0.001

The years differed significantly with respect to the numbers of syrphids ( $F = 22.14$ ,  $p = 0.001$ ), flies ( $F = 8.30$ ,  $p = 0.004$ ) and *Eristalis* ( $F = 48.85$ ,  $p < 0.001$ ). For each of these groups, the numbers per 10 m crop were higher in the second than in the first year. The years did not differ significantly with respect to the numbers of honeybees ( $F = 1.69$ ,  $p = 0.20$ ).

When analysed for each year separately, there was an overall significant difference between the locations ( $F = 2.92$ ,  $p < 0.001$  in year 1 and  $F = 2.067$ ,  $p = 0.003$  in year 2). Post-hoc test with Bonferroni correction, for each of the species, showed significant

differences between locations in the number of flies in the first year ( $F = 7.98, P < 0.001$ , and *Syrphus* and *Eristalis* in the second year ( significant differences.

The variability in the presence of honeybees, *Eristalis*, *Syrphus* and flies over locations and time is shown in (Fig 2.2, Table 2).



**Figure 2.2.** Average numbers ( $\pm$  s.e.) of different insects on 10 m of fertile (white) and male-sterile (black) carrot flowers at different locations, during 2009/10 and 2010/11. Note the different scales of the y-axis.

For leek, honeybees were the most frequent visitors (Fig 2.1). Coccinellidae and Cantharidae are not depicted in Fig 2.1, as their numbers were negligible compared to the more frequently observed insects. The visitation rates of the different species were affected by year and farm, but not by sex (Table 2). For all groups of insects, sterile flowers were not significantly more attractive than fertile flowers (Fig 2.1).

**DISCUSSION**

The most dominant flower visitors of carrot belonged to the order of the Diptera. None of the fly groups discriminated between fertile and male sterile carrot. Among the flies, *Eristalis* may provide good pollination, as they are large, hairy flies that move about and carry pollen on their bodies. These observations have recently been confirmed by

independent research both in cages (Schittenhelm et al. 1997), and in the field (Pérez-Bañon et al. 2007) Spurr pers. com.).

For leek, the data give no clear indications of what may be useful pollinators, as there were no differences observed in visitation between the sexes. This is surprising, because Parker (1982) found that fertile heads were much more attractive than sterile heads both to honeybees and to halictine bees.

The numbers of all insects (apart from honeybees) were higher in the second year than in the first year of the study. It is likely that this is the consequence of a very unfavourable spring in 2009. An unduly early hot spell in November 2009 may have resulted in a rapid decline of floral resources, and hence in reduced survival and reproductive activity of the generations that preceded the flowering of the crop. During spring and early summer of the second year, the conditions were extremely wet; the total rainfall was twice that of normal years ([www.bom.gov.au](http://www.bom.gov.au)). This led to ample available forage in early summer. In this context, it is interesting to note that the number of honeybees, which were placed at similar densities in the crop each year, were significantly more abundant in the first year than in the second year. This can be understood if, in response to ample alternative food sources, the honeybees moved off the crop in the second year.

Although there was a higher frequency of all insects on the crops in the second year, compared to other farms, the high numbers at location 8 (Rijk Zwaan) are particularly striking. With regard to the insect other than honeybees, these differences may well be caused by a combination of factors. First, spraying against Rutherglen bug did not occur at this location (L. Hannah pers. com.), and has a profound influence on crop visitors (Chapter 3). Second, the carrot crop at this location consisted of many cultivars with different attributes, possibly constituting an overall more attractive bouquet. Third, the crop at Rijk Zwaan had a much higher frequency of fertile plants, which could increase the attractivity.

The differences between the years in weather, locations, spraying activities, and the different parental lines used at different locations precluded any meaningful analysis of the yield against the visitation by insects. Furthermore, a very large variation in insect visitor assemblages over time has been reported in two other studies (Bohart and Nye 1960; Lamborn and Ollerton 2000). There is no doubt that a diverse insect community, with high numbers of insects of various species can contribute to carrot seed yield (Gaffney et al. 2011).

## **CONCLUSION**

Flies are the dominant visitors of carrot.

There is a high variation in the presence of insects on carrots, both over time and between sites.

Unlike any of the other insects, honeybees preferred fertile carrots.

## **RECOMMENDATION**

Maintenance of high numbers of insects and local breeding of *Eristalis* may improve carrot pollination.

## CHAPTER 3: EFFECTS OF DIMETHOATE SPRAYS ON VISITORS

### BACKGROUND

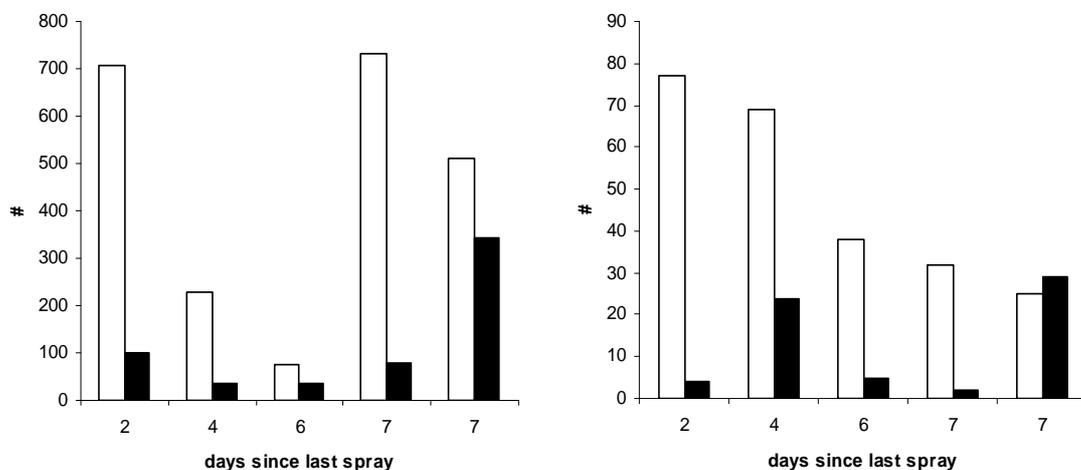
During the project it became clear that the number of insects varied in seemingly unpredictable ways. It was surmised that this variation could be partly caused by the regular sprays of the crops with dimethoate, aimed at removing a seed parasite, the Rutherglen bug (*Nysius vinitor*). It was decided that some insight into the effects of these sprays on potential pollinators was required.

### METHODS

Using the data from the crop scans of the second year (Chapter 1 and 2), the total number of insects and the numbers of bees were assessed before the onset of spraying and after spraying. The number of days since the last spray was also taken into account. The numbers before and after spraying were compared using Wilcoxon's matched pairs signed ranks test.

### RESULTS

There was a significant reduction of all crop visitors after spraying (Wilcoxon matched pairs test,  $p = 0.04$ , Fig 3.1). For native bees, the effect was not significant ( $p = 0.08$ ). The latter result is likely due to the fact that the native bee fauna at one farm had recovered in 7 days after spraying. No full recovery was seen in any of the other farms. There was no correlation between the days after spraying and the difference in the numbers before and after spraying (in percentage of initially observed; Spearman rank correlation tests: all insects:  $r_2 = 2.1$ ,  $p = 0.74$ ; bees:  $r_2 = 0.46$ ,  $p = 0.43$ )



**Figure 3.1.** The total numbers of insects observed (left), and the number of native bees observed and caught in traps (right), at different locations, before (white bars) and after (black bars) sprays with dimethoate. The abscissa shows the number of days since the last spray had been done.

### DISCUSSION

Although regular removal of Rutherglen bug is a necessary action in the seed industry, the data indicate that spraying with dimethoate could have a long-term adverse effect on the presence of potential pollinators, including native bees. This effect may partly explain the large variation in insect numbers on the crops.

The recovery at one farm, after seven days, could indicate that the insect population can recover. However, this observation is not in line with what happened at the other farms after six and seven days of spraying.

## **RECOMMENDATIONS**

Spraying should be delayed as long as possible to improve presence of pollinators, and when possible, insecticides applied should have no systemic action. Spraying is preferably done in the evening, when native bees are in their nests. Care should be taken with spray drift into neighbouring vegetation.

The effects of spraying dimethoate on visitors and pollinators need to be better understood.

Potential alternative methods for the control of Rutherglen bug, that do not affect the other visitors, should be actively pursued.

## CHAPTER 4: IDENTIFICATION OF POTENTIAL NON-APIS POLLINATORS OF LEEK IN ENCLOSURES

### BACKGROUND

The aim of this part of the project was to assess the utility of native bees for the pollination of leek and carrot in captivity.

Yield of greenhouse *Allium* species can be quite low when honeybees are used, due to a lack of pollen transfer (Parker 1982). Therefore, we investigated whether several available native bee species would be useful for the pollination of leek in enclosures, and

On the basis of the literature (Gaffney et al. 2011 and references therein) and results presented in Chapter 1, it was likely that certain ground-nesting species of native bees were the best candidates for carrot pollination in enclosures. However, apart from for a Japanese species (Miyana, 1999 #1031), methods to keep ground-nesting bees in enclosures for pollination purposes have not been developed. Therefore, we investigated whether a common ground-nesting bee species (*Lasioglossum orbatum*) could be kept and would reproduce in enclosures.

### MATERIALS AND METHODS

#### *Locations*

All trials, apart from those involving *A. murrayensis*, were performed at the premises of Rijk Zwaan Australia in Musk, VIC. Experiments involving *A. murrayensis* were performed at the Waite Campus of the University of Adelaide.

#### *Enclosures and timing of experiments*

In Musk, two types of enclosures were used:

- a. Outside greenhouse tunnels, henceforth called “tunnels”, of 4 m wide by 8 m long, with vented sides. In the first year, the roofs were covered with plastic. In the second year, the plastic cover was replaced with biomesh. The experiments in these enclosures performed in late December and January of 2009/10 and January- February of 2011.
- b. Mesh cages (“cages”, 1.5 m wide by 6.0 m long), which were erected inside a large greenhouse, with elevated temperatures. The experiments in these cages were performed in December 2010.

The trials with *A. murrayensis* took place in a 3 by 6 m greenhouse tunnel covered with thrips mesh, in November 2010 and December 2010.

#### *Leeks*

At Rijk Zwaan, all the cages and greenhouse tunnels contained a bed with one row of male fertile leek (approximately 13 plants) and two rows, a total of 26 plants of male-sterile leek. The tunnels also contained feedplants (various native and introduced flowering plants that are known to be attractive to bees), which were removed as soon as the crop was in flower. Arthropod plant pests were treated using biological control. The leeks from the tunnels were harvested on the 25<sup>th</sup> of March 2011.

At the University of Adelaide, batches of 12 fertile and 24 male sterile leek plants in pots were used. The plants had been grown in a bee-free greenhouse in two batches, one early and one delayed flowering. They were introduced in the enclosures in early November and early December 2010, just before anthesis, and were transported back to this greenhouse after flowering had finished. The seeds were harvested on the 15<sup>th</sup> of

March 2011. The yield of the fertile plants served as a control for the efficacy of the bees for the pollination of male sterile plants

### Bees

The following bee species were experimentally assessed for their ability to pollinate leek in captivity: *Exoneura robusta* and *E. angophorae* (combined), *Amegilla murrayensis*, *Megachile rotundata*, *M. heliophila*, and *M. erythropyga*. Management of the ground-nesting species *Lasioglossum orbatum* in enclosures was also attempted. For the bee species used in this study, the collection sites, numbers and timing of collections from the wild are given in Table 4.1 and further explained below.

All bees had access to sugar water feeders (50% sugar, 50% water vol:vol), which were replaced twice a week, or more often during spells of warm weather. If feedplants were provided to maintain the bees, these were cut back when the leek came into flower. Twice weekly, the nests were checked for the presence of ants, cobwebs were cleaned off and spiders were killed whenever feasible.

**Table 4.1.** Dates and sites of collections of nests and individuals of bees for release in tunnels and cages. UoA indicates that the bees were sourced from a breeding program at the University of Adelaide.

species	collected around	date collected	number	
<i>Amegilla murrayensis</i>	UoA	2/11/2009	10	nests
<i>Exoneura angophorae</i>	Daylesford	9/09/2009	100	nests
<i>E. angophorae</i>	Daylesford	30/11/2009	30	nests
<i>E. angophorae</i>	Daylesford	15/01/2010	90	nests
<i>E. robusta</i>	Toolangi	13/09/2009	100	nests
<i>E. robusta</i>	Murrindindi	19/10/2009	50	nests
<i>E. robusta</i>	Toolangi	13/01/2010	100	nests
<i>E. robusta</i>	Toolangi	4/02/2010	150	nests
<i>Lasioglossum orbatum</i>	Musk	20/10/2009	700	females
<i>L. orbatum</i>	Musk	2/12/2009	40	females
<i>Megachile heliophila</i>	Daylesford	woodblocks	20	nests
<i>M. erythropyga</i>	Daylesford	woodblocks	20	nests
<i>M. rotundata</i>	Keith	4/12/2010	120	brood

### *Exoneura*

The *Exoneura* species were collected from several sites around the localities indicated in Table 4.1. Nests of *E. angophorae* were found in dead blackberry and fennel stems, and in twigs of several trees with soft pithy centres in and around Daylesford. Nest of *Exoneura robusta* were found in dead tree fern fronds (*Cyathea australis*). To prevent damage to native populations, only a small number of nests were taken from each site. However, in 2010, many nests of *E. robusta* were collected from a tight location that had been earmarked for fuel reduction burning. As it was foreseen that the bees were not going to survive this, the area was intensively sampled.

The nests were plugged with paper and kept cool during transport and overnight. They were introduced in the cage and tunnel the following day, at dusk, to prevent bees from immediately leaving the nests.

In *Exoneura*, adults are present year-round, and will forage whenever the temperature allows it. Therefore all cages and tunnels into which *Exoneura* species were introduced contained a large variety of flowering plants including *Boronia*, *Buddleia*, *Felicia*,

*Lavendula*, *Carpobrotus*, *Nepeta* and *Leptospermum*. During winter of 2010 all previously sampled and newly collected nests were concentrated in a single tunnel. The nests were placed upon a platform that was protected from ants using Tanglefoot, and from direct sunlight using a double layer of shade cloth. The nests to which females returned were marked with marking tape on a regular basis.

#### *Amegilla*

Emerging brood from *A. murrayensis* was obtained from the on-going breeding program at the University of Adelaide (Hogendoorn et al. 2007). Small individual mudbricks were provided as nesting substrate. These were housed in Styrofoam boxes that were protected from ants using Tanglefoot on the stand. The species was initially tested in Adelaide for its ability to forage on leek (2009/10). After this was confirmed, it was tested for its ability to pollinate a hybrid crop in November 2010.

#### *Megachile*

During 2010/2011 four *Megachile* species were tested in greenhouse tunnels and cages. Three of these species, *M. (Hackeriapis) heliophila*, *M. erythropyga* and *Megachile ordinaria* were obtained from the artificial nesting substrate placed in the nest boxes at the farms (Appendix 1 and chapter 4). The nests were harvested in late autumn and kept outside over winter, to ensure normal development. They were moved into a cage (n = 20 nests) and a tunnel (n = 20 nests) on 18/11/ 2010. Nest blocks with entrances of 7 and 8 mm were placed in the cage, and nests with entrances of 4, 5 and 6 mm diameter were placed in the tunnel, in an attempt to obtain different species at the different locations. However, the split between species was not complete, as they had partly nested in the same block (see Chapter 5). The nesting blocks were housed in a nesting box (see Figure in Appendix 3), that was protected from ants using Tanglefoot. The nest entrances were monitored for signs of eclosion to obtain insight in the phenology of the bees at different locations.

Developing brood of *Megachile (Eutricharea) rotundata* (n = 120 cells) was obtained from the breeding stock of Mr J. De Barro of Keith.

The cells were placed in a 130-hole Binderboard obtained from Pollinator Paradise (<http://www.pollinatorparadise.com>), and housed in a nesting box that was protected from ants. The developing brood was placed in the tunnel on 9 December. Non-flowering lucerne plants were added to the tunnel to allow the construction of cells.

#### *Lasioglossum*

A total of 740 females of *Lasioglossum (Chilalictus) orbatum* were collected. Of these, 700 had landed on a windscreen at Rijk Zwaan on a single day in October, and none had been seen the day before or after. Judging from the numbers of females present and the unworn status of their wings, it was assumed that these bees had recently emerged from their winter nests. After collection, the bees were kept in a cool (9 C) and dark environment until dusk, after which they were released into three cages at Rijk Zwaan. The females were sprinkled over the ground and over buckets of compacted soil, into which artificial entrance holes had been made with a skewer. However, these were not taken up, and bees nested in the soil. Feedplants were present but no leeks were provided.

#### **Observations**

Bee activity was recorded during every visit (see Appendix 1 for dates). Nests and flowers were scanned to estimate the number of bees active in each of the cages and tunnels.

## RESULTS

### *Enclosures*

None of the bees introduced during the first year of the project settled in the tunnels. Behavioural observations indicated that there was a problem with the roofing. The bees would fly up to the roof, as if unable to see it. Then they would fly downwards along the curve of the roof, often with their wings and or upper thorax touching the roof. This gave the impression that the bees could not perceive the plastic until they were physically withheld from flying further upwards. While following the curve of the plastic downwards, they would reach a ledge, and either fly back up, or get stuck between the ledge and the plastic. In the end, the bees died either from exhaustion or from heat, as the ledge was often very hot due to exposure to direct sunlight. Because the behaviour of the bees indicated that they were negatively influenced by the plastic covers, the covers of all tunnels were replaced with biomes during the second year of the project.

### *Exoneura*

In cages, the placement of winter collected nests (collected in September) did not result in active provisioning. As winter nests do not contain inexperienced bees [young brood ecloses between January and February (*E. robusta*) and end of December and February (*E. angophorae*)] it was thought that more success could be achieved with the *E. robusta* collected in January/ February, and with *E. angophorae* from Daylesford collected in January, as they would contain inexperienced individuals (Table 1). This was confirmed as pollen foraging in the cage was observed in February of 2009.

In October and November 2010, many *Exoneura* females were active on the warmer, sunny days and on 7/12/10 a total of 33 occupied nests had been identified. Most bees collected nectar only, but a small number of bees were seen foraging for pollen on the native plants, mainly on *Boronia*, *Leptospermum*, and *Felicia*. The bees were never observed to go to the feeders. In December, there could be up to 12 females foraging simultaneously on warm days. This declined to 4 by the last week of December.



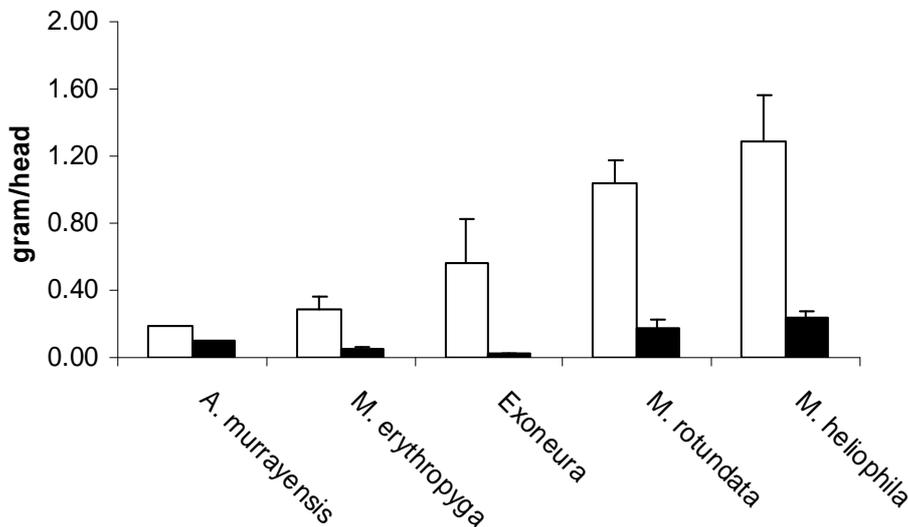
**Figure 4.1.** Female *Exoneura robusta* collecting pollen on leek in captivity. Photo taken By L. Hannah, 15/12/2010

In the tunnel, the leek started to flower from the sixth of December onwards. All plants were in flower by the 23rd of December. The bees were observed foraging on leek, and although most collected nectar, some also collected pollen (Fig 4.1).

The yield from fertile and sterile plants differed significantly ( $t = 4.20$ ,  $p = 0.001$ ), and the average seed yield of fertile plants was 28 times that of sterile plants (Fig 4.2). Hence *Exoneura* did not effectively cross-pollinate the leeks. Neither the yield of sterile or fertile flowers was correlated with the timing of the onset of flowering. Therefore, the results are not influenced by a decrease in bee numbers over time. The plants suffered from fungal disease due to the uncharacteristically wet weather during set.

### *Amegilla*

A total of eight bees were present: four males and four females. Although in the first year of the project pollen collection by *Amegilla* females on leek was observed and filmed, the second year females did not collect pollen. The flower visits were observed on 10 days for half an hour. Of a total 189 visits to individual flower heads, 80% were to fertile flowers.



**Figure 4.2.** The seed yield of fertile and male sterile leek plants visited by various bee species in enclosures.

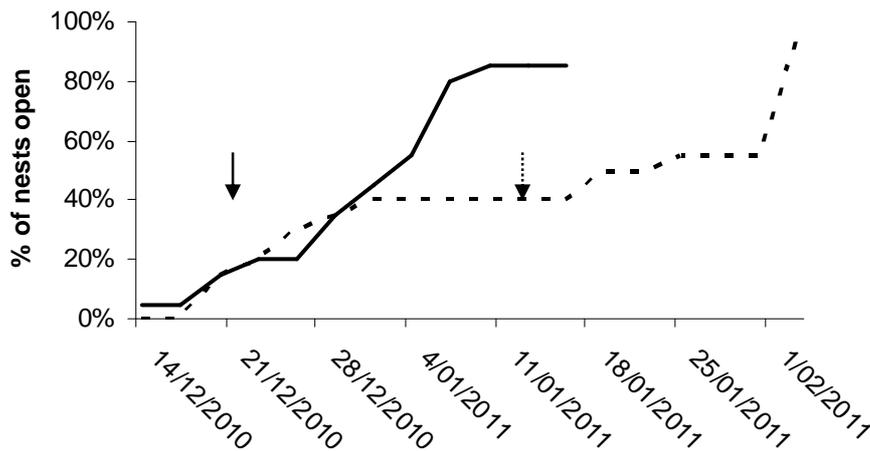
Seed yield was extremely low for both fertile and sterile plants (Fig 4.2). It is likely that this was caused by a combination of bad pollination, hard-to-control thrips and disease caused by the extreme wet conditions during seed set. As all heads were harvested together, there is no information about the variance. Fertile plants produced 1.8 times as much seeds as sterile plants.

### *Megachile* - Resin bees

In the cage, the first nest with signs of eclosion was documented on 14/12/2010, and from then onwards, more and more nests eclosed within two weeks (Fig 4.3). However, some of the first eclosed individuals were parasitic wasps (*Gasteruption* spp. Evanioidea: Gasteriuptionidae). The first bees were seen on 21/12/2010, and at that stage three parasitic wasps had been caught. Four bees (one *M. heliophila* and three *M. erythrogyga*) were flying in the cage on 29/12/2010. Some nectar and pollen was collected by the bees, but the flowers were not frequented, and the bees did not reproduce. On 15/1/2011, 13 resin bee nests had signs of eclosion, and 3 *M. heliophila*

and 10 *M. erythropyga* were observed. At that stage, the sterile leek had finished flowering, and only some fertile leek was still in flower.

Seed yield was low for both fertile and sterile plants (Fig 4.2). There was a significant difference between fertile and sterile plants ( $t = 3.23$ ,  $p = 0.007$ ), and the yield of fertile plants was 5.4 times that of sterile plants. It seems likely that the bad yield was partly caused by the fact that, for most of the flowering time, there were no bees in the cage. However, there was no correlation between the yield of either sterile or fertile flowers and the timing of the onset of flowering (Table 4.2), indicating that the results are not influenced by a lack of bee numbers at the onset of flowering.



**Figure 4.3.** The cumulative percentage of nests that showed signs of eclosion over time in the cage (solid line) and in the tunnel (dashed line). The arrows indicate when the first bee was observed. Eclosions prior to observations of bees were most likely due to eclosions of parasitic wasps. Leek started flowering at the end of November (cage), and in the second-third week of December (tunnel).

In the tunnel, the fertile leeks started flowering on average on the 19<sup>th</sup> of December, and the sterile leeks started flowering either around the 9<sup>th</sup> or the 16<sup>th</sup> December. The first signs of eclosion were found on 20/12/10, but the first bee was seen on 12/1/2011. Thus, there was close to a month between the onset of flowering of the sterile plants and bee activity. On 15/1/2011, there were 9 *M. heliophila* (6 males and 3 females) and 2 *M. erythropyga* active. However, they were not foraging on the leek. It was decided to remove the sugar water feeders to force the bees to collect nectar from the leeks. This was done the next day, and foraging by two females on leek was observed. When the feeders were placed back, they remained foraging on the leek. From then on, the feeders were taken out in the morning at 9, and placed back in the tunnels after 3. On 2/2/11, at least 20 *M. heliophila* were observed flying in the tunnel. However, the leek had all but finished flowering.

The average seed yield was quite low (Fig 4.2) There was a significant difference between fertile and sterile plants ( $t = 3.78$ ,  $p = 0.002$ ), with the average seed yield of fertile plants 5.4 times that of sterile plants. However, the yield of sterile or fertile flowers was not correlated with the timing of the onset of flowering (Table 4.2). Therefore, the results do not seem to be influenced by a lack of bee numbers at the onset of flowering. The plants also suffered from fungal disease due to the uncharacteristically wet weather during set.

For both fertile and sterile flowers, the yield in the tunnel was significantly higher than in the cage (fertile:  $t = 3.50$ ,  $p = 0.002$ ,  $df = 23$ ; sterile:  $t = 4.71$ ,  $p < 0.001$ ,  $df = 43$ ).

***Megachile rotundata***

In the tunnel with *Megachile rotundata*, the leeks started flowering from early December onward, and about half started flowering in the second half of December. The first bee was seen on the 10<sup>th</sup> of January, thus some of the leek had been in flower for more than a month before the bees appeared, but some had been in flower for two weeks only. On 15<sup>th</sup> of January, at least 40 bees were observed in the tunnel. Both males and females collected nectar and females were observed to collect pollen on leek. They constructed cells, but did not reproduce. Two weeks later, the leek had all but finished flowering.

The average seed yield was quite low for both fertile and sterile plants (Fig 4.2). There was a significant difference between fertile and sterile plants ( $t = 6.19$ ,  $p < 0.001$ ), and the average seed yield of fertile plants was 5.7 times that of sterile plants. However, the yield of sterile or fertile flowers was not correlated with the timing of the onset of flowering (Table 4.2). Therefore, the results do not seem to be influenced by a lack of bee numbers at the onset of flowering. The plants also suffered from fungal disease due to the uncharacteristic wet conditions during set.

There was no significant difference in set between resin bees and leafcutter bees used in tunnels (fertile:  $t = 0.86$ ,  $p = 0.40$ ,  $df = 27$ ; sterile:  $t = 1.23$ ,  $p = 0.23$ ,  $df = 46$ ).

**Table 4.2.** The correlation between flowering date, recorded per plant, and seed yield in fertile (f) and male sterile (ms) leek plants.

species	<i>Exoneura</i>		<i>M. erythropyga</i>		<i>M. heliophila</i>		<i>M. rotundata</i>	
	f	ms	f	ms	f	ms	f	ms
n flower heads	13	26	12	24	12	24	16	27
r <sup>2</sup>	0.07	0.02	0.03	0.09	0.12	0.02	0.13	0.04
F	0.85	0.38	0.26	2.07	1.2	0.4	2.05	1.03
p	0.38	0.54	0.62	0.16	0.3	0.53	0.17	0.32

***Lasioglossum orbatum***

In both cages where these bees were introduced, a small proportion (2 % and 3%, a total of 10 females) started to nest and provision cells. The females that have been observed foraging for pollen on a variety of plant species, in particular *Felicia* and catmint and leek. A second generation (n = 8 females) emerged inside both cages in early February.

**CONCLUSIONS AND DISCUSSION**

With average seed yields of well under one gram per flower head, none of the bees tested seemed adequate pollinators of leek. However, in some cases this conclusion may be overly pessimistic, as the yield of male sterile plants is expected to be at most half of that of the fertile plants, which were used as controls in this study. In addition, in each of the cages and tunnels, the set was affected by a range of issues, which are further discussed below

Pollination by *Amegilla* and *Exoneura* gave the lowest yield, in spite of the fact that the synchrony in the presence of the bees and the flowering of the crop was achieved in these trials. In the tunnels, the wet conditions affected the plant development, disease status and the foraging opportunities for the bees. Furthermore, *Exoneura* are rather

small compared to flower size and nectar production of leek (Fig. 4.1), and the nectar and or pollen from a single leek flower could constitute a nearly full load. This could make them less satisfactory pollinators. In addition, the predominant bee used, *E. robusta*, produces a single generation per year (Schwarz 1993). At the time the leek was flowering, the nests would have contained pupae, and therefore not a lot of pollen collection would have been expected. The deployment of *Exoneura* in captivity for pollination purposes is problematic: adults are present year round, which (a) makes it difficult to move nests to locations where the bees are needed; (b) requires continued presence of floral resources.

The lack of success of pollination with *Amegilla* was surprising, as these bees moved well between flowers, despite a strong preference of fertile flowers. The results are a good illustration of the fact that a flower visitor is not automatically a pollinator (Kevan and Baker 1983). The results confirm an earlier pilot study by L. Hannah, who also found good visitation of the fertile plants, but a lack of seed yield (L. Hannah pers. com). However, it remains unclear how far the production in Adelaide was reduced due to disease caused by the unusually high precipitation and the effect of a hard-to control leek pests (thrips and mites).

The low pollination inside the cage, mainly by *Megachile erythropyga* could have been influenced by a combination of two factors. The onset of flowering and the emergence of bees were three weeks apart. This was caused in part by the fact that estimated eclosion from the blocks had been based on what happened in the previous year. However, due to the weather differences between the two years, eclosion was a full three weeks later in the second year than in the first year (Chapter 6).

By the time the bees had eclosed, the nectar had crystallised on many flowers. This could have made nectar collection difficult, if not impossible. Moreover, *Allium* nectar has a very high concentration of potassium, about ten times the concentration of other flora which can inhibit foraging by honeybees (Hagler 1990). Evaporation of nectar could have contributed to highly elevated levels of potassium in the cage, compared to the situation in the tunnels. This can explain the lower frequencies of bees on the leek, and lower yield in the cages compared to the tunnels.

Out of the bees used in this study, the best pollination was achieved by Megachilid bees in the tunnels. Pollination by *Megachile rotundata* and native resin bees caused similar seed yield. However, the yield of male sterile plants was low, at only 20% of fertile production. The reason for this could be that the bees were eclosing a full month after the crop had started flowering, that the high rainfall has affected the set and or visitation, and that the potassium concentration made the flowers unenticing... It should be possible to cover the crops in the tunnel by a sloping (not domed) UV permeable plastic cover that keeps the rain off the crops. Alternatively, a plastic cover could be placed over the biomes. If the latter option is used, care needs to be taken to use UV permeable plastics, as the lack of UV has a large effect on the propensities of bees to forage in enclosures. Furthermore, none of the *Megachile* species successfully reproduced in the enclosures, even though *M. rotundata* collected pollen. Hence, if these bees are to be used for the pollination of leek, a population would have to be sourced from nests maintained elsewhere.

The late eclosion of the bees compared to the flowering was a general problem, and deserves some discussion. A rough estimate of the time of eclosion had been based on the phenology of bees outside in the previous year, which were active from half December onwards. It was therefore thought that placement in the cage would shorten

time to eclosion by one or two weeks. However, the spring of 2009 was very hot, while the spring of 2010 turned out to be extremely cool, which would have delayed development. In support of this, the first resin bees outside were only noted on 15 January 2011, close to a full month later than the previous year. Compared to activities outside, the elevated temperatures in the cage had sped up eclosion by three weeks. If these bees are to be used for pollination of crops in confined areas, a detailed experimental study of the effects of temperature regimes on developmental times, as has been done for *M. rotundata* (Kemp and Bosch 2000) and *Osmia* (Kemp and Bosch 2005) should be performed. This would allow improved synchronicity between bees and plants.

The introduction of *Lasioglossum orbatum* females in the cages had a very low success rate. Nevertheless, these were the only bees that reproduced in the tunnels and cages. The intention was to test the utility of these bees for pollination of leek in the second year, by placing a cage over part of the aggregation. This was not done as the aggregation was lost due to flooding, and no new aggregation was found on the premises.

## **RECOMMENDATIONS**

The study presented here does not give a final answer with respect to useful native bees for the pollination of leek, but excludes *Exoneura* and *Amegilla*, as useful pollinators. It would be worthwhile to repeat the experiments with the *Megachile* species. Synchronicity between emergence of bees and flowering of crops needs to be achieved, by manipulating flowering and/or emergence times, and the plants need to be protected from precipitation using UV permeable plastic roofing that doesn't interfere with bee behaviour. When sugar-water feeders are provided, provision of feedplants is not necessary for these bees, but they should be removed when the crop is in flower to encourage the bees on the crops.

The amenability and suitability of ground-nesting species should be investigated in particular because: (a) Several ground-nesting bees were present on the leek, and hence chose to forage on it; (b) one halictine species (Parker 1982) has proven to be an effective pollinator of *Allium* in the field; (c) Halictine bees are social species which are often more amenable to manipulation (Dukas and Real 1991), as indicated by the fact that this was the only species that reproduced inside the greenhouse; (d) although a ground-nesting bee may be problematic, methods to introduce and maintain *Lasioglossum* in greenhouses have been partially developed in Japan (Miyanaga et al. 1999 Goubara, 2004 #1029), which indicates that there may be possibilities to use these species in captivity.

## **CHAPTER 5: HOW TO INCREASE NATIVE BEE DENSITY ON FARMS**

### **BACKGROUND**

Most native bee populations have a low density and are notably variable in space and time (Roubik 2001 Williams, 2001 #775). Therefore the services provided by a single species are unlikely to be consistent enough to meet the demands of large scale intensive agriculture (Kremen et al. 2004). However, when wild pollinator diversity is enhanced, it is possible to augment the services provided by commercial pollinators by maintaining a diverse community that in synergy provides a more stable service (Kremen et al. 2002a; Klein et al. 2003; Kremen et al. 2004; Kremen 2008 Delaplane & Mayer 2000 Cunningham, 2002 #344).

In a classic study, Krombein (1967) substantially increased bee density and species abundance by trapnesting bees in artificial nests. Furthermore, an increase in nest substrate availability enhanced the abundance of the native bee *Osmia* on blue-berry farms in the US (Stubbs and Drummond 2001). For Australian native bees, shortage of nesting sites could be a limiting factor, but this has not been investigated.

The aim of this part of the project was to undertake some simple measures to increase the presence and abundance of native bees, to evaluate their effects, both on densities of native bees and on the presence of native bees on the crops.

### **MATERIALS AND METHODS**

#### **Nestboxes and locations**

A single nesting box (See Appendix 3 for Figure) was placed alongside the crop at the locations presented in Appendix 1. In 2009/2010 locations 3, 4, 7, 8, and 9 were used.

At location 8, nesting substrate (blocks of untreated pine with 10 cm long holes of 4-7 mm diameter) had been placed during earlier years, and had attracted cavity nesting *Megachile* (resin bees) and *Hylaeus* (masked bees) species of several subgenera

The content of each nest box was as follows:

- (1) At least 8 untreated wooden blocks of approximately 150 by 50 mm, of various origins: rough pine, hard pine, blackwood and eucalypt. Each block had holes of varying diameter ( 4 – 8 mm) drilled along the grain.
- (2) Two Binderboards (supplied by Pollinator Paradise, Idaho, USA) one “*Osmia* board” with 98 holes of 8 mm diameter, and one leafcutter board with 130 holes of 5.5 mm. A paper tube insert was placed in half of the holes of each binderboard.
- (3) Ten small mudbrick blocks with 8 mm entrance holes;
- (4) A bundle of approximately 80 waxed paper drinking straws in pieces of polypipe tubing;
- (5) Approximately 40 stretches of dry dead blackberry stems, approximately 10 mm diameter 200 mm in length;

During the second year of the project, the mud nests (4) and blackberry stems (5) were removed, as they had failed to attract bees. In addition, four additional nesting boxes were placed at location 8, and one at location 3, to increase bee availability for the coming years.

Access of ants to the nest boxes was prevented by Tanglefoot, but this was not always successful during the first year, because some ants used cracks in the wood support pole to get into the nestbox. Therefore, during the second year, a termite guard was placed between the support and the box, which was treated with Tanglefoot on the underside. This was very effective in keeping ants off.

The nestboxes were regularly checked for ants and spiders, which were removed upon detection.

### **Observations**

The use of these nest substrates by native bees was monitored at all locations at every visit (Appendix 1), and data were analysed to investigate preferred substrates and hole sizes. Only occasionally was a nesting bee caught for identification purposes. The presence of parasitoids (Evanoid and chrysidid wasps) was noted, and some were caught and killed. The properties of the nest closures were evaluated against the bee species that were observed to provision cells or to make the closures. On the basis of this, many nests were later assigned as having been closed by bees, as activity in the nestboxes did not completely coincide with the period of fieldwork

### **Harvest**

All nesting blocks were individually marked and collected from the locations on 25 March 2010, and 15 April 2011. The nest entrances were examined and classified, and the blocks were stored in a shaded area in individual cloth bags, to protect them from any insect pests, and to allow brood development.

The binder boards and some of the straws were opened on 1/9/2010, and some nests were opened on 4/8/2011 to investigate the contents, development, breeding success and to monitor parasitisation rates. Some of the brood were placed in incubators, monitored through to adulthood and identified.

During the second year of the project, several of the nesting boards were placed in tunnels and cages. The parasites emerging from these nests were caught, and the timing of their capture was documented.

## **RESULTS**

### **Total nests provisioned**

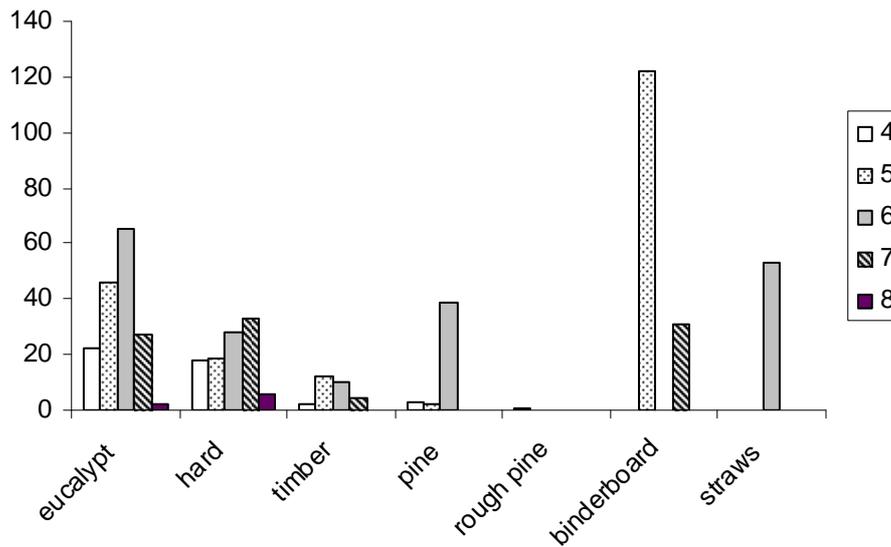
A total of 552 nesting holes were seen to be in use, or later found to be closed by bees, 86 in the first year( 7 nesting boxes at 5 farms), and 466 in the second year(10 nesting boxes at 6 locations). Of these nests, 504 were later found with various nest closures (Fig 5.2).

The bee that had been provisioning these nests had been observed in 147 cases. It was therefore investigated whether the nest closure is a reliable indication of the bee species involved. This can be important when selecting the species to trial for pollination experiments.

### **Nesting substrates**

The uptake of nesting substrates by bees strongly depended on the type of wood, the diameter of the nesting holes and the location.

Eucalypt was taken up more than any other type of wood, and after that, the coarser the wood, the less attractive (Fig 5.1). The binderboards are made of Western Cedar and are very smooth inside due to a poly-urethane coating.



**Figure 5.1.** The type of wood and the diameter of the nesting holes number of nests taken up during the project. Apart from rough pine, which was only used in the first year, approximately equal numbers of holes of each size and substrate were offered throughout the project.

**Can one recognise the bee by its nest closure?**

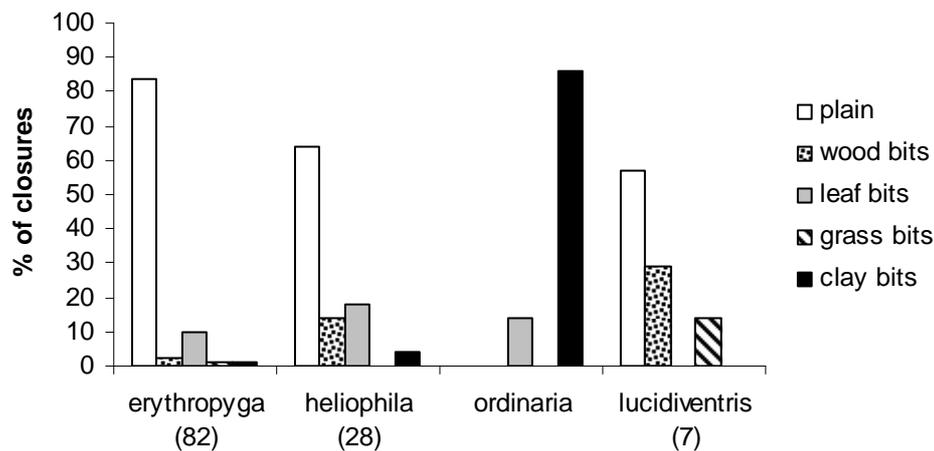
Unless the nestboxes are frequently observed, the bees that provisioned the nest may not have been seen. As there can be useful and less useful bees for crop pollination, it would be helpful if nest closures could be used to select the right species for trials and propagation using the nest closures. Therefore, the nest closures were classified. Seven types of closures were recognised (Fig 5.2).



**Figure 5.2.** Nest closures of several bee species that nest in trap nests. Top row, from left to right: Fibers (*Hyleoides concinna*), two types of cellophane (*Hylaeus spp*) leaves:leafcutter bees (*Megachile*), Macerated leaf material:*Megachile chrysopyga*;

Bottom: Various resin bee closures with shiny or dull resin, adornments of clay, wood, or pieces of grass.

For the resin bees (n=131 nests for which the species was seen), it was investigated whether the different species could be identified from the size of holes they used, combined with the type of adornment and shininess of the closures. However, it was soon established that plain resin closures can become dull with age, so that aspect was left out of consideration. The distribution of type cell closures over the different bee species was significantly different (Chi square = 117,  $p < 0,001$ ; Fig 5.3).



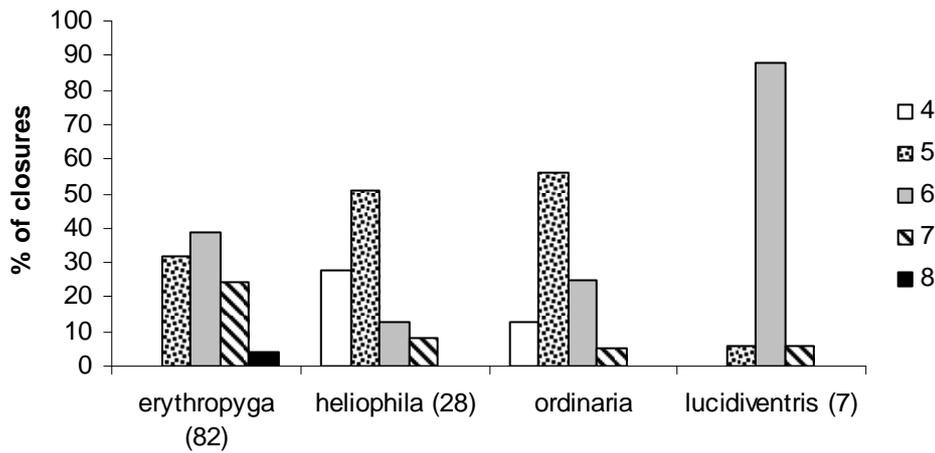
**Fig 5.3.** The percentage of nest closure adornments of the resin bees in the study. Between brackets, the numbers of bees observed.

The main differences were as follows: *M. erythropgya* constructed nearly only unadorned closures. In most of these, the resin was not shiny from the start. *M. heliophila* also produced mainly unadorned closures, but adorned some nests with bits of plants (not grass). It was noted that in some of these cases the adornments disappeared over time. Thus, these bees may adorn more nests than observed here. The *M. ordinaria* species was the only species that predominantly used clay bits. *M. lucidiventris* used grass.

With regard to nest diameters, there were differences between the species as well (Chi square = 46.3,  $df = 12$ ; Fig 5.4), with the smaller bees (*M. heliophila* and *M. ordinaria*) more often using nest substrates with smaller diameters than the two larger species. *M. lucidiventris* seems to prefer 6mm holes

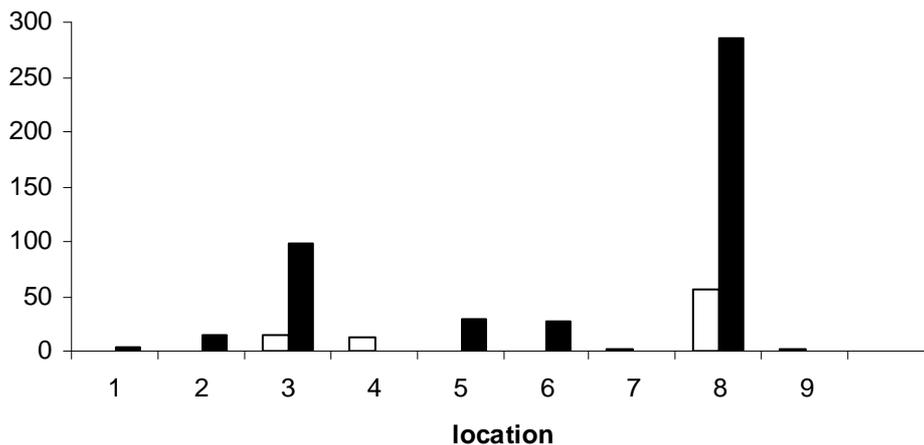
Thus, nests closures can be easily classified at a higher taxon level (i.e. genus/subgenus), as hyleaine species, and leafcutter bees (*Megachile* (Euticharea) are easily recognised. For the resin bee subgenera or species, the nest closures do not provide completely reliable information. Therefore, the closed nests of resin bees for which the provisioning bee had not been observed (mainly due to provisioning after the flowering of the crops was over), were classified into “small resin bees” (*M. heliophila* or *M. ordinaria*), and “large resin bees” (*M. erythropgya* and *M. lucidiventris*), according to the following criteria:

- at farms where only a single species (*M. erythropgya*, location 4 and 6) was observed, all closed nests were classified as being produced by that species.
- in the other cases, nests of 4 and 5 mm diameter were classified as “small resin bees”, and the larger diameters as being constructed by “large resin bees”.



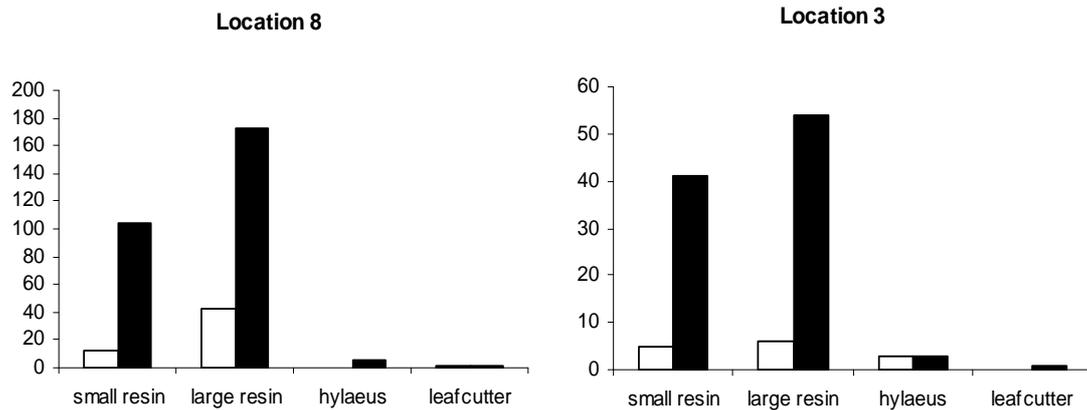
**Fig 5.4.** The diameter of nests taken up by the resin bees in this study, expressed as a percentage of the nests observed per species. Between brackets, the numbers of bees observed.

Using this classification, Figure 5.5 shows the number of bee nests provisioned at the different locations at different years.



**Figure 5.5.** The number of bee nests provisioned and closed at different locations in the first year (white) and the second year (black) of the project. Note that location 8 had four nestboxes each year, while location 3 had one nestbox in the first and two in the second year. All other locations had a single nestbox.

The numbers of nests were greatly increased at the two locations that had their nest boxes for a second year (location 3 had seven times more nests in the second year, location 8, 5 times more; Fig 5.5), presumably by bees emerging from the blocks that were provisioned the previous year, as part of these were placed back on the farms. These increases were due to the increase in resin bees (Fig 5.6).



**Fig 5.6.** The sum of types of nest closures and bees observed at two locations in the first (white) and the second (black) year. Location 8 had five boxes, location 3 had one box in the first, two in the second year.

### Further observations

At location 8, two nest boxes were not well protected from ants during the first year of the study. Ants started to nest in the nesting blocks and no bees were observed in these blocks until the ants had been removed and the nestboxes protected. From then on, the nest boxes started to be used. This demonstrates that ant-protection is crucial. We protected the nests with Tanglefoot. Unfortunately, in the second year numerous female *M. erythropyga* were observed to collect Tanglefoot as if it was resin. Nest openings revealed that cell closures had been made with Tanglefoot. Therefore, to keep resin bees, the ant protection must be modified so there is either no Tanglefoot involved, or it cannot be reached.

In the first year, bees were observed robbing resin from each other's (or their own) closed nests. This indicates that resin is in short supply. An attempt to solve this by supplying cerumen from *Trigona* nests was unsuccessful, as honeybees avidly collected this material. Placing the nestboxes close to an old stand of resin producing trees (in particular Eucalypt or Acacia) may help in acquiring and maintaining resin bees.

Two undescribed species of parasitic wasps (Evanoidea: Gasteruptiidae, genus *Gasteruption*, J. Jennings pers. com.) were observed flying at all nestboxes, and reached particularly high numbers in the second year.

### Reproductive success and brood development

In the first year, nests were opened on the first of September. In the 13 straws that had been provisioned by *M. erythropyga*, cells and cocoons were easily identifiable from the outside, by looking through the straws. These straws contained 64 cells (3-9 per nest, 4.85 cells on average).

Two straws were opened. These nests had basal plug made of resin, resin cell closures and a double resin plug at the entrance. In some nests the space between the two plugs was filled up with grass. The first nests contained 4 soft cocoons, which each contained a prepupa. They were reared through to adulthood in an incubator at 20 C, and turned out to be 2 female and 2 male *M. erythropyga*. The female were from cells in the back of the nest. The other nest was opened because it was the only nests in which the prepupae had no cocoons. This nest contained 4 prepupae, one of which was very large and two larvae, which were very small. In 4 of the cells, there was pollen left. Rearing the brood yielded one male *M. erythropyga*, and two Evanoid wasps (*Gasteruption* species). The small larvae and one prepupa died. The morphology and activity levels of the wasp larvae had been different from that of the bees.

Furthermore, a small binderboard was opened. It contained seven nests of *M. heliophila* with 25 live brood cells and three nests of *M. ordinaria* with 20 live brood cells. All brood cells had cocoons, and there were no obvious differences that would allow a distinction between parasitised and unparasitised brood. It was difficult to remove the cocoons from the nests, and keep them whole, as they are soft casings.

In the second year, two small binderboards were opened on the 4<sup>th</sup> of August. These had 50 closed nests with on average  $2.25 \pm 0.29$  cells. However, only 23 nests contained live brood. In total, there were 61 live larvae. The live brood is currently being reared through in an incubator, and it is estimated that half are parasitic wasps. Furthermore, in 14 nests, Tanglefoot had been used to make cell closures. It seems unlikely that any brood will eclose from such nests.

## **DISCUSSION**

Large numbers of wood nests were taken up by resin bees. A preference was for the hardest wood, but it is likely that this was due to the fact that this had the smoothest interior.

The diameter of the nests taken up differed between species, and therefore the nest substrate can be used to partially manipulate the size and the species of bees on the farm.

The data presented here clearly demonstrate that large increases in bee numbers can be achieved by the provision of adequate nest substrate at horticultural farms in Australia. This observation is very important for all horticultural industries that depend on pollination for their yield. The possibilities for increasing both leafcutter and resin bees, and their utility for crop pollination needs to be further explored.

## **RECOMMENDATIONS**

If Tanglefoot is used protect nests from ants, it should not be accessible for the resin bees, as they will use it to construct cell and nest closures. Thus alternative methods to prevent ants coming into the nestboxes should be developed. Furthermore, binderboards, or similar nesting substrate that can be opened to view the brood, should be used. This will allow control of parasites and cleaning of used nests, as it is very difficult to clean the resin off the binderboards. In addition, the nesting holes should be fitted with an insert. The paper inserts need to be made out of waxed paper, to allow some ventilation, and to prevent any nectar, that is deposited in the cells, from soaking into the paper. This would foul the brood and attract fungus (J. King, pers. com). Furthermore, pre-slitting the waxed paper tubes could increase the ease with which the soft cocoons can be removed.

## CHAPTER 6: THE LIFE CYCLE OF SUITABLE POLLINATORS IN RELATION TO CROP PHENOLOGY

### BACKGROUND

The timing of the presence of suitable native bee pollinators crucially influences the management requirements. Such management actions can involve, for example, the provision of forage for earlier generations, or, in particular for non-ground-nesting bees, influencing the phenology to coincide with crop flowering. To investigate potential matters that are important in the management of the most common native bees on the crops, the phenology of these species was analysed relative to the flowering of the crops.

### MATERIAL AND METHODS

The synchrony between the flowering of the crop and the phenology of the bees was investigated. This was done using all dates that insects were collected during visits at Musk.

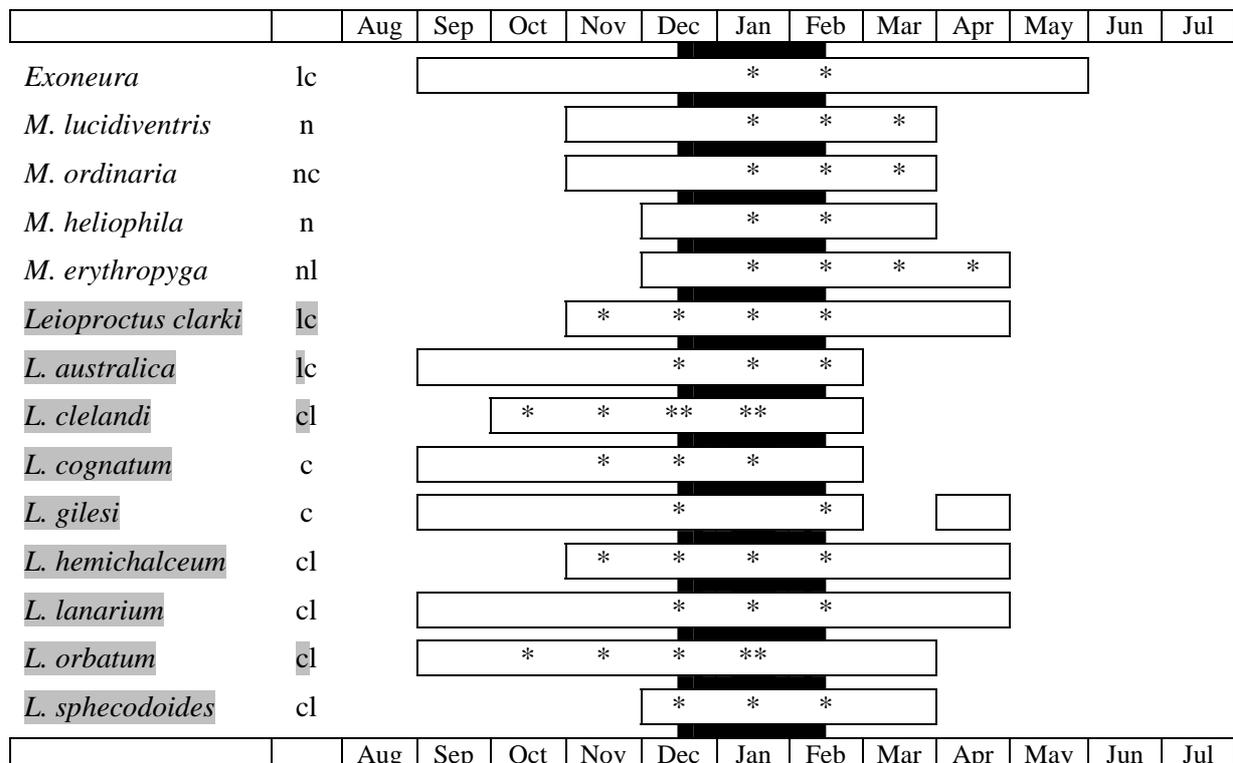
The visits made during the flowering period of the crops are given in Appendix 1, Table A1.1. However, many visits were made to location 8 outside the flowering period of the crop (Appendix 1; Table A1.2), and, weather permitting, the flowering plants were checked for the presence of native bees during each of these visits. Furthermore, staff of Rijk Zwaan collected bees and noted activity at location 8 on an ongoing basis. Despite this, sampling effort was clearly not consistent throughout the year, as none of the other locations were visited outside crop flowering periods. Therefore, for each species, the phenology was also deduced from the occurrence record list in the Atlas of Living Australia (<http://bie.ala.org.au/>), and from a database from the Museum of Victoria (<http://flyaqis.mov.vic.gov.au/bees/>). Because the area around Musk is relatively cool due to its high elevation, it is likely that all species are a bit later than the on-line databases would indicate, in particular if the species occur in any other states than Victoria. Therefore, only the records of specimens collected in Victoria were used. In addition, the timing of male eclosion was used to investigate the lifecycle, as this may give an indication whether the species have more than one generation.

### RESULTS

Many ground-nesting species are present from November until the beginning of February (Fig. 6.1). For *L. clelandi*, the main species found on carrot, males were collected during our study at the end of December and in January ( $n = 11$ ). This is at the end of the activity period for this species (Table 6.1), indicating that there is a single generation. Thus, the main provisioning of the nests occurs in November. This conclusion is also supported by the data from the Victorian museum (covering 1183 specimens), which show a single high peak of activity in November.

The other frequently observed species for which males were caught, *L. orbatum*, shows activity from September till March (Victorian Museum). A mass eclosion of females at Musk on 20/10/2009 indicates that these bees are indeed a bit earlier than *L. clelandi*. Males were caught in January ( $n = 10$ ), and therefore it seems that this species also has its peak activity in November.

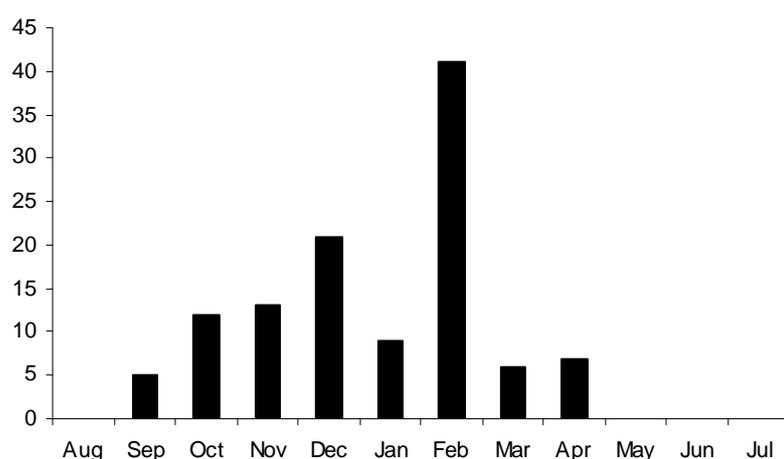
The literature indicates similar patterns for *L. cognatum*, *L. lanarium* and *L. gilesi*. Our data are not conclusive for these species, as they occurred mainly on farms that were sampled only during flowering of the crop.



**Figure 6.1** The phenology of the most important native bee visitors of leek and carrot, in relation to the flowering phenology of the crops. Starting with August (Aug), displayed are: the months for which the species was observed in this study (\*,\*\* if males have also been observed), and has been recorded in Victoria (horizontal time bars). Flowering time of carrot and leek during this study is indicated by the black bars. Highlighted species names indicate ground-nesting. The dominant species seen on leek (l) and carrot (c) are highlighted. n = in nestboxes, l = seen or caught on leek, c = seen or caught on carrot.

The data show a different pattern for *Lipotriches australica*. This primitively social species can have an extended period of reproduction and overlapping generations (Vogel and Kukuk 1994; Kukuk 1996), as indicated by the protracted activity patterns (Fig 6.2).

Both the literature and our data indicate that *Lasioglossum hemichalceum*, *L. sphecodoides* and *Leioproctus clarkii* become active for the first time in November. Therefore, in particular the phenology of *Leioproctus clarkii*, a species frequently observed on both crops, seems to coincide well with crop flowering.

Phenology of *Lipotriches australica*

**Fig 6.2.** The phenology of *Lipotriches australica* in Victoria (Museum of Victoria)

## DISCUSSION

The flowering of the crops clearly does not cover the whole period of activity of the bees. In particular, most of the ground-nesting species that visit the crops are often active in the weeks before the crop is in flower.

Furthermore, most megachilid species that used the nest substrate only become active when flowering of the crops is well underway. This would make them less apt natural pollinators. However, it should be noted that the development in such nests can be protracted to suit crop phenology as has been done for other species of hollow nesting bees (e.g. Bosch, 2000 #728).

## RECOMMENDATIONS

Further improvement of the densities of native ground-nesting bees on farms should include provision of flowering plants when the crops are not in flower. This is particularly important for both halictine bees and *Leioproctus*, as the bees in the carrot and leek are a second generation. These measures can include planting windbreaks with flowering native bushes and trees, or a canola crop, which is harvested when the carrot comes into flower (see Appendix 3 for further information).

It is important to realise that treatment with insecticides in these crops will diminish the number of pollinators in the successive crops.

## **CHAPTER 7: TECHNOLOGY TRANSFER**

A leaflet (Appendix 3) has been produced explaining what can be done to enhance native bees on farms. This leaflet has so far been presented at a growers' meeting at Rijk Zwaan (5 August 2011, 10 participants), will be distributed at a workshop organised by the Adelaide and Mount Lofty Ranges Natural Resources Management Board (21<sup>st</sup> September, Virginia), and at a growers' presentation organised by the York Peninsula Alkaline Soils Group (date to be announced).

A leaflet (Appendix 4) has been produced about the production, placement and management of native bee nesting substrate. This has been distributed among workers at Rijk Zwaan Australia (15 March 2011, 20 participants), at a meeting of the Native Plant Society SA (24 August 2011, 50 participants), at the book launch of "Native bees, a glimpse into their world", by S. Richards (20 August 2011, 40 participants), and at a meeting of the South Australian Beekeepers Society (8 July 2011, 50 participants).

At each of these occasions, a presentation has been given by K. Hogendoorn about the importance of native bees as crop pollinators.

A workshop for Tasmanian plant breeders (Bejo and SPS), to present the outcomes of this project and the project lead by Cameron Spurr (Seedpurity) with respect to pollination and pest control in leek and carrot is in the planning phase.

A company "Pollinators" will be starting later this year to produce native bee nesting boards for the Australian market.

## CHAPTER 7: RECOMMENDATIONS

Recommendations have been formulated at the end of each Chapter. Here, the conclusions and recommendations will be briefly restated and evaluated in the light of the project aims.

These aims were:

### 1. Identify possible pollinators of leek and carrot in hybrid seed production.

The crops were mainly visited by ground-nesting bees: carrot by *Lasioglossum* species and *Leioproctus* leek by *Leioproctus* and *Lipotriches* (Chapter 1). The presence of other crop visitors is highly variable between years and farms, and unlike the other visitors, honeybees have a strong preference for fertile plants (Chapter 2). This variation can be partly explained by factors related to the weather (Chapter 2) and partly by spraying regimes (Chapter 3). Out of six bee species tested, three *Megachile* species showed the most promise for the pollination of leek in enclosures, while *Amegilla* and *Exoneura* showed no promise (Chapter 4). However, yields were quite low. *Lasioglossum* has been successfully introduced into a greenhouse, and a low percentage of individuals reproduced (Chapter 4).

Methods for the maintenance of ground-nesting bees have been suggested (Chapter 1, 3, and Appendix 3). Methods to enhance resin bees have been developed. A longer term study is needed to validate and improve these methods. The ability of resin bees and *M. rotundata* to pollinate leek in captivity should be further investigated.

### 2. Investigate possibilities to increase local densities of native bees.

The provision of nesting blocks in our area of study, in particular over several years, can lead to large increases in resin bees (Chapter 5). Ground-nesting bees can be stimulated using measures suggested in the leaflet “Farming for native bees” that was developed during the project (Appendix 3). The leaflet suggests supplying flowering plants when the crop is not in flower, exercising diligence with spraying, and providing and maintaining nesting opportunities by creating no-till areas of open compacted soil.

The construction and placement of nest substrates are explained in leaflet “How to make nesting blocks for native bees” that was developed during this project (Appendix 4). It contains advice about the type of wood, placement and protection of nest substrates.

### 3. Investigate life cycle and main brood parasites of suitable pollinators

Many of the ground-nesting bees are often present before the onset of crop flowering, while the Megachilid bees were late relative to crop flowering (Chapter 6).

The “Farming for native bees” leaflet (Appendix 3) suggests methods to enhance the presence of bees on the crops.

When using artificial nesting substrate, the frequency of parasitisation can build up. (Chapter 5). If these bees are reared for crop pollination purposes, the parasite numbers need to be kept under control by the opening of nests and removal of infested brood in the late winter months. Methods that allow this are suggested in Chapter 5.

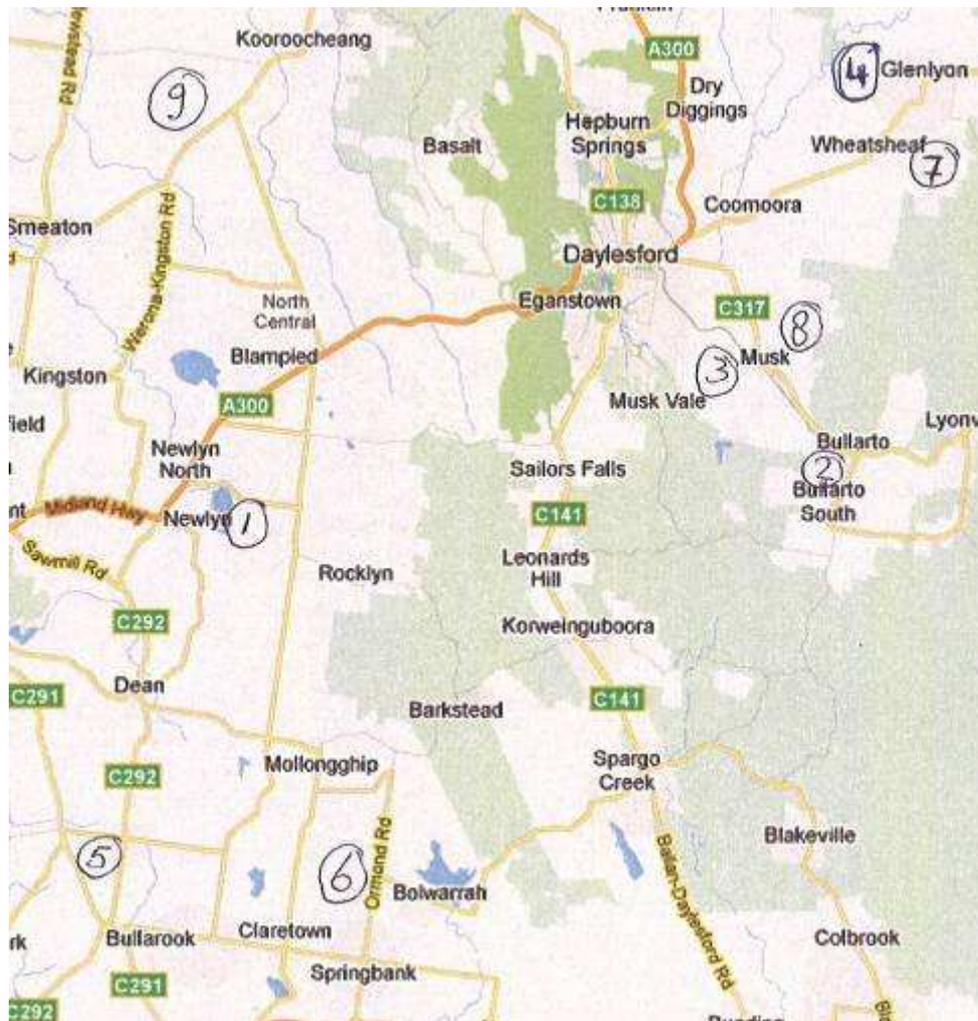
## REFERENCES

- Abrol D (1997) Impact of insect pollination on carrot seed production. *Insect Environment* 3:61
- Aizen MA, Garibaldi LA, Cunningham SA, Klein AM (2009) How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. In, vol 103, pp 1579-1588
- Allen-Wardell G, Bernhard P, Bitner R, Burquez A, Buchmann S, Cane J, Cox PA, Dalton V, Feinsinger P, Ingram M, Inouye D, Jones CE, Kennedy K, Kevan P, Koopowitz H, Medellin R, Medellin-Morales S, Nabhan GP, Pavlik B, Tepedino V, Torchio P, Walker S (1998) The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology* 12:8-17
- Batley M, Hogendoorn K (2009) Diversity and conservation status of native Australian bees. *Apidologie* 40:347-354
- Batra SWT (2001) Coaxing pollen bees to work for us. In: Stubbs CS, Drummond FA (eds) *Bees and crop pollination: Crisis, crossroads, conservation*. Entomological Society of America, Lanham, MD
- Bohart GE, Nye WP (1960) Insect pollinators of carrots in Utah. In: *Agricultural Experimental Station Bulletin 49*. Utah State University
- Bosch J (2005) The contribution of solitary bees to crop pollination: From ecosystem service to pollinator management. In: Guerra-Sanz J, Roldan A, Mena Granero A (eds) *First short course in pollination of horticulture plants*. CIFA La Mojonera, Almeria, pp 151 - 165
- Bosch J, Kemp W (2001) How to manage the blue orchard bee as an orchard pollinator. *Sustainable Agriculture Network*, Beltsville MD
- Bosch J, Kemp WP (2002) Developing and establishing bee species as crop pollinators: the example of *Osmia* spp. (Hymenoptera: Megachilidae) and fruit trees. *Bulletin of Entomological Research* 92:3-16
- Cane J (2008) A native ground-nesting bee (*Nomia melanderi*) sustainably managed to pollinate alfalfa across an intensively agricultural landscape. *Apidologie* 39:315-323
- Cook DC, Thomas MB, Cunningham SA, Anderson DL, De Barro PJ (2007) Predicting the economic impact of an invasive species on an ecosystem service. *Ecological Applications* 17:1832-1840
- Cunningham SA, Heard T, FitzGibbon F (2002) The future of pollinators for Australian agriculture. *Australian Journal of Agricultural Research* 53:893-900
- Davidson MM, Butler RC, Howlett BG (2010) *Apis mellifera* and *Megachile rotundata*: a comparison of behaviour and seed yield in a hybrid carrot seed crop. *New Zealand Journal of Crop and Horticultural Science* 38:113-117
- Delaplane KS, Mayer DF (2000) *Crop pollination by bees*. CABI Publishing, New York
- Dukas R, Real LA (1991) Learning foraging tasks by bees: a comparison between social and solitary species. *Animal Behaviour* 42:269-276
- Free JB (1993) *Insect pollination of crops*, 2nd edn. Academic Press, London, UK
- Freitas BM, Oliveira Filho JHd (2003) Ninhos racionais para mamangava (*Xylocopa frontalis*) na polinização do maracujá-amarelo (*Passiflora edulis*), vol 33. Branco Santander, Fortaleza, Brasil
- Gaffney A, Allen GR, Brown PH (2011) Insect visitation to flowering hybrid carrot seed crops. *New Zealand Journal of Crop and Horticultural Science* 39:79-93
- Gallai N, Salles J-M, Settele J, Vaissière BE (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68:810-821

- Hagler J (1990) Honey bee (*Apis mellifera* L) response to simulated onion nectars containing variable sugar and potassium concentrations. *Apidologie* 21:115-121
- Heard TA (1999) The role of stingless bees in crop pollination. In, vol 44, pp 183-206
- Hogendoorn K, Coventry S, Keller MA (2007) Foraging behaviour of a blue banded bee, *Amegilla chlorocyanea* in greenhouses: implications for use as tomato pollinators. *Apidologie* 38:86-92
- Howlett BG, Walker MK, Newstrom-Lloyd LE, Donovan BJ, Teulon DAJ (2009) Window traps and direct observations record similar arthropod flower visitor assemblages in two mass flowering crops. *Journal of Applied Entomology* 133:553-564
- Kemp WP, Bosch J (2000) Development and emergence of the alfalfa pollinator *Megachile rotundata* (Hymenoptera: Megachilidae). *Annals of the Entomological Society of America* 93:904-911
- Kemp WP, Bosch J (2005) Effect of temperature on *Osmia lignaria* (Hymenoptera : Megachilidae) prepupa-adult development, survival, and emergence. *Journal of Economic Entomology* 98:1917-1923
- Keogh R, Robinson A, Mullins I (2010) Pollination aware - The real value of pollination in Australia. In: RIRDC (ed) Report 10-081. RIRDC, Canberra
- Kevan PG, Baker HG (1983) Insects as flower visitors and pollinators. In, vol 28, pp 407-453
- Klein AM, Steffan-Dewenter I, Tschardt T (2003) Fruit set of highland coffee increases with the diversity of pollinating bees. *Proceedings of the Royal Society of London Series B-Biological Sciences* 270:955-961
- Klein AM, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tschardt T (2007) Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B-Biological Sciences* 274:303-313
- Kremen C (2008) Crop pollination services from wild bees. In: James R, Pitts-Singer TL (eds) *Bee pollination in agricultural ecosystems*. Oxford University Press, Oxford, pp 10-26
- Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R, Packer L, Potts SG, Roulston T, Steffan-Dewenter I, Vazquez DP, Winfree R, Adams L, Crone EE, Greenleaf SS, Keitt TH, Klein AM, Regetz J, Ricketts TH (2007) Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters* 10:299-314
- Kremen C, Williams NM, Bugg RL, Fay JP, Thorp RW (2004) The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecology Letters* 7:1109-1119
- Kremen C, Williams NM, Thorp RW (2002a) Crop pollination from native bees at risk from agricultural infestation. *Proceedings of the National Academy of Sciences* 99:16812-16816
- Kremen C, Williams NM, Thorp RW (2002b) Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences of the United States of America* 99:16812-16816
- Krombein KV (1967) *Trap-nesting wasps and bees: life histories, nests, and associates*. Smithsonian Press, Washington
- Kukuk PF (1996) Male Dimorphism in *Lasioglossum (Chilalictus) hemichalceum*: The Role of Larval Nutrition. *Journal of the Kansas Entomological Society* 69:147-157

- Lamborn E, Ollerton J (2000) Experimental assessment of the functional morphology of inflorescences of *Daucus carota* (Apiaceae): testing the 'fly catcher effect'. *Functional Ecology* 14:445-454
- Miyanaga R, Maeta Y, Sakagami SF (1999) Geographical variation of sociality and size-linked color patterns in *Lasioglossum (Evylaeus) apristum* (Vachal) in Japan (Hymenoptera, Halictidae). *Insectes Sociaux* 46:224-232
- Parker FD (1982) Efficiency of bees in pollinating onion flowers. *Journal of the Kansas Entomological Society* 55:171-176
- Pérez-Bañón C, Petanidou T, Marcos-García A (2007) Pollination in small islands by occasional visitors: the case of *Daucus carota* subsp. *commutatus* (Apiaceae) in the Columbretes archipelago, Spain. *Plant Ecology* 192:133-151
- Roubik DW (2001) Ups and downs in pollinator populations: When is there a decline? *Conservation Ecology* 5
- Schittenhelm S, Giadis T, Rao VR (1997) Efficiency of various insects in germplasm regeneration of carrot, onion and turnip rape accessions. *Plant Breeding* 116:369-375
- Strickler K, Cane J (2004) For nonnative crops, whence pollinators of the future? Thomas Say Foundation, Lanham, M.D.
- Stubbs CS, Drummond FA (2001) Bees and Crop Pollination- Crisis, Crossroads, Conservation. Thomas Say Publications in Entomology, Lanham, M.D.
- Velthuis HHW, van Doorn A (2006) A century of advances in bumblebee domestication and the economic, and environmental aspects of its commercialization for pollination. *Apidologie* 37:421 - 451
- Vogel ME, Kukuk PF (1994) Individual foraging effort in the facultatively social halictid bee, *Nomia (Austronomia) australica* (Smith). *Journal of the Kansas Entomological Society* 67:225-235
- Westerkamp C, Gottsberger G (2000) Diversity pays in crop pollination. *Crop Science* 40:1209-1222
- Williams IH, Free JB (1974) Pollination of onion (*Allium cepa* L.) to produce hybrid seed. *Journal of Applied Ecology* 11:409-417
- Winfree R, Kremen C (2009) Are ecosystem services stabilized by differences among species? A test using crop pollination. *Proceedings of the Royal Society B-Biological Sciences* 276:229-237
- Winfree R, Williams NM, Dushoff J, Kremen C (2007) Native bees provide insurance against ongoing honey bee losses. *Ecology Letters* 10:1105-1113
- Winfree R, Williams NM, Gaines H, Ascher JS, Kremen C (2008) Wild bee pollinators provide the majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA. *Journal of Applied Ecology* 45:793-802

## APPENDIX 1: LOCATION OF FARMS, TIME OF VISITS, TYPES OF CROPS



*Figure A1.1 Map of locations of the paddocks visited during this project.*

**Table A1.1** Location and timing of visits for crop scans and trapping

Year	Period	crops	locations
2009/10	30/11 – 4/12	carrot	8,9
		leek	8,9
	20/12 – 22/12	carrot	3,4,7,8,9
		leek	3,8,9
2010/11	14/1 – 17/1	carrot	3,4,7,8,9
		leek	3,8,9
	28/12-31/12	carrot	1,2,5,6,8,9
		leek	not yet flowering
	15/1-17/1	carrot	1,2,5,6,8,9
		leek	3,9
	2/2 – 4/2	carrot	1,2,5,6,8,9
		leek	3,9
	8/2-10/2	carrot	2,8
		leek	3

**Table A1.2.** Dates of all visits and checks for the presence of native bees at Musk

	2009	2010	2011
Jan		14 - 17	17 – 19, 31– 4 Feb
Feb		1 – 4, 10 - 15	8 – 11, 23 - 25
Mar		24 - 28	
Apr		23 - 26	14 - 17
May			
Jun			
Jul			
Aug			2 - 5
Sep	8 - 11	1 - 3	
Oct	19 - 23	20 -22	
Nov	30 – 3Dec	16 - 19	
Dec	20 – 23, 28 – 2 Jan	7 – 11, 20 – 23, 28 – 1 Jan	

## APPENDIX 2: SPECIES COLLECTED AND SEEN

Table A2.1. Number of bee specimens collected and seen on crops per species per location

subfamily	genus	species	location										Total	
			1	2	3	4	5	6	7	8	9	10		
Anthophorini	Amegilla	chlorocyanea	1	0	0	1	0	0	0	0	0	0	0	2
Euryglossini	Euhesma	species 1	0	1	0	0	0	0	0	0	2	0	0	3
Euryglossini	Euhesma	species 1	0	0	0	0	0	0	0	0	2	0	0	2
Hylaeini	Euryglossa	species 1	0	1	0	0	0	0	0	0	0	0	0	1
Hylaeini	Hylaeus	species 2	0	0	0	0	1	0	0	0	0	0	0	1
Paracolletini	Paracolletes	species 1	0	1	0	0	0	0	0	0	0	0	0	1
Hylaeini	Amphylaeus	morosus	0	0	0	0	0	0	0	0	1	0	0	1
Hylaeini	Hyleoides	concinna	0	0	0	0	0	0	0	0	1	0	0	1
Paracolletini	Leioproctus	clarki	0	5	9	6	2	2	2	12	8	0	0	46
Halictini	Lipotriches	australica	0	1	0	0	0	0	1	3	12	0	0	17
Halictini	<i>Lasioglossum</i>	clelandi	33	36	21	13	71	33	3	25	5	0	0	240
Halictini	<i>Lasioglossum</i>	cognatum	32	1	6	1	5	11	0	0	0	0	0	56
Halictini	<i>Lasioglossum</i>	gilesi	0	42	20	0	0	0	0	5	0	0	0	67
Halictini	<i>Lasioglossum</i>	hapsidum	0	0	0	1	0	0	0	0	0	0	0	1
Halictini	<i>Lasioglossum</i>	hemichalceum	1	0	2	1	0	1	1	7	7	0	0	20
Halictini	<i>Lasioglossum</i>	lanarium	8	1	8	2	2	0	1	0	6	0	0	28
Halictini	<i>Lasioglossum</i>	macrops	0	0	0	0	0	0	0	1	0	0	0	1
Halictini	<i>Lasioglossum</i>	mesembryanthemi	0	0	1	0	0	0	0	2	0	0	0	3
Halictini	<i>Lasioglossum</i>	orbatum	1	0	1	1	0	1	0	29	0	0	0	33
Halictini	<i>Lasioglossum</i>	pachycephalum	0	0	0	0	1	0	0	0	0	0	0	1
Halictini	<i>Lasioglossum</i>	pulvitectum	0	0	1	0	0	0	0	0	0	0	0	1
Halictini	<i>Lasioglossum</i>	sculpturatum	0	0	0	0	0	0	0	3	0	0	0	3
Halictini	<i>Lasioglossum</i>	speculatum	0	0	2	0	0	0	0	0	0	0	0	2
Halictini	<i>Lasioglossum</i>	punctatum	0	0	0	0	1	0	0	1	0	0	0	2
Halictini	<i>Lasioglossum</i>	spec	0	0	0	0	0	0	0	1	0	0	0	1
Halictini	<i>Lasioglossum</i>	sphecooides	0	1	1	3	0	2	1	3	1	0	0	12
Halictini	<i>Lasioglossum</i>	hiltacum	0	2	1	1	0	0	0	1	0	0	0	5
Megachilini	<i>Megachile</i>	chrysopyga	0	0	0	1	0	0	0	1	0	0	0	2
Megachilini	<i>Megachile</i>	erythropyga	0	0	1	0	0	0	0	4	0	0	0	5
Megachilini	<i>Megachile</i>	lucidiventre	0	0	1	0	0	0	0	0	0	0	0	1
Megachilini	<i>Megachile</i>	canifrons	0	0	1	0	0	0	0	1	0	0	0	2
Megachilini	<i>Megachile</i>	heliophila	1	0	1	0	0	0	0	4	0	0	0	6
Megachilini	<i>Megachile</i>	spec	0	2	1	0	0	0	0	3	0	0	0	6
Megachilini	<i>Megachile</i>	ordinaria	0	0	0	0	0	0	0	1	0	0	0	1
Allodapini	Exoneura	nigrescens	0	0	0	0	0	0	0	1	0	0	0	1
Allodapini	Exoneura	robusta	0	4	0	0	0	0	0	0	0	2	0	6
total number of specimens			77	98	78	31	83	50	9	114	39	2	0	581

## APPENDIX 3. LEAFLET: FARMING FOR NATIVE BEES

This leaflet goes over two pages. Print full sized, on A4, two-sided. Folds in threes



### Farming for native bees

#### More ways to promote native bees:

**Minimize tillage.** Ground-nesting bees overwinter in their nest, which are often in the crop. To protect their nests, turn over soil only where you need to.

**Allow some crops to bolt.** This gives bees additional food sources

**Plant windbreaks.** Use a variety of native flowering plants and shrubs.



**Take Care with Insecticides.** Use the ones that are least harmful to bees. Spray on calm, dry evenings, soon after dark when bees are not active. Prevent drift, even when the crop is not in flower, as this may kill pollinators visiting nearby flowers.

**Create patches of bare soil.** Do not cover all soil with grass, mulch, or weed mat, but create some open areas for ground-nesting bees.



Furrow bee on Canola (photo: M. Edwards). These bees often nest in the crop, and pollinate a large range of plants

**2. Protect flowering plants and nest sites.** Once you know where native bees are living and foraging, do what you can to protect these resources from disturbance and pesticides.

**3. Provide food and shelter.** Simple measures to increase the number of native bees on your farm are:

- leave some bare soil for nesting;
- do not remove all weeds;
- add a variety of native flowers along field edges;
- provide nesting opportunities in wood: for example in old eucalypt fence posts and dead wood; drill tunnels of between 4 and 8 mm wide and ~120 mm long to encourage nesting in untreated wood.



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This project is supported by



## NATIVE BEES AS CROP POLLINATORS

In addition to the introduced honey bee, Australian native bees are valuable crop pollinators. Our 1600 described species take care of 10% or more of our crop pollination needs.

Some of the crops that rely on pollinators for the production of fruit or seed are: almond, apple, asparagus, avocado, beans, beet, all berries, cabbage, carrot, cherry, cotton, kiwi, leek, macadamia, melons, onion, passionfruit, peach, pear, pumpkin tomato, strawberry, and sunflower.

Maintaining and improving free pollination services by native bees is important, as honeybees are under threat from pests and diseases, such as the Varroa mite and small hive beetle. Therefore, we should not rely on a single species for the pollination of our crops.



Blue-banded bees are excellent pollinators of tomatoes and melons



Native resin bee on a nesting block

### What do native bees need?

To enhance native bees on the farm, we need to understand their requirements. Native bees need:

**Food.** Bees eat only pollen and nectar. They rely on an abundance and variety of flowers and need blooming plants *throughout* the growing season. Native plant species are particularly valuable.

**Shelter.** Native bees need places to nest, which vary depending on the species. These include patches of bare ground, twigs with pithy centres, hollow tunnels in mudbrick or wood.

**Protection from pesticides.** Most insecticides are deadly to bees, and herbicides can remove many of the flowers that they need for food.

## WHAT CAN FARMERS DO?

There are some inexpensive and simple ways to enhance free pollination by native bees. Such measures also support other beneficial insects and wildlife.

**1. Know where native bees are.** Native bees nest in bare soil, dead trees, old fence-posts, field borders, windbreaks, north-east facing embankments and need areas of natural vegetation for feeding, nesting, and overwintering.

Many native bees nest in the soil. Open areas of compacted earth, with infrequent traffic and afternoon shade are very attractive.



These trunks of untreated wood have holes of various sizes (5-8 mm, 120 mm long) drilled in them.

They are used by wood-nesting resin and leafcutter bees

They are placed in positions with full or at least afternoon shade.

## APPENDIX 4. LEAFLET: HOW TO MAKE NESTS FOR NATIVE BEES



A nestbox on a stand

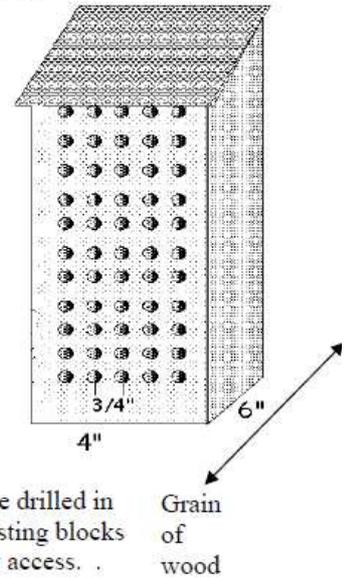


Leafcutter bee

### How to prepare nesting blocks for native bees

#### Nest Block Construction

Masked bees, leafcutter bees and resin bees will nest in holes drilled in a wooden block. Find a piece of untreated dry wood, at least 13 cm "deep". Avoid wood with deep cracks. The bees won't use it as it gives parasites easy access. Holes of a diameter of 5-7 mm drilled in the wood. They should be 100-150 mm deep (depending upon the size timber used), smooth. The denser the wood, the smoother the sides of the holes become, and the better the bees will like it.



Small resin bee closing her nest

Do not drill completely through the timber. Drill the hole to a depth about 10 – 15 mm from the back of the block. Attach a roof to provide protection from the midday sun and rain. Outside surfaces may be painted or stained, but don't use wood preservatives. One hole may be drilled in protect it from rain, or place in a sheltered position. Hang nesting blocks in the shade or morning sun, but so that bees have open flight access. Affix firmly so that the block does not sway in the wind.

Do not move the blocks during the weeks of active nesting. Remove cobwebs and spiders on occasion, and remove ant nests. Once all nesting activity has stopped you can move the blocks, but be **gentle** when moving occupied blocks at this time of year.



Large resin bees at nesting blocks

Blocks can be made from any shape wood. They may be cut to a fancy shape, be a small piece of dead tree limb, fence post (untreated) or scrap of firewood. You can vary the diameter of the drilled holes (4 – 8mm) to attract different species of tube-nesting bees or beneficial wasps.



Waxed paper straws used by resin bees

Another possibility is to use a piece of PVC drainage pipe, close the back, and fill the pipe with waxed **paper** straws. Plastic straws hold moisture and allow mould to develop and are not recommended.



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<http://www.ces.ncsu.edu/depts/ent/notes/Other/note109/note109.html>  
see also: <http://www.wingsinflight.com/gardbees.html>

or:

<http://www.youtube.com/watch?v=ZwUILOsRCM>  
<http://www.youtube.com/watch?v=5YzNSjmZ3Wg>  
<http://www.youtube.com/watch?v=mTRhEypIT5k>

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Nest entrance of a masked bee



A shelter, well-filled with nesting materials