CHAPTER 6
SWEAT BEES (HALICTIDAE): NATURAL HISTORY AND PESTICIDE EXPOSURE

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INTRODUCTION

Halictidae are a diverse and widespread family, found in all terrestrial biogeographic regions of the world. They are known as "sweat bees" from the habit of seeking salts from perspiration on humans and domestic animals, though this behaviour is not limited to halictids and found in several other bees including members of the Megachilidae and Apidae. In some temperate habitats halictids may nearly dominate the bee fauna, less abundant only than the honey bee (Michener 2000).

There are over 4 000 described species of these "short-tongued" bees[1]. Halictids are small to medium-sized (Table 6.1), many with metallic blue or green coloration, often in bands across the abdomen. Many also are black and brown and often have metallic hues, or bands of pale hairs. The four subfamilies of Halictidae are Rophitinae, Nomiinae, Halictinae and Nomioidinae (Michener 2000; Borror *et al.* 1989).

1 http://www.discoverlife.org/mp/20q?guide=Apoidea_species&flags=HAS

Table 6.1

AVERAGE BODY MASS (LIVE WEIGHT) OF HALICTIDAE

SPECIES	COUNTRY	AVERAGE BODY WEIGHT	REFERENCE
***Nomia melanderi* 'alkali bee'**	USA	Males: 96.8 mg (15.8 s.d.) Females: 83.0 mg (14.4 s.d.)	(Rust 2006)
Nomioides variegatus	France	Male: 2.56 mg Female: 2.80 mg (note that these are dry weights)	(Rust *et al*. 2004)
Halictus rubicundus	The Netherlands	Male pupae: 0.063 g (0.003 s.d.) Female pupae: 0.082 g (0.0006 s.d.)	(Hogendoorn and Leys 1997)
H. ligatus	Canada	Males: 6.59 mg (1.08 s.d.) Females: 5.64 mg (1.14 s.d.) (note that these are dry weights)	(Richards and Packer 1994)

NATURAL HISTORY OF HALICTIDAE IN RELATION TO FORAGING AND POLLINATION

Given the high diversity within Halictidae, it is not surprising that their foraging habits are varied. Most are not well studied, but among species that are better researched is the alkali bee (*Nomia melanderi*). It has been recorded visiting flowers in 48 genera within 21 families, with a predominance of Fabaceae and Asteraceae (Rust 2006). Although they are important pollinators for some crops and are managed for alfalfa pollination (Cane 2008), halictids depend strongly on native flowers and can be fairly selective, or even restricted to certain small plant groups.

Halictids appear to be most active in flight (during sunny periods), as are many bees (Martins 2003; Klein *et al*. 2007; Williams *et al*. 2010, 2011). In some species the males appear to visit flowers later in the day and sometimes spend the night in the flowers (pers. obs.). This needs to be taken into consideration in assessing pesticide exposure. Furthermore, some halictids are nocturnal or crepuscular. Because pesticide application regimes often focus on those periods to avoid poisoning the diurnal bees, this part of halictid biology should be seriously considered, especially in subtropical and tropical habitats.

Halictids are highly seasonal (Rust 2006; Schwarz *et al*. 2007). Many species are adapted to synchronized seasonal emergence or sharp population peaks, followed by intensive foraging, and provisioning of brood cells. Their limited flight periods and foraging patterns make them especially vulnerable to pesticide exposure in both temperate and tropical ecosystems, if, of course, pesticide exposure coincides with their activity. In seasonal tropical dryland ecosystems that experience distinct wet and dry seasons, many solitary bee species have synchronised adult emergence and foraging patterns (Roubik 1989; Martins 2003). At such times, even a single major exposure during the foraging and brood provisioning period can be devastating. Better data on these life history patterns, in different environments, would inform pesticide application calendars and additional human factors that impact wild bees (Winfree *et al.* 2009).

There are not much data available on the number of days per season in which halictids forage. However, alkali bee research suggests a wide range of foraging patterns in different environments. Bees in warmer environments may forage over a longer time period, while those in more temperate areas are more restricted and therefore potentially more vulnerable — when pesticide application coincides with their foraging. Studies suggest large differences in the number of days halictids spend foraging in a season, even in a relatively uniform climatic period. For example, in a study of *Halictus rubicundus* in the Netherlands, those halictids were found to be a single generation (univoltine) in cooler areas and bivoltine (two broods a year) at more sheltered sites (Hogendoorn and Leys 1997). The two bee populations were only 150 km apart. Similar patterns are observed in studies of *Halictus rubicundus* in New York, USA, where variation in the number of broods and environmental effects on male production are documented by Yanege (1988-1993).

There are some data that demonstrate the effects of pesticides on the alkali bee. It is the only species of halictid for which controlled, tested pesticide exposure information is available (Johansen and Eves 1963; Torchio 1973). In standardized LD_{50} trials the alkali bee was tested with DDT, toxaphene and parathion. This halictid is the most susceptible species to these three chemicals (the other two species being instead tested were honey bees and the alfalfa leafcutter bee, *Megachile rotundata*). The alkali bee is, however, less susceptible to phosmamidion, dimethoate and malathion (Torchio 1973). The LD_{50} data from the study are presented in Table 6.2.

Halictids have been widely observed to include species that are oligolectic (Figures 6.1 and 6.3). They specialize on pollen from a limited number of plant families and even just a few species. For example, *Systropha* feed primarily on Convolvulaceae while a *Xeralictus* appears oligolectic on *Mentzelia* (Loasaceae), found in southwestern USA (Michener 2000).

In the dry areas of eastern Africa, halictids have been widely recorded as abundant and frequent flower visitors. Some are only observed on a few species of flowers, while others are consummate generalists that visit many of the available flower species. *Lasioglossum* are common visitors and pollinators of *Barleria* and other Acanthaceae. *Pseudapis* are widely seen visiting the flowers of *Aloe* to collect pollen during the protandrous (pollen-only) floral phase, and are an important pollinator of *Indigofera* (D. Martins, unpublished data). *Nomioides* can seasonally be among the most abundant bee visitors to wildflowers in France (Rust *et al.* 2004);

Table 6.2

EXPERIMENTAL LD_{50} SCORES FOR THE HALICTID BEE, *NOMIA MELANDERI*

PESTICIDE TESTED	LD_{50} OBSERVED IN NOMIA MELANDERI
DDT (93%)	0.0074
Toxaphene (71%)	0.0023
Mevinphos (75%)	0.0022
Trichlorfon (45.3%)	0.0465
Oxydementonmethyl (50%)	0.0082
Demeton (99%)	0.0260
Tepp (100%)	0.0032
Naled (64.5%)	0.0016
Parathion (95%)	0.0015
Diazinon (48%)	0.0020
Dieldrin (17. 9%)	0.0023
Dimethoate (46%)	0.0021
Malathion (57%)	0.0036
Phosphamidon (80%)	0.0054
Dicrotophos (90%)	0.0010

Source: Torchio, 1973

in East Africa they visit *Acacia* (Martins 2003) and are found on *Heliotropium zeylanicum, Tribulus* and *Argemone mexicana* (pers. obs.). *Nomia* (Subgenus *Lipotriches*) has been recorded on many different plants, including *Acacia* in East Africa, and flowering grasses and sedges (Bogdan 1962; Immelman and Eardley 2000; Gemmill and Martins 2003).

Many halictids opportunistically forage on invasive and weedy species like *Argemone* that may be targets for control or removal/eradication. The management of such weedy species with herbicides needs to be carefully evaluated, especially in environments where they are a significant proportion of the alternative nectar resources available to halictids.

The main crops of interest where halictids have been studied or managed are alfalfa (*Medicago sativa*) and to a lesser extent vegetables managed for seed (Baird *et al.* 1991), such as onion (*Allium cepa*). *Macronomia rufipes* is a specialized pollinator on eggplant (*Solanum melongena*) in East Africa (Gemmill-Herren and Ochieng 2008). *Lipotriches* and *Halictus* are also common buzz pollinators (bees that vibrate their flight muscles to sonicate anthers and thereby release pollen from a pore at the anther tip) on eggplant and other members of the Solanaceae in East Africa. Halictids contribute to the pollination of watermelon (*Citrullus lanatus*) both in the USA and East Africa (Kremen *et al.* 2002; Njoroge *et al.* 2004). *Halictus tripartatus* pollinates watermelon in the western USA where it is also a pollinator of prickly pear (*Opuntia*; Parfitt 1980). *Lasioglossum* has

Figure 6.1

HALICTIDAE FORAGING IN KENYA

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(a) *Nomia* sp. on flowers of eggplant *(Solanum melongena)*, Baringo, Kenya; (b) *Lipotriches* sp. approaching a flower of *Solanum incanum*, Laikipia, Kenya; (c) *Halictus (Seladonia)* sp. on Asteracae flowers, Laikipia, Kenya; and (d) *Systropha* sp. visiting a flower of *Ipomea*, Mogotio, North Rift, Kenya been recorded on sunflower (*Helianthus annuas*) and apple (*Malus*). The mining bees *Homalictus* are pollinators of Macadamia nuts (*Macadamia ternifola*; Free 1993). Halictids are also known to contribute to blueberry pollination (Isaacs and Kirk 2010).

The foraging ranges of halictid species should be correlated with their relatively small size (Greenleaf *et al.* 2007), but remain unknown. From observations on farming and dryland systems in Eastern Africa, it appears that many tropical dryland halictid species have fairly restricted foraging ranges (Martins 2003). On small scale or subsistence farms, often rich in halictid species, pesticide exposure needs to be limited through understanding and managing bees more directly than in larger-scale more commercially developed farming systems, because small-scale farms often have more of an 'edge' in terms of being adjacent to natural habitat or fallow areas where halictids are likely to be nesting/foraging. Many halictids also spend extensive periods resting on foliage between foraging bouts. This, too, is important to consider in assessing pesticide exposure risk, since foliage may retain residues or metabolites that could be harmful to bees.

NATURAL HISTORY OF HALICTIDS IN RELATION TO BROOD CARE

An important aspect of halictid biology for assessing the risks of pesticide exposure is the diverse sociality in this family (Packer *et al.* 2007). The Halictidae include solitary species that can nest either alone (dispersed), or in aggregations. There are also some social species, including small colonies that are considered parasocial, subsocial and quasisocial and persist up to several months. The degree of sociality in some groups appears to be influenced strongly by environmental conditions and this is of particular relevance in agroecosystems where such environmental conditions are modified or extended by various farming practices (Borror *et al.* 1989; Roubik, 1989, 2012). For example, modification by agricultural practices could take the form of creating areas of bare ground with greater sun exposure lead to higher success for social species that develop nest aggregations.

Eusocial species of halictids have perennial colonies lasting 4 to 5 years. These communal nesters have workers that share responsibility for rearing offspring (sisters) with a gyne (female reproductive) laying eggs that develop into new workers, males and future queens.

One general trend observed of halictids is that eusocial species are more widespread and successful. For example, *Halictus ligatus* and *Lasioglossum malachurum* are two strictly eusocial species in temperate Europe and North America. There they are among the most successful of bees, when measured in terms of both abundance and diversity of habitats occupied (Michener 2000). They have reduced breeding seasons in a 'delayed eusociality' system where queens and workers overwinter, then emerge in the following spring to produce brood. Queens and workers thus emerge early in the season as mature adults and begin to forage. This extends their potential exposure to many pesticides (Schwarz *et al.* 2007), and their food resources need to be free of potential contamination across seasons.

Halictid diversity, and the difference in life history between solitary and social species, remain to be studied in greater detail, in order to better understand pesticide exposure risks.

NATURAL HISTORY OF HALICTIDS IN RELATION TO NESTING RESOURCES AND REPRODUCTION

Nesting patterns and nest-site choice are of particular relevance for Halictidae, in relation to their pesticide exposure. Halictid species typically nest in burrows, either in soil or in dead wood. Earth banks, sheltered rocks and bare or level ground can often hold aggregations of nests, and these appear to be used by sequential bee generations (Roubik 1989; Michener 2000). Large nest aggregations correspond to specific soil moisture, pH and drainage conditions. Those nesting aggregations are of special concern. Localized sub-populations at these sites may number in the thousands, and exposure could impact a large portion of those pollinators (Figure 6.2).

Alkali bees are managed using artificial nesting sites to enhance alfalfa pollination (Torchio 1973; Wilchens *et al.* 1992; Rust 2006). Every attempt needs to be made to prevent pesticide run-offs into such halictid nest aggregations.

There are major gaps in basic life history information for many bees. The Halictidae span a wide range of social behavioral strategies (Sakagami and Michener 1962). They include variation

Figure 6.2

GROUND NESTING SITE OF SOLITARY BEES (*ANDRENA VARGA*) AGGREGATED IN A SMALL AREA

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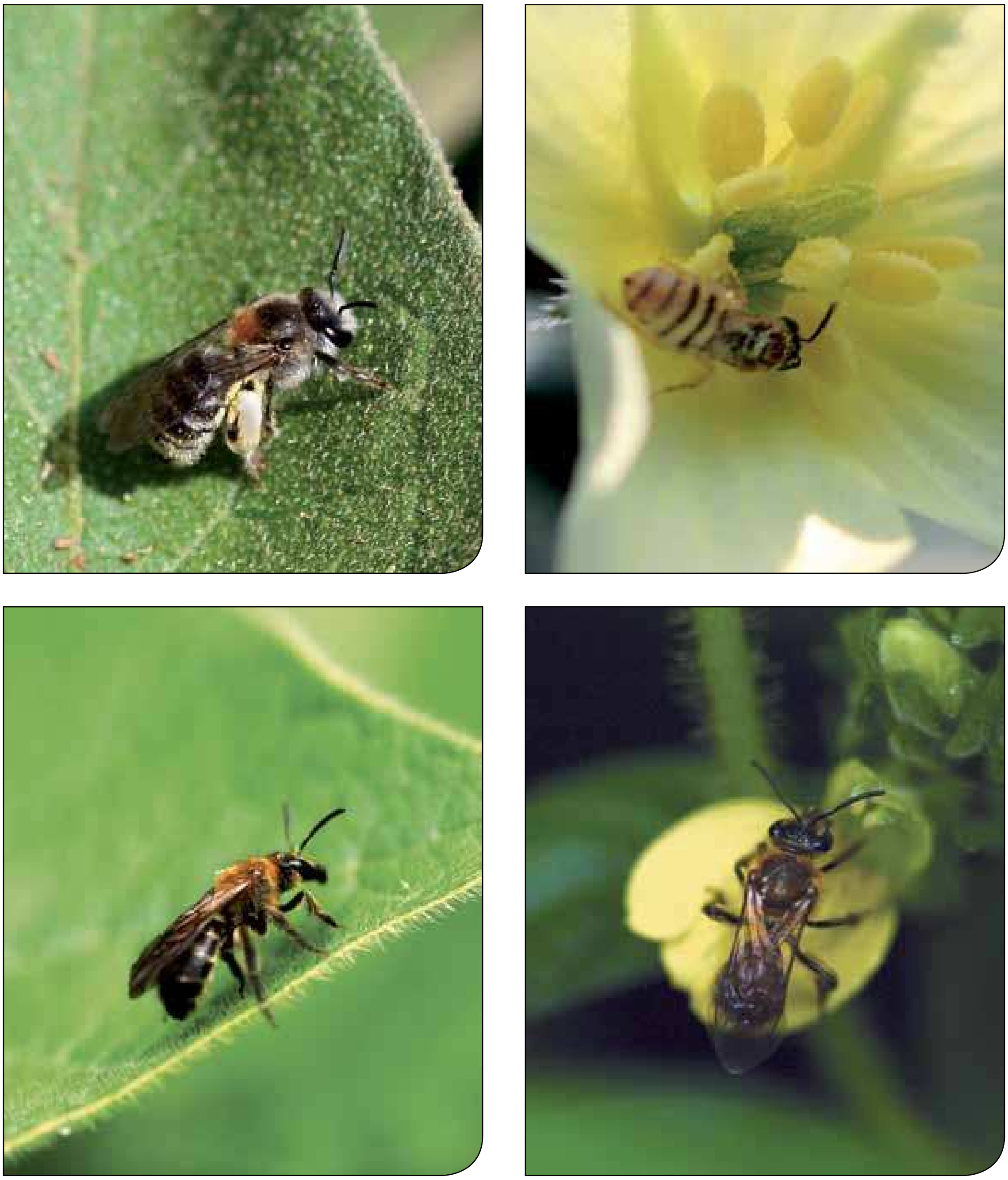
Figure 6.3

SMALL SOLITARY BEES IN KENYA



(a) *Lipotriches* sp. resting on a leaf of *Solanum incanum* in between foraging, Laikipia, Kenya; (b) *Nomioides* sp. on a flower of *Tribulus terrestris*, South Turkwel, Turkana, Kenya; (c) Long-faced bee, *Thrincostoma* sp. resting on a leaf at forest edge, Kakamega Forest, Kenya; and (d) Long-faced bee, *Thrincostoma* sp. foraging on a flower of *Justicia flava*, Kakamega Forest, Kenya in the number of individuals housed in a nest as well as variation in division of labor in castes. This is further embellished by both interspecific and intraspecific variability (Richards 2000; Soucy and Danforth 2002; Michener 1974; Wcislo *et al.* 1993). Studies continue to uncover examples of sociality in halictids. For instance, communal nesting in the South African *Patellapis,* a diverse genus, was recently described (Timmerman and Kuhlmann 2008).

The sharing of nests, the sometimes large nest aggregations, and sharing of food between nest-mates all raise the issue of potentially multiplying the effect of a single foragers' exposure to pesticides — to multiple individuals. The implications for sociality and exposure in halictids are outlined below.

SOCIALITY, BROOD CARE AND GREGARIOUS BEHAVIOR, AND IMPLICATIONS FOR EXPOSURE IN HALICTIDS

- Single foragers return to nests where they may share nectar with multiple brood or nest mates through regurgitation (trophallaxis). They may also share pollen food, which potentially extends exposure of one individual to many.
- Shared food resources in a single nest aggregation or single nest potentially concentrate residues. Concentration levels that might be below those considered detrimental in the environment, or in crop fields, may be augmented within the nest, due to storage of both pollen and nectar (Richards and Packer 1994).
- Foragers may also share nest-building materials, even where actual brood food resources are not shared. Glandular secretions or gathered materials for construction of, for example, the lining of the nest tunnel walls, may be exposed and thus extend exposure to other individuals.
- Aggregated nests at the edges of fields are directly vulnerable, with serious consequences for exposure at a local population level. For example, bees in East Africa nest alongside 'bomas' (traditional livestock enclosures), often sprayed or treated for ticks, biting flies, etc.
- Sociality typically goes hand-in-hand with multivoltine (multiple generations per season or year) life history and this expands both active season and total exposure.
- Sociality influences the volume of pollen consumed by different kinds of brood. Some halictids have caste-variation in larval size and development. Typically the largest larvae become reproductive individuals. Therefore, exposure to even small amounts of residues has the potential to affect the next generation and number of reproducing individuals, although this needs more study (Richards and Packer 1994; Hogendoorn and Leys 1997).

CONCLUSIONS

There is a deficiency in the information on both the direct and the multiplied or 'downstream' effects of exposure to pesticides among halictids, which remains to be addressed. Management techniques used for honey bees could be extended for use with halictids, but halictid sociality is more varied, and nest sites and aggregations may be unrecognized within agroecological landscapes. In small-scale intensive farming, farmers could use the following basic questions as a guide to managing their pesticide use, so as limit the potential exposure of halictid bees:

- What are the seasonal patterns of bee foraging in relation to the crop calendar? A calendar of crop phenology and spraying regimes needs to be developed alongside that of bee abundance, seasonality, flower visitation and nesting pattern.
- Where in the landscape are nest aggregations and other resources relevant to both solitary and social species? Limiting or preventing exposure at these sites is a key component for protecting the bees.
- What happens to residues on leaves, drainage ditches and in soils? Potential ways of mitigating such exposure is through careful spraying regimes, strict adherence to manufacturer user guidelines and working with extension agents and agro-chemical suppliers for up-to-date information.

Critical gaps in knowledge about halictids:

- There are no measurements or direct data on the toxicity of pesticides to halictids, for most if not all widely-used chemicals and their formulations. Work with known crop pollinators can be matched with studies of wild halictids under different pesticide exposure regimes.
- More detailed studies are needed of aggregated/communal nest sites. For example, what factors guide bees to select certain sites? Information on such criteria will enable farmers to manage landscapes for halictids more effectively.
- More information is needed on floral calendars and flower species used by halictid bees when foraging away from crop fields.
- More study is also needed on details of the general biology and foraging patterns of tropical halictids, both in wet and dry environments.

Management practices that can reduce risks to halictids:

- Identify halictids as a component of wild bee fauna on crops and as important pollinators.
- Avoid spraying crop field edges, compacted earth sites, sheltered banks.
- Map and protect aggregated/communal nest sites.

- Construct and protect artificial nest sites for communal species.
- Develop spraying regimes that avoid critical foraging periods to limit direct exposure of adults to toxins — in particular avoid spraying flowers. Take into consideration exposure routes, through direct action of active ingredients as well as though secondary metabolites.

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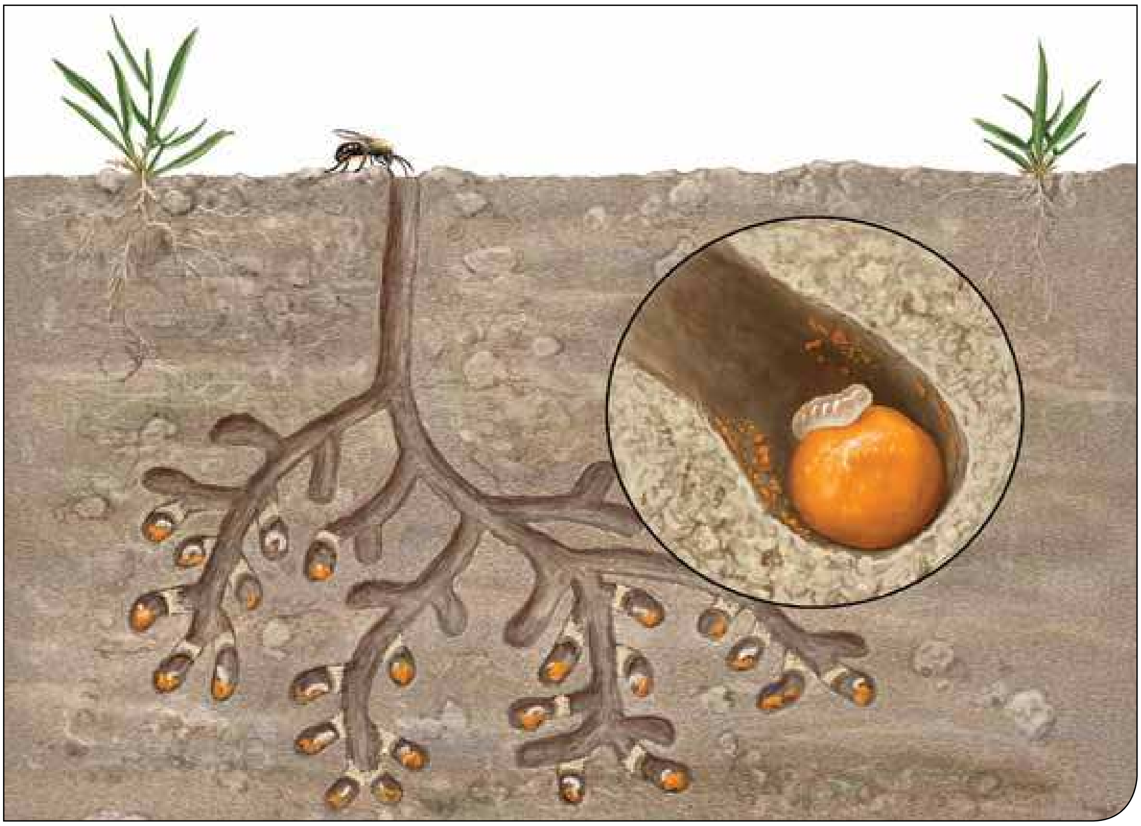

Underground features of the nest of a mining bee (e.g. Diadasia *or* Mellisodes*). Cells show larvae feeding upon bright orange pollen masses.*

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