

Potential pollinators of the Cape Group of Crotalariaeae (*sensu* Polhill) (Fabales: Papilionaceae), with implications for seed production in cultivated rooibos tea

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This study characterizes the assemblages of Hymenoptera that visit flowers of the genera *Aspalathus* Linnaeus, *Lebeckia* Thunberg, *Wiborgia* Thunberg and *Rafnia* Thunberg, the Cape Group of Crotalariaeae (*sensu* Polhill 1981) (Papilionaceae), and evaluates the potential of their members as pollinators. All the assemblages from the western and eastern Cape are characterized by the presence of Megachilinae (Megachilidae) and Xylocopinae and/or Anthophorinae (Anthophoridae), and those from the west (excluding *Rafnia*) by the presence of Masarinae (Vespidae). Although not restricted to Polhill's Cape Group, the Megachilinae and Xylocopinae are potential pollinators. Two species of *Masarina* Richards (Masarinae) are apparently restricted to *Aspalathus*, *Lebeckia* and *Wiborgia*, and are potential pollinators of the smaller-flowered species of these genera. Two species of *Ceramius* Latreille (Masarinae) are apparently restricted to *Aspalathus* and are potential pollinators and, within their distribution ranges, the most dependable visitors of this genus. *Apis mellifera* Linnaeus (Apidae) and Eumeninae (Vespidae) visit all four genera but are probably of little importance as pollinators. *Apis mellifera* is certainly able to obtain nectar from the smaller-flowered species without tripping the flowers. The implications of these findings for seed production in the rooibos tea industry are discussed.

Key words: *Aspalathus*, *Lebeckia*, *Wiborgia*, *Rafnia*, rooibos tea, Masarinae, Megachilinae, Xylocopinae, pollinators.

INTRODUCTION

The Crotalariaeae (Papilionaceae) are principally African although a few genera are represented in the Mediterranean Region, India, Australia and South America (Van Wyk 1991). The greatest generic diversity is centred in southern Africa where 13 of the 15 genera occur (Van Wyk 1991). Four genera, *Aspalathus* Linnaeus, *Lebeckia* Thunberg, *Wiborgia* Thunberg and *Rafnia* Thunberg, constitute the Cape Group hereafter referred to as the Cape Crotalariaeae. This grouping, originally based on morphological characters (Polhill 1981), was supported by a cladistic analysis, using both morphological and chemical characters (Van Wyk 1991). The cladistic analysis further indicated a close subgrouping of *Aspalathus*, *Lebeckia* and *Wiborgia*, and placed *Rafnia* in a separate subgroup.

The distributions of the four genera overlap but do not coincide. *Aspalathus* is most species-diverse in the Cape fynbos but a few outliers extend to Transkei and Natal (Van Wyk 1991; Cowling & Holmes 1992). *Lebeckia* is mainly restricted to Namibia and the Cape Province and *Wiborgia*

entirely to the western and southwestern Cape Province. *Rafnia* is found from the southwestern Cape to Natal (Van Wyk 1991).

Flowers of the Cape Crotalariaeae are characteristically 'pea-flowers.' Both pollen and nectar are concealed and pollen becomes available only after tripping. In some species, e.g. *A. spinescens* Thunberg and *L. sericea* Thunberg, the yellow petals change to a reddish hue as the flowers age. This colour change is alleged to follow pollination and thereby to increase pollination efficiency by discouraging non-productive visits (Vogel 1954; Arroyo 1981).

Van Wyk (1991), referring to the Crotalariaeae, states that 'despite on-going taxonomic research, virtually no biological information has been added to the literature.' Those Papilionaceae that have been investigated show a high frequency of self-incompatibility in woody groups in both the temperate and tropical regions (Arroyo 1981). Self-incompatibility has apparently been established for *A. linearis* (Burman f.) Dahlgren (rooibos tea) (Barnard, pers. comm.).

It is generally considered that the Papilionaceae are bee-pollinated and that they have been associated with bees throughout their evolutionary history. Arroyo (1981) considers that melittophilous legumes as a whole may be classed as 'generalist,' as pollination by a wide range of bees is common and dependence on a limited number of bees is unusual. She states further, that within the broad category of generalist, relationships between bees and legumes are diverse and complex, and that the legume family cuts across the entire spectrum of bees.

There are no published data on the insect visitors to the economically important *A. linearis*. However, two species of Masarinae, *Masarina familiaris* Richards and *Ceramius clypeatus* Richards, that provision their nest cells with pollen and nectar from *Aspalathus* species (Gess & Gess 1988, 1990), are potential pollinators of the congeneric *A. spinescens* Thunberg (Gess & Gess 1989).

The present contribution attempts to characterize the assemblages of Hymenoptera that feed on nectar and/or pollen of the Cape Crotalariaeae and to evaluate the potential of the members of these assemblages as pollinators. Eleven species, six *Aspalathus*, two *Lebeckia*, two *Wiborgia* and one *Rafnia* were sampled. As naturally occurring *A. linearis* was included, cultivated stands of this economically important crop plant were also investigated to broaden the relevance of the project. Attention is consequently drawn to the implications of these findings for seed production in the rooibos tea industry.

RATIONALE

It has been assumed that the nine families of bees occurring in southern Africa are all important pollinators of the local flora since they require pollen as a protein source for their progeny (Whitehead *et al.* 1987). This is misleading. It is possible for an insect to collect large amounts of pollen without being a pollinator. Such an insect is a pollen thief rather than a pollinator. For pollination to be effected a visitor must receive pollen in such a position that, when it enters a conspecific flower, pollen is transferred to a receptive stigma. Pollen that brings about pollination is free pollen that adheres to the carrier and not pollen collected for provisioning. Pollen which is available for pollination is just as likely to be transferred by an insect collecting nectar as by an insect collecting

pollen. Indeed, this transfer is most frequently performed by insects seeking nectar rather than pollen (Kevan & Baker 1983). As papilionate flowers need to be tripped, their visitors must fit them and follow a regular pattern of behaviour. Having determined that an insect has the potential to transfer pollen from one flower to the receptive stigma of another establishes that such an insect is a potential pollinator. It should not be regarded as a pollinator unless there is proof that successful transfer does take place.

Examination of purposely collected pollen from an insect's pollen-carrying apparatus or nest is of value in establishing the degree of dependence of that insect on a study plant by indicating whether it collects pollen solely from that plant or from other species as well. Sufficient samples should be examined to eliminate the possibility of temporary constancy such as is known to be practised by some bees.

MATERIAL AND METHODS

Of the 11 species sampled, nine are endemic to the southwestern Cape: *A. divaricata* Thunberg, *A. linearis*, *A. pulicifolia* Dahlgren, *A. spinescens*, *W. monoptera* Meyer, *Wiborgia* sp., *L. sericea*, *L. spinescens* Harvey and *R. amplexicaulis* Thunberg (Dahlgren 1975, 1988; Bond & Goldblatt 1984). The two remaining species occur beyond the western Cape and have wider distributions. *Aspalathus subtingens* Ecklon & Zeyher ranges from Laingsburg in the west to the Albany and Somerset East Districts in the east, and *A. chortophila* Ecklon & Zeyher is principally an eastern Cape species but has a scattered occurrence eastwards and northwards to Zululand (Dahlgren 1988).

Visitors to all plants in flower at study sites were sampled throughout the day using hand nets. This established which insects visit flowers of a selected study plant and which of these insects also visit flowers of other species.

Pollen collected by the insects for provisioning was removed from their pollen-carrying apparatus and, when possible, from their nests. It was examined microscopically and compared with pollen from the plants visited.

Repeated observations on the behaviour of the insects on the flowers were made and location of free pollen on the insects was noted.

All voucher specimens of the insects and plants are housed in the Albany Museum, Grahamstown.

Sampling sites and dates for plant species

Western Cape

Aspalathus divaricata. Bokkeveld, dry fynbos/renosterveld: Gydo Pass (33.13S 19.19E), 30.xi.1989.

Aspalathus linearis. Western escarpment, fynbos: Nieuwoudtville/Vanrhyn's Pass (31.23S 19.04E), 29–30.ix.1990. Olifants River Valley and westwards to Graafwater; cultivated: Clanwilliam (32.11S 18.54E), 16.x.1989; Seekoevlei (32.09S 18.44E), 17.x.1989; 11 km W Clanwilliam (32.10S 18.48E), 2–8.x.1990.

Aspalathus pulicifolia. Olifants River Valley, karroid scrub/dry fynbos: Kransvlei (32.14S 18.51E), 7–13.x.1987; Caleta Cove (32.14S 18.56E), 19–20.x.1989; Driehoek, W bank Clanwilliam Dam (32.12S 18.52E), 13.x.1990; Clanwilliam/Klawer (32.11S 18.54E/31.45S 18.40E), 9.x.1990; Clanwilliam/Citrusdal (32.11S 18.45E/32.35S 19.01E), 11.x.1990, 6.x.1991; 22 km E Clanwilliam (32.09S 19.02E), 3.x.1991.

Aspalathus spinescens. South of Namaqualand to north of the Olifants River mountains, west to Paleisheuvel and east to Biedouw Valley, dry fynbos: Clanwilliam Dam (32.11S 18.54E), 14.x.1987, 3–7.x.1988, 16–20.x.1989; Klein Alexandershoek (32.20S 18.46E), 26.ix.1985, 8–13.x.1987, 3–7.x.1988, 4.x.1991; 6 km NW Algeria Forestry Station (32.21S 19.00E), 19.x.1989; 5 km W Clanwilliam (32.10S 18.50E), 12.x.1987; 11 km W Clanwilliam (32.10S 18.48E), 2–8.x.1990; 7 km N Paleisheuvel (32.25S 18.44E), 13.x.1987; Witelskloof (32.21S 18.48E), 13.x.1987; W slope Pakhuis Pass (32.08S 18.56E), 5.x.1990; between Pakhuis Pass and Biedouw Valley (32.04S 19.07E), 5.x.1990; 35 km E Clanwilliam (32.04S 19.08E), 3.x.1991; Clanwilliam/Klawer (32.11S 18.54E/31.45S 18.40E), 9.x.1990; Clanwilliam/Citrusdal (32.11S 18.54E/32.35S 19.01E), 12–13.x.1990, 2.x.1991; Citrusdal (32.35S 19.01E), 16.x.1990; Piekenierskloof/Paleisheuvel (32.37S 18.57E/32.29S 18.43E), 6.x.1990; Ratelfontein (32.02S 18.32E), 20–22.ix.1992.

Lebeckia sericea. Namaqualand, scrub on rocky slopes: Nababeep (29.36S 17.45E), 11–13.x.1989; Goegab Nature Reserve (Hester Malan Nature Reserve) (29.38S 18.00E), 10–11.x.1989, 8–10.ix.1992; Kamiesberg Pass, 4 km ENE Kamieskroon (30.15S 17.58E), 12.ix.1992; Sors Sors, 9 km NE Kamieskroon (30.09S 18.01E), 12 & 17.ix.1992; Groenekloof, 7.5 km SE Leliefontein (30.22S 18.07E), 13.ix.1992.

Lebeckia spinescens. Namaqualand, scrub on raised sandy plain: Goegab Nature Reserve (29.38S 18.00E), 8–10.ix.1992.

Wiborgia monoptera. Namaqualand, scrub: Sors Sors, 9 km NE Kamieskroon (30.09S 18.01E), 17.ix.1992; Narap (29.53S 17.46E), 14.x.1989.

Wiborgia sp. Southern Tankwa Karoo, karroid scrub: Karoopoort (33.12S 19.44E), 2–3.xii.1989.

Rafnia amplexicaulis. Hills to west of Olifants River Valley, dry fynbos: Klein Alexandershoek (32.20S 18.46E), 26–28.ix.1985, 8–13.x.1987, 1 & 6.x.1990; 5 km W Clanwilliam (32.10S 18.52E), 12.x.1987.

Eastern Cape

Aspalathus chortophila. Scrub: Riebeeck East (33.12S 26.10E), 7 & 14.xi.1992.

Aspalathus subtingens. Scrub: 8 km NW Grahams-town (33.16S 26.28E), 15.ii.1990, 24–25.iii.1992.

RESULTS

Visitors to flowers of *Aspalathus*

The solitary aculeate Hymenoptera that visited the flowers of the six species of *Aspalathus* are listed in Table 1. A pattern can be recognized. All the assemblages are characterized by the presence of Megachilinae (Megachilidae) and Xylocopinae and/or Anthophorinae (Anthophoridae) and, those from the western Cape, by the presence of Masarinae (Vespidae). The Megachilinae, represented by the tribes Megachilini and Anthidiini, are generally the most numerous in species and individuals. However, where they occur, four species of Masarinae, *Ceramium clypeatus* Richards, *C. micheneri* Gess, *Masarina familiaris* Richards and *M. hyalinipennis* Richards may be more abundant. There is species replacement through the season. For example, *M. hyalinipennis* is abundant in early spring but is replaced in mid to late spring by *M. familiaris*. The Anthophoridae, although a characteristic constituent of the assemblages, are never present in large numbers. Representation by other solitary aculeates, except possibly the Eumeninae (Vespidae), is incidental. *Apis mellifera* Linnaeus (Apidae) is sometimes present in considerable numbers.

Some indication of the degree of dependence of the visitors on the plants was obtained. Twenty of the 29 species of Megachilidae and 12 of the 13 species of Anthophoridae that visit *Aspalathus* flowers were also collected from flowers of taxa

Table 1. Solitary aculeate Hymenoptera recorded from flowers of *Aspalathus* Linnaeus.

WESTERN CAPE

<i>Aspalathus divaricata</i> Thunberg	
Vespidae, Masarinae	<i>Masarina familiaris</i> Richards
	<i>Masarina</i> sp. A
Megachilidae, Megachilinae, Anthidiini	<i>Afranthidium reicherti</i> (Brauns)
	<i>Branthidium braunsi</i> (Friese)
	<i>Spinanthidium volkmanni</i> (Friese)
Anthophoridae, Xylocopinae	<i>Allodape friesei</i> Strand
	<i>Ceratina</i> sp. J
<i>Aspalathus linearis</i> (Burman f.) Dahlgren	
Tiphiidae	<i>Mesa</i> sp. A
Vespidae, Masarinae	<i>Ceramius clypeatus</i> Richards
	<i>Masarina familiaris</i> Richards
Vespidae Eumeninae	<i>Delta caffer</i> (Linnaeus)
Philanthidae	<i>Cerceris languida</i> Cameron
	<i>Philanthus triangulum</i> (Fabricius)
Megachilidae, Megachilinae, Anthidiini	<i>Branthidium braunsi</i> (Friese)
	<i>Immanthidium junodi</i> (Friese)
	<i>Serapista rufipes</i> Friese
	<i>Spinanthidium trachusiforme</i> (Friese)
	<i>Spinanthidium volkmanni</i> (Friese)
Megachilidae, Megachilinae, Megachilini	<i>Chalicodoma karoensis</i> Brauns
	<i>Chalicodoma murina</i> Friese
	<i>Chalicodoma schultessi</i> (Friese)
	<i>Chalicodoma sinuata</i> (Friese)
Anthophoridae, Xylocopinae	<i>Xylocopa caffra</i> (Linnaeus)
	<i>Xylocopa rufitarsis</i> Lepeletier
<i>Aspalathus pulicifolia</i> Dahlgren	
Vespidae, Masarinae	<i>Ceramius clypeatus</i> Richards
	<i>Ceramius micheneri</i> Gess
	<i>Masarina familiaris</i> Richards
Nyssonidae	<i>Bembix cameronis</i> Handlirsch
Megachilidae, Megachilinae, Megachilini	<i>Chalicodoma fulva</i> (Smith)
	<i>Chalicodoma karoensis</i> Brauns
	<i>Chalicodoma murina</i> Friese
	<i>Chalicodoma reicherti</i> Brauns
	<i>Chalicodoma sinuata</i> (Friese)
<i>Aspalathus spinescens</i> Thunberg	
Chrysididae	<i>Elampus guillarmodi</i> Kimsey
Tiphiidae	<i>Mesa</i> sp. A
	<i>Mesa</i> sp. C
Scoliidae	<i>Cathimeris capensis</i> (Saussure)
Vespidae, Masarinae	<i>Ceramius braunsi</i> Turner
	<i>Ceramius clypeatus</i> Richards
	<i>Ceramius micheneri</i> Gess
	<i>Masarina familiaris</i> Richards
	<i>Masarina hyalinipennis</i> Richards
	<i>Masarina mixta</i> Richards
Vespidae, Eumeninae	<i>Delta caffer</i> (Linnaeus)
	<i>Delta emarginatum</i> (Linnaeus)
	<i>Raphiglossa flavoornata</i> Cameron
Sphécidae	<i>Ammophila bonaespei</i> Lepeletier
	<i>Podalonia canescens</i> (Dahlbom)
Philanthidae	<i>Philanthus capensis</i> Dahlbom
Megachilidae, Megachilinae, Anthidiini	<i>Branthidium braunsi</i> Pasteels
	<i>Carinanthidium cariniventre</i> (Friese)
	<i>Oranthidium</i> sp.
	<i>Spinanthidium neli</i> (Brauns)
	<i>Spinanthidium trachusiforme</i> (Friese)
	<i>Spinanthidium volkmanni</i> (Friese)

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Table 1 – continued

Megachilidae, Megachilinae, Megachilini	<i>Chalicodoma aridissima</i> Cockerell <i>Chalicodoma fulva</i> (Smith) <i>Chalicodoma karoensis</i> Brauns <i>Chalicodoma murina</i> Friese <i>Hoplitis</i> sp. C <i>Megachile</i> sp. B
Anthophoridae, Xylocopinae	<i>Ceratina</i> sp. F <i>Ceratina</i> sp. H <i>Xylocopa caffra</i> (Linnaeus) <i>Xylocopa capitata</i> Smith <i>Xylocopa lugubris</i> Gerstaecker <i>Xylocopa rufitarsis</i> Lepeletier
EASTERN CAPE	
<i>Aspalathus chortophila</i> Ecklon & Zeyher	<i>Cerceris armaticeps</i> Cameron
Philanthidae	<i>Melitta</i> sp.
Melittidae	<i>Chalicodoma fulva</i> (Smith)
Megachilidae, Megachilinae, Megachilini	<i>Chalicodoma lineofasciata</i> Pasteels <i>Chalicodoma murina</i> Friese <i>Chalicodoma sinuata</i> (Friese) <i>Coelioxys bruneipes</i> Pasteels <i>Coelioxys foveolata</i> Smith <i>Coelioxys setosa</i> Friese <i>Creightoniella dorsata</i> (Smith) <i>Creightoniella seewaldi</i> (Strand) <i>Megachile spinarum</i> Cockerell <i>Amegilla (Zebramegilla)</i> sp. B
Anthophoridae, Anthophorinae	<i>Antepipona sesquicincta</i> (Saussure)
<i>Aspalathus subtingens</i> Ecklon & Zeyher	<i>Delta hottentottum</i> (Saussure)
Vespididae, Eumeninae	<i>Leuconomia</i> sp. A <i>Leuconomia</i> sp. C
Halictidae	<i>Coelioxys penetratrix</i> Smith
Megachilidae, Megachilinae, Megachilini	<i>Megachile gratiosa</i> Gerstaecker <i>Megachile semiflava</i> Cockerell <i>Megachile spinarum</i> Cockerell <i>Megachile unguolata</i> Smith
Anthophoridae, Xylocopinae	<i>Allodape rufogastra/exoloma</i> <i>Allodapula variegata</i> (Smith) <i>Halterapis nigrinervis</i> (Cameron) <i>Xylocopa sicheli</i> Vachel

other than Papilionaceae. From one to six (average 2.3) plant families per species were recorded for Megachilidae and from one to 11 (average 4.4) families per species for Anthophoridae (Gess 1992b).

Pollen from some of the species of these bee families was found to be mixed, further indicating lack of dependence.

Of the *Ceramius* species, *C. clypeatus* and *C. micheneri* are apparently restricted to foraging on *Aspalathus* species for both pollen and nectar. They have not been found on flowers of any other plants

although other families favoured by different masarines were flowering abundantly in association with *Aspalathus*, and samples of cell provision were found to contain only pollen matching that of *Aspalathus* species. Although they are not restricted to single species of *Aspalathus*, these wasps seem to be dependent on the genus. By contrast, *C. braunsi* Turner is a casual visitor only occasionally visiting *Aspalathus* for nectar, otherwise being restricted to Asteraceae.

Of the *Masarina* species, *M. hyalinipennis* and *M. familiaris* forage on *Lebeckia* and *Wiborgia* in

addition to *Aspalathus*. They are therefore not dependent on a single genus but on a complex of three genera, all of Cape Crotalariaeae. *Masarina mixta* Richards typically forages on *Wahlenbergia* species (Campanulaceae) and is therefore only a casual visitor to *Aspalathus*.

The Eumeninae, provisioning as they do with caterpillars, only visit flowers to obtain nectar for their own nourishment. Furthermore, they are not restricted to *Aspalathus*, having been recorded from flowers of two to nine (average 6.0) families. They are consequently considered to be casual visitors and as such are of little or no importance as potential pollinators.

When visiting *Aspalathus* flowers, all the species of Megachilidae, Anthophoridae and Masarinae trip the flowers. The megachilids, anthophorids and *Ceramius* alight on the alae. A firm footing on the small alae is aided by the sculpturing of the petal surface – a common feature in Papilionaceae (Stirton 1981). The insects receive pollen on the ventral surface as illustrated for *Ceramius* in Gess & Gess (1989), the position of the pollen being dependent on the size of the visitor. The *Masarina* species differ in that they alight on the standard and receive pollen on the frons as illustrated in Gess & Gess (1989). When making successive nectar-drinking visits, the behaviour of all these species is constant and so they would successfully transfer pollen from the anthers of one flower to the stigma of another and therefore satisfy the requirements of potential pollinators.

The combination of potential pollinators employing two methods of triggering the opening of the carina and exposing the essential parts is akin to that recorded by Stirton (1977) for *Canavalia virosa* (Roxburgh) Wight & Arnott (Papilionaceae) which is pollinated by two different size categories of bees which, as with the *Ceramius* and *Masarina* species, have different strategies for operating the flowers.

Apis mellifera, unlike the megachilids, anthophorids and masarines, does not have a consistent way of entering the flowers. It rarely triggers the opening of the carina and certainly, as it has no set way of positioning itself on the flowers, would be unlikely to transfer pollen from one flower to the stigma of another even if it were occasionally to receive a pollen load. *Apis mellifera* should therefore be considered a thief rather than a pollinator.

The reliability of the potential pollinators of an *Aspalathus* species is directly related to the degree

of their dependence on flowers of that species, in particular as a source of nectar, and the degree to which their distributions overlap. As none of the potential pollinators is restricted to a single species, none is totally dependable. *Ceramius clypeatus* and *C. micheneri* are, however, within their limited distribution ranges (Gess 1992a), the most dependable as they are restricted to the genus *Aspalathus*, whose species show little overlap in their distributions. This is explained by the marked individual preferences of *Aspalathus* species for specific soil types (Dahlgren 1988), possibly linked to microsymbiont diversity (Cowling *et al.* 1992). The *Masarina* species are more widely distributed in the western Cape and so, where *Lebeckia* and *Wiborgia* are not in flower with *Aspalathus*, are more widely dependable. Where megachilids and anthophorids occur together with the masarines, they will be less dependable as they are less restricted in their choice of flowers. However, in areas where the masarines do not occur they will be the most important potential pollinators.

Visitors to flowers of *Lebeckia*

The solitary aculeate Hymenoptera that visit the flowers of the two species of *Lebeckia* are listed in Table 2. A pattern can be recognized – all the assemblages are characterized by the presence of Masarinae and Megachilinae of the tribes Megachilini and Anthidiini. Species of these groups are the most abundant visitors. Occasional visits by a species of Xylocopinae, *Xylocopa rufitarsis* Lapeletier, to *L. sericea* were recorded. *Apis mellifera* is sometimes present in considerable numbers.

Some indication of the degree of dependence of the visitors was obtained. Five of the seven species of Megachilinae and the single species of Xylocopinae that visit *Lebeckia* flowers were also collected from flowers of taxa other than Papilionaceae. From one to four (average 2.8) plant families per species were recorded for the Megachilinae and three families for the Xylocopinae (Gess 1992b). Pollen from some of the species of these bee taxa was found to be mixed, further indicating lack of dependence.

The behaviour of the insects on the flowers follows the same pattern as that described for *Aspalathus*. The flowers of *L. spinescens* were tripped by its megachilid and masarine visitors. Those of the much larger-flowered *L. sericea* are not

Table 2. Solitary aculeate Hymenoptera recorded from flowers of *Lebeckia* Thunberg.

<i>Lebeckia sericea</i> Thunberg	
Vespidae Masarinae	<i>Masarina familiaris</i> Richards
	<i>Masarina hyalinipennis</i> Richards
Megachilidae Megachilinae Anthidiini	<i>Spinanthidium volkmanni</i> (Friese)
Megachilidae Megachilinae Megachilini	<i>Chalicodoma bullata</i> (Friese)
	<i>Chalicodoma fulva</i> (Smith)
	<i>Chalicodoma karoensis</i> Brauns
	<i>Chalicodoma murina</i> Friese
	<i>Megachile apiformis</i> Smith
	<i>Serapista rufipes</i> Friese
	<i>Xylocopa rufitarsis</i> Lepelletier
Anthophoridae Xylocopinae	
<i>Lebeckia spinescens</i> Thunberg	
Vespidae Masarinae	<i>Masarina hyalinipennis</i> Richards
Megachilidae Megachilinae Anthidiini	<i>Spinanthidium volkmanni</i> (Friese)
Megachilidae Megachilinae Megachilini	<i>Chalicodoma karoensis</i> Brauns

as readily tripped. The *Masarina* species alight on the flower in the same manner as they do on *Aspalathus* flowers. However, when they insert the tongue at the base of the standard to obtain nectar they do not trigger the opening of the carina. Even if the carina were to open the wasp would not receive a load of pollen because of the relative sizes of wasp and flower. Clearly, on their nectar collecting visits to *Aspalathus* and *L. spinescens*, the *Masarina* species are potential pollinators, whereas on their visits to *L. sericea* they are thieves. It was noted that, when seeking pollen, the *Masarina* species walk outwards along the keel and in so doing trip the flower, facilitating pollen collection.

Apis mellifera, when taking nectar from the relatively large *L. sericea* flowers, seems to be less able to position itself to avoid tripping them than when taking nectar from the small *Aspalathus* flowers. It should therefore be considered a potential pollinator.

It is concluded that the larger megachiline visitors to the flowers of *L. sericea* are their most important potential pollinators. Furthermore, it was found that, although the *Chalicodoma* species are not restricted to *Lebeckia*, the provision from nest cells of *C. murina* Friese and *C. karoensis* Brauns visiting *Lebeckia* contained only *Lebeckia* pollen.

Visitors to the flowers of *Wiborgia*

The assemblage of hymenopteran visitors to the flowers of the two species of *Wiborgia* was similar to those of *Aspalathus* and *Lebeckia* (Table 3). Overall numbers of visitors at any one time was comparatively low.

The megachilines have been recorded from the flowers of from two to five (average 3.3) plant families per species and the xylocopine from nine families (Gess 1992b). These bees are therefore not dependent on *Wiborgia* or on the Cape Crotalariaeae as a whole. The only other anthophorid, *Epeolus amabilis* Gerstaecker, and the eumenine *Zethus yarrowi* Giordani Soika were not recorded from other flowers. Only one specimen of each was, however, collected from *Wiborgia*.

The flowers are of comparable size to those of the *Aspalathus* species and *L. spinescens* and, like those flowers, will be tripped by the megachilids, the anthophorids, and the *Masarina* species, which can similarly be regarded as potential pollinators. The colletid was represented in the samples by one male only and so, at the study times and places, it was of no importance. *Apis mellifera*, as it is able to avoid tripping the flowers, is a thief. The eumenines are casual visitors.

Where *M. hyalinipennis* occurs with *Wiborgia* it is that plant's most dependable visitor and therefore most reliable potential pollinator. Elsewhere, megachilines are likely to be the most important potential pollinators.

Visitors to the flowers of *Rafnia*

A very limited range of insects was recorded from the relatively large-flowered *R. amplexicaulis* (Table 4): one species of Megachilinae, *Chalicodoma cincta* (Fabricius); two species of large Xylocopinae, *Xylocopa capitata* Smith and *X. caffra* (Linnaeus); and one species of Eumeninae, *Synagris maxillosa bequaerti* Brauns. *Apis mellifera* was an occasional visitor. No Masarinae were

Table 3. Solitary aculeate Hymenoptera recorded from flowers of *Wiborgia* Thunberg.

<i>Wiborgia monoaptera</i> E. Meyer	
Vespidae Masarinae	<i>Masarina hyalinipennis</i> Richards
Vespidae Eumeninae	<i>Zethus yarrowi</i> Giordani Soika
Megachilidae Megachilinae Anthidiini	<i>Spinanthidium trachusiforme</i> (Friese)
	<i>Spinanthidium volkmanni</i> (Friese)
Megachilidae Megachilinae Megachilini	<i>Chalicodoma fulva</i> (Smith)
	<i>Chalicodoma karooensis</i> Brauns
	<i>Chalicodoma murina</i> Friese
<i>Wiborgia</i> sp.	
Vespidae Eumeninae	<i>Delta caffer</i> (Linnaeus)
	<i>Delta emarginatum</i> (Linnaeus)
	<i>Delta hottentottum</i> (Saussure)
Colletidae	<i>Colletes</i> sp. B
Megachilidae Megachilinae Megachilini	<i>Chalicodoma laminata</i> (Friese)
	<i>Chalicodoma niveofasciata</i> Friese
	<i>Chalicodoma sinuata</i> (Friese)
	<i>Megachile</i> sp. A
Anthophoridae Nomadinae	<i>Epeolus amabilis</i> Gerstaecker
Anthophoridae Xylocopinae	<i>Xylocopa scioensis</i> Gribodo

Table 4. Solitary aculeate Hymenoptera recorded from flowers of *Rafnia* Thunberg.

<i>Rafnia amplexicaulus</i> Thunberg	
Vespidae Eumeninae	<i>Synagris maxillosa</i> Brauns
Megachilidae Megachilinae Megachilini	<i>Chalicodoma cincta</i> (Fabricius)
Anthophoridae Xylocopinae	<i>Xylocopa caffra</i> (Linnaeus)
	<i>Xylocopa capitata</i> Smith

recorded despite repeated samplings.

Within the study areas, *C. cincta* was not collected from any flowers other than those of *R. amplexicaulis*. However, it is more widely distributed than all the genera of the Cape Crotalariaeae and is therefore not dependent on any of them.

Both species of *Xylocopa* were recorded from other Papilionaceae. *Xylocopa capitata* also visits Boraginaceae and *X. caffra* 11 other plant families (Gess 1992b). These bees are therefore not dependent on *Rafnia* nor on the Cape Crotalariaeae as a group.

Synagris maxillosa bequaerti was not recorded from flowers of any other plants but it is unlikely that it is totally dependent on *Rafnia*.

The megachilines and the xylocopines are all regular visitors to the flowers of *R. amplexicaulis*. Their behaviour on the flowers was identical to that of their counterparts on the flowers of the other three genera and, as they were seen to be heavy enough to trip the more robust flowers of *R. amplexicaulis*, they are considered to be potential pollinators.

Synagris maxillosa bequaerti was a regular visitor and constant in its behaviour on the flowers, which it is sufficiently heavy to trip. It should therefore also be considered a potential pollinator.

Apis mellifera being too light to trip the flowers is not of any consequence.

None of the potential pollinators is apparently dependent on *R. amplexicaulis* and none will therefore be dependable.

DISCUSSION

Potential pollinators of the Cape Group of Crotalariaeae

When considering assemblages of visitors to flowers of the four genera of the Cape Crotalariaeae, certain similarities are immediately apparent. All the assemblages from the western and eastern Cape are characterized by the presence of Megachilinae, Xylocopinae and/or Anthophorinae and, those from the west (excluding *Rafnia*), by the presence of Masarinae, Eumeninae and not infrequently *A. mellifera*.

Evaluation of the visitors as potential pollinators led to the conclusion that the most important potential pollinators are species of Megachilinae, Xylocopinae and Masarinae. The most dependable visitors are the Masarinae, although their distributions are more limited than those of the genera of the Cape Crotalariaeae. *Apis mellifera* is not a potential pollinator of the smaller-flowered species but may be considered as a potential pollinator of some of the larger-flowered species. The Eumeninae seem to be of no importance as pollinators except possibly of *R. amplexicaulis*.

That the Cape Crotalariaeae attracts an assemblage of potential bee-pollinators is consistent with the general pattern presented for the Papilionaceae by Arroyo (1981). The number of bee species is large compared to the two to three species noted by Scott-Elliott (1890–1891) for South African Papilionaceae. However, the potential bee-pollinators belong to only two families, Megachilidae and Anthophoridae and, furthermore, principally to only two subfamilies, the Megachilinae and Xylocopinae. What is remarkable about the assemblages of potential pollinators of the Cape Crotalariaeae, as compared to Papilionaceae in general, is the membership by species of Masarinae. These species are unusual in their choice of forage plants. They represent only 7 % of the 92 species of southern African Masarinae for which plant associations are known (Gess 1992b). The more common associations are with Aizoaceae (predominantly *Mesembryanthema sensu* Hartmann (1991)) 45 %, Asteraceae 41 %, Campanulaceae 18 % and Scrophulariaceae 13 % (Gess 1992b). No associations between Masarinae and Papilionaceae have been recorded from elsewhere in the Afrotropical Region or from any other zoogeographic regions (Gess 1992b).

Implications for seed production in cultivated rooibos tea

Aspalathus linearis is of economic importance as rooibos tea. It occurs from Cape Point to the Vanrhynsdorp and Nieuwoudtville Districts. Only selected forms from the Cedarberg Mountains are, however, cultivated for tea production.

Rooibos tea growers have hitherto obtained seed either by sieving seed from topsoil in the tea-producing plots or by removing collected seed from the nests of ants, replacing it with bird seed. The seed is sent to a central depot for cleaning and redistribution (Barnard, pers. comm.). Seed

production using seed plots is now under consideration (Barnard, pers. comm.).

With regard to the establishment of seed plots, it should be stressed that, as *A. mellifera* is not an efficient pollinator of *Aspalathus*, placement of beehives will not enhance seed production. Rather, the nesting requirements of the potential pollinators, species of Megachilinae, Masarinae and Xylocopinae, should be satisfied.

At least four of the *Chalicodoma* species, *C. sinuata* (Friese) and *C. schultessi* (Friese) (which construct mud cells in cavities) and *C. karooensis* and *C. murina* (which build aerial mud cells on stones), and the *Ceramius* and *Masarina* species (that excavate nests in the ground) require soil with a clay content sufficient for it to be malleable when mixed with water (Gess 1981; Gess & Gess, unpubl.; Gess & Gess 1988, 1990). These species neither occur in areas of loose sandy soil nor, as some require water and others mud, will they be present far from water or in areas where the only available water is contained by steep walls with no seepage.

Soils from Citrusdal (32.35S 19.01E) to Vredendal (31.40S 18.30E) in the Olifants River Valley and eastwards generally have a clay content high enough to render them suitable for nesting by the species using mud. Selection of seed plot sites should in addition take into account availability of suitable water and or mud sources as these are likely to be a limiting factor, as is the availability of suitable stems for nesters in plant stems. There are two categories of stem nesters, Xylocopinae of the genera *Xylocopa*, *Ceratina*, *Allodape* and *Allodapula* which excavate their own burrows and some of the Megachilinae which utilize abandoned burrows.

In the area to the west of Clanwilliam between the Olifants River Valley and the coastal sandy plain the soils are derived from quartzitic sandstone and shale and are consequently a mixture of sand and clay. The proportions of each varies between areas, resulting in the soils being variably malleable when mixed with water. The Rooibos Tea Board has recorded low seed production from the Graafwater District in this area. Certainly, the fields which the authors were shown were sited on loose, sandy soil, were far from water and the tea bushes, although in flower, were receiving very few visits from insects. This is unimportant when tea production is the aim, but as plots for seed production are under consideration it is clear that

to be successful they should be differently sited. For those Megachilini using mud, and for the Masarinae to be present, it will be necessary to select sites where soil with a sufficient clay content and suitable water sources are ensured. Furthermore, for Megachilini nesting on stones a suitable substrate should be present, and for those Xylocopinae excavating their own burrows in pithy stems or soft wood, as well as for Megachilinae nesting in pre-existing cavities in plant stems, thick-stemmed shrubs or trees should be available. Such plants occur naturally in the fynbos of this area but are absent where large areas have been cleared for cultivation. Bee boards, boards drilled with suitably sized galleries, can be pro-

vided to increase nesting sites for Megachilinae in such areas.

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