Records of the Western Australian Museum Supplement Number 52: 49–53 (1995).

Dancing on the head of a pin: mites in the rainforest canopy

David Evans Walter

Department of Entomology and Centre for Tropical Pest Management, University of Queensland, St Lucia 4072, Australia

Abstract – Mites, the most diverse taxon in the Arachnida, are a major component of the rainforest canopy fauna. Twenty-nine species of mites were identified from the outermost canopy (leaves and their subtending stems) of a single rose marara tree (*Pseudoweinmannia lachnocarpa*) growing in subtropical rainforest in south-eastern Queensland. None of these species were found in suspended soils collected from a treehole and the root mats of two epiphytic ferns on the same tree, although 21 other mite species lived in the soils. Forty-seven leaves and 290 cm of small stems from brown beech trees (*Pennantia cunninghamii*) at two subtropical rainforest sites 110 km apart contained 1615 mites representing 43 species. The average brown beech leaf contained three times as many species as the average rose marara leaf. Most mites collected from brown beech leaves were found within domatia, structures lacking on rose marara leaves. When domatia were blocked, average species number per leaf was reduced to half that on leaves with open domatia. Only four mite species were common to both sites, and only five species were found on both rose marara and brown beech, suggesting that a very diverse fauna awaits discovery.

INTRODUCTION

The Acari are admittedly the most abundant and diverse group in the Arachnida; yet, mites often appear to be absent or rare in studies of arthropods in rainforest canopies (e.g. Basset 1991), except from collections of suspended soils (Nadkarni and Longino 1990). The latter case provides no real exception, because the soil has traditionally been considered the centre of acarine abundance and diversity (Krantz 1978; Dindal 1990). However, in Australia this apparent lack of arboreal Acari results more from the technical problems involved in collecting minute animals than from any absence of mites (Yves Basset, personal communication). In fact, arboreal mites are exceedingly abundant, often being the most abundant arthropods in Australian rainforest canopies (Coy *et al.* 1993; Walter 1993); numerous species live on the leaves of plants (Walter *et al.* 1994), especially in leaf surface structures (domatia) that appear to have evolved to house mites (e.g. O Dowd and Willson 1989; Walter and O'Dowd 1992, 1995).

What factors account for this abundance and diversity of minute animals in the rainforest canopy? In this paper I test the hypothesis that suspended soils act as a reservoir of arboreal diversity by comparing the acarofauna of the outermost canopy, the leaves and the small stems that produce them, to that present in the perched litter on the bole of a single rose marara tree. I also compare the mite species composition of leaves and small stems of brown beech trees growing at two sites to determine whether the arboreal fauna is similar between sites and test the effect of leaf domatia on the diversity of the foliar fauna.

MATERIALS AND METHODS

I sampled the upper canopy leaves, small stems (to 33 m above the ground), and *ca.* 50 cm^3 each of suspended soils from a tree hole (at 30 m) and the root balls of two epiphytic ferns, a hare's foot fern *Davallia pyxidata* Cav. (32 m) and a crow's nest fern *Asplenium australasicum* (J. Smith) Hook. (at 20 m), on a large rose marara tree, *Pseudoweinmannia lachnocarpa* (F. Muell.) Engl. (Cunoniaceae). The tree grew in a subtropical rainforest (complex notophyll vine forest) at O'Reilly's Mt Resort adjacent to Lamington National Park on the Queensland–New South Wales border. Access was by suspended walkway and ladder. I also collected leaves and small stems (to 5 m) from a small brown beech tree, *Pennantia cunninghamii* Miers (Icacinaceae), near Elabana Falls at Lamington and from four others along the Green Falls trail at Miala National Park on Mt Glorious 110 km north of Lamington. Shoots were clipped using extendable pole-pruners, placed in plastic bags, and refrigerated. Suspended soils were collected by hand (tree hole) or using a cork borer (fern roots), bagged, and kept cool.

Mites were removed from leaves and sections of small stems (< 6 mm diameter) under a stereomicrosope using cool light; any structures

(domatia, galls, webbing, exuviae, detritus, bark fissures, etc.) or growths (lichens, liverworts, etc.) were dissected with a scalpel. Suspended soil samples were extracted in funnels under incandescent light into 80% ethanol. Species identifications were based on mites cleared in Nesbitt's solution and mounted in Hoyer's medium on glass slides (Krantz 1978). Summary statistics are presented as means (rounded to the nearest whole number where practical) ± one standard error. Mean species numbers were compared using standard t-tests and treating each leaf or stem segment as independent estimates of diversity. Voucher specimens are deposited in the University of Queensland Insect Collection, St Lucia, Queensland.

The effect of leaf domatia on foliar mite species number was assessed using a domatia blocking experiment. In September 1991 at the Elabana Falls site, equal numbers of newly flushed brown beech leaves were randomly assigned to one of two treatments: entrances to leaf domatia were blocked off using a bitumen paint or domatia were left open, but paint dabbed was below the domatia (see Walter and O'Dowd 1992). Five months later in February 1992, leaves were collected and processed as above.

RESULTS

Rose marara mites

Upper canopy leaves of rose marara are trifoliate, small (leaflets *ca.* 6 x 2 cm), glabrous, and thick. The main vein is slightly raised, providing the only relief on an otherwise smooth and featureless surface which is fully exposed to winds, insolation, and rain. Although an apparently desolate habitat, an average leaf was inhabited by nine mites, and a total of 18 species was identified over the course of the study (Table 1). The small stems subtending the leaves of rose marara were also rather smooth and featureless, with some growth of crustose lichens. About one mite was collected for every 2 cm of stem examined, and 17 species of mites were identified. Eleven of these species were not found on leaves. The suspended soils contained an additional 21 species of mites, none of which inhabited stems or leaves (Table 1).

The fifty species of mites collected from rose marara represented both major orders (Acariformes, Parasitiformes) and four suborders (Prostigmata, Oribatida, Astigmata, Mesostigmata) of the Acari. Four species of Eriophyidae and a spider mite (*Schizotetranychus* sp.) fed on rose marara leaves. Six species of predatory mites

Table 1 A diverse, and often abundant fauna of mites, lived on a single rose marara tree in subtropical rainforest adjacent to Lamington National Park, Queensland. Fifty species of mites were identified from leaves, small stems, and suspended soils; six species were collected from both leaves and small stems; other species were restricted to leaves, stems, or suspended soils. Values represent means ± standard errors for N leaves or segments of small stems subtending leaves.

Leaves:

Date	N	Mites / Leaf	Species / Leaf
9 March 1993	75	5 ± 1	0.9 ± 0.1
7 Dec. 1993	15	0.4 ± 0.2	0.2 ± 0.1
17 May 1994	15	20 ± 6	1.5 ± 0.3
21 June 1994	15	22 ± 6	1.8 ± 0.3
27 July 1994	15	14 ± 6	1.5 ± 0.3
Overall dates	**135**	**9 ± 1**	**1.0 ± 0.1**
Range		0 – 74	0 – 5
Total		1158	18

Stems:

Date	N	Length (cm)	Mites / cm	Species / Stem
7 Dec. 1993	3	14 ± 3	3.0 ± 2.0	5 ± 2
17 May 1994	3	22 ± 2	1.2 ± 0.2	6 ± 1
21 June 1994	3	15 ± 2	0.6 ± 0.2	5 ± 2
27 July 1994	3	14 ± 1	0.3 ± 0.2	2 ± 1
Overall dates	**12**	**16 ± 1**	**1.3 ± 0.6**	**4 ± 1**
Range		8 – 24	0 – 7.4	0 – 8
Total		278	194	17

Suspended Soils:

	Tree hole	Hare's foot fern	Crow's Nest Fern	Total
Species	13	5	6	21

(*Typhlodromus dachanti* Collyer, Bdellidae sp., Erythraeidae sp., *Agistemus* sp., *Muellederia* sp., *Zetzellia* sp.) inhabited leaves and stems, and an additional five species (*Geogamasus* sp., Ologamasidae sp. 2, *Pseudoparasitus* sp., Rhagidiidae sp., Labidostomatidae sp.) were identified from suspended soils. The remainder included 18 species of scavengers and fungivores (*Adhaesozetes polyphyllos* Walter and Behan-Pelletier, Astigmata sp., *Crassoribatula* sp., *Czenspinskia* sp., *Daidalotarsonemus* sp., *Eupodes* sp., 2 spp. of *Fungitarsonemus*, *Oripoda* sp., *Plumobates* sp., *Scapheremaeus* sp. s, *Sellnickia caudata* (Michael), *Symbioribates* sp., 2 spp. of *Tarsonemus*, 3 spp. of Tydeidae) from leaves and stems and 16 species (Austrachipteriidae sp., *Cosmochthonius* sp., *Eupodes* sp. 2, *Galumna* sp., *Hypochthoniella* sp., *Liochthonius* sp., Oppiidae sp., *Phyllhermannia* sp., Plateremaeidae sp., *Quadroppia* sp., Scutacaridae sp., *Suctobelbella* sp., *Sulcoribula* sp., Tydeidae sp., Uropodidae sp., *Xylobates* sp.) from suspended soils.

Brown beech mites

Lower canopy leaves of brown beech are relatively large (typically *ca.* 6 x 12 cm) and glabrous, but contain numerous (9 – 58) pit-like domatia in the vein axils on the abaxial surface. Near Elabana Falls, an average brown beech leaf was inhabited by 40 mites and 3 mite species (Table 2). Most mites (97%) were found within domatia. I identified a total of 13 species on leaves over the course of the study (September 1991, February 1992, January 1994), and an additional four species from the three small stem segments (January 1994), which averaged *ca.* 1 mite for every 5 cm of stem.

I also sampled four brown beech trees along Green Falls Trail in May 1994. An average leaf was inhabited by only about a third as many mites as at Elabana falls (Table 2), but by a similar number of species (t_{45} = 0.935, P = 0.355). Again, most mites (92%) were found within leaf domatia, where a total of 11 species was identified. Small stems contained two mites for every 3 cm examined and a total of 25 species (Table 2). Only four species were collected from brown beech at both sites.

Only five species of mites were collected from both brown beech at Elabana Falls and the nearby rose marara. Both trees carried about four mite species per segment of stem examined (t_{29} = 0.806, P = 0.427); but the average brown beech leaf contained nearly three times as many species as those of rose marara (t_{179} = 9.447, P < 0.0001). However, five months after leaf domatia on brown beech leaves were blocked, significantly fewer (t_{26} = –3.890; P = 0.0006) species were found on an average leaf compared with controls (1.3 ± 1.1 vs 2.7 ± 0.7).

In total, 43 species were collected from the leaves and small stems of understory brown beech leaves at the two sites. Two species were plant-parasites (Eriophyidae sp., *Tenuipalpus* sp.). While ten species were predatory (*Agistemus* sp., *Amblyseius* sp., *Asca garmani* Hurlbutt, Erythraeidae sp. 2, *Exothoris* sp., *Lasioseius* sp., *Oudemansicheyla coprosomae* Thewke and Enns, *Prosocheyla traubi* (Baker), *Typhlodromus dachanti* Collyer, *Zetzellia* sp.), a further 31 species were scavengers and fungivores (*Adhaesozetes polyphyllos* Walter and Behan-Pelletier, *Austrachipteria* sp., ?*Capillibates* sp., *Czenspinskia* sp., *Daidalotarsonemus* sp., *Eupodes* sp., Histiostomatidae sp., 4 spp. of Licneremaeoidea, ?*Maculobates* sp., *Neotrichozetes* sp., *Oripoda* sp.,

Table 2 A diverse and abundant fauna of mites inhabited brown beech trees in subtropical rainforests both in Lamington (Elabana Falls) and Miala (Green Falls) National Parks, Queensland. Forty-three species of mites were identified from leaves and small stems, with little overlap between sites (8%). Only five species collected from brown beech were also collected from rose marara. Values represent means ± standard errors for N leaves or segments of small stems subtending leaves.

Leaves:

Site	N	Mites / Leaf	Species / Leaf
Elabana Falls	30	41 ± 5	2.9 ± 0.2
Green Falls	17	13 ± 2	2.6 ± 0.3
Overall	**47**	**31 ± 4**	**2.8 ± 0.1**
Range		2 – 117	1 – 5
Total		1457	20

Stems:

Site	N	Length (cm)	Mites / cm	Species / Stem
Elabana Falls	3	14 ± 0.3	0.2 ± 0.1	2 ± 0.6
Green Falls	13	19 ± 1	0.6 ± 0.1	5 ± 0.7
Overall	**16**	**18 ± 1**	**0.5 ± 0.1**	**4.4 ± 0.7**
Range		10 – 27	0 – 1	0 – 8
Total		290	158	28

Pedrocortesella sp., Phthiracaroidea sp., *Pirnodus* sp., *Plumobates* sp., 5 spp. of *Scapheremaeus*, *Sulcoribula* sp. 2, 3 spp. of *Tarsonemus*, 3 spp. of Tydeidae, *Zeanothrus* sp.).

DISCUSSION

One hundred thirty-four leaves and 278 cm of small stems collected from the upper canopy of a single rose marara tree over a 16 month period were inhabited by 1352 mites representing 29 species. None of these species were found in samples of suspended soils from the bole of the same tree. Therefore, the mite fauna of the outermost canopy of a subtropical rainforest does not represent habitat extension by soil-inhabiting mites. Instead, as demonstrated for the oribatid mite fauna of a small temperate rainforest tree (Walter *et al.* 1994), mites inhabiting leaves and small stems in the subtropical canopy represent a distinct fauna. Another, richer fauna of mites probably awaits discovery among the epicorticolous lichens, mosses, and other epiphytes on the bole and large stems of the rose marara. This fauna should be distinct from both the soil fauna (see André *et al.* 1992; Wunderle 1992) and the leaf-small stem fauna.

Few species (five) were found in common between the rose marara and the brown beech at Lamington, although the trees are only a few kilometres apart. This is surprising; because, except for eight species of plant-parasitic mites, the remaining 29 species are predators and microbivores which might be expected to be non-specific in their plant assoiations. Similar functional groups in the soil fauna tend to occur widely within a habitat type (Dindal 1990) and many arboreal mites are known to have broad distributions and show no sign of species specificity (Walter 1992; Walter and Behan-Pelletier 1993; Walter *et al.* 1993; Walter *et al.* 1994). However, it is likely that the leaves of the two species represent strikingly different microhabitats to the mites.

The upper canopy rose marara leaves are directly exposed to the extremes of a subtropical climate. I recorded the lowest density of mites from leaves this of species on 7 December 1993 (Table 1), during a stormy period with intense rains. Rose marara leaves shed rain effectively, and probably tend to shed their mite fauna as well. Two of the most numerous leaf-inhabitants were both plant-parasites (an eriophyid mite and a *Schizotetranychus* spider mite) that spin silken webs under which they live. During the December rains, only the eriophyid mite and a *Tarsonemus* sp. (also found lurking under an eriophyid web) inhabited rose marara leaves.

In contrast, the leaves of brown beech have numerous refugia – the small cave-like pits formed by leaf domatia. Ninety-six percent of all the mites collected from brown beech leaves were found within leaf domatia. Although both rose marara and brown beech had up to five species of mites on a single leaf, brown beech leaves averaged three times as many mite species. Both the range and mean number of species per segment of stem was the same in both tree species, suggesting that the differences in habitat (e.g. upper vs lower canopy) or tree species was not affecting diversity per se. But, removing access to refugia by blocking leaf domatia reduced the average number of species per leaf by half, down to a mean similar to that found on rose marara. Thus, even at the level of the leaf surface, microhabitat influences mite diversity.

ACKNOWLEDGEMENTS

Many thanks to Dennis O'Dowd for his help on the blocking experiments and to Peter O'Reilly, the Queensland Forestry Commission, and the Queensland National Parks and Wildlife Service for their permission to collect, and to two anonymous referees for their comments.

REFERENCES

André, H.M., Lebrun, P. and Noti, M.-I. (1992). Biodiversity in Africa: a plea for more data. *Journal of African Zoology* **106**: 3–15.

Basset, Y. (1991). The taxonomic composition of the arthropod fauna associated with an Australian rainforest tree. *Australian Journal of Zoology* **39**: 171–190.

Coy, R., Greenslade, P. and Rounsevell, D. (1993). *A survey of invertebrates in Tasmanian rainforest.* Tasmanian NRCP Technical Report No. 9. Parks and Wildlife Service, Tasmania and Department of Arts, Sport, the Environment and Territories, Canberra.

Dindal, D.L., ed. (1990). *Soil Biology Guide.* John Wiley and Sons, New York.

Krantz, G.W. (1978). *A Manual of Acarology.* Oregon State University Book Stores, Corvallis, Oregon.

Nadkarni, N.M. and Longino, J.T. (1990). Invertebrates in canopy and ground organic matter in a neotropical montane forest, Costa Rica. *Biotropica* **22**: 286–289.

O'Dowd, D.J. and Willson, M.F. (1989). Leaf domatia and mites on Australian plants: ecological and evolutionary implications. *Biological Journal of the Linnean Society* **37**: 191–236.

Walter, D.E. (1992). Leaf surface structure and the distribution of *Phytoseius* mites (Acarina: Phytoseiidae) in south-east Australian forests. *Australian Journal of Zoology* **40**: 593–603.

Walter, D.E. (1993). Queensland's rainforest canopies – a mitey cornucopia. *Australian Entomologist* **20**: 115–116.

Walter, D.E. and Behan-Pelletier, V. (1993). Systematics and ecology of *Adhaesozetes polyphyllos*, sp. nov. (Acari: Oribatida: Licneremaeoidea) leaf-inhabiting mites from Australian rainforests. *Canadian Journal of Zoology* **71**: 1024–1040.

Walter, D.E., Halliday, R.B. and Lindquist, E.E. (1993). A review of the genus *Asca* (Acarina Ascidae) in Australia, with the description of three new leaf-inhabiting species. *Invertebrate Taxonomy* **7**: 1327–1347.

Walter, D.E. and O'Dowd, D.J. (1992). Leaf morphology and predators: effect of leaf domatia on the abundance of predatory mites (Acari: Phytoseiidae). *Environmental Entomology* **21**: 478–484.

Walter, D.E. and O'Dowd, D.J. (1995). Life on the forest phylloplane: hairs, little houses, and myriad mites. *In* M. Lowman and N. Nadkarni (eds), *Forest canopies – a review of research on this biological frontier*. Academic Press, New York. (in press)

Walter, D.E., O Dowd, D.J. and Barnes, V. (1994). The forgotten arthropods: foliar mites in the forest canopy. *Memoirs of the Queensland Museum* **36**: 221–226.

Wunderle, I. (1992). Arbicolous and edaphic oribatids (Acari) in the lowland rainforest of Panguana, Peru. *Amazoniana* **12**: 119–142.

Manuscript received 30 August 1994; accepted 21 September 1994.