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Observations on a *Diphucephala* species (Coleoptera: Scarabaeidae) and its feeding relationship with the giant stinging tree, *Dendrocnide excelsa* (Wedd.) Chew (Urticaceae) in Queensland, Australia

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Introduction

The genus *Diphucephala* (Scarabaeidae: Melolonthinae) contains many species which are adapted for feeding on leaves and a few for imbibing nectar (Britton, 1970). There are about 65 described species but the genus is in need of revision and almost nothing has been recorded on their biology. One *Diphucephala* species has been recorded on flowering *Acacia dealbata* Link. (Mimosaceae) in dry sclerophyll forest in the Blue Mountains, New South Wales (Hawkeswood, 1989) and Froggatt (1923) earlier recorded one species *D. aurulenta* (Kirby) as common on the foliage of the black wattle, *Acacia decurrens* (Wendl.) Willd. in eastern Australia. Hawkeswood (1989) recently provided field observations on the feeding and mating behaviour of *D. affinis* Waterhouse from heathlands in Western Australia. Nothing has been recorded previously on the biology of any *Diphucephala* species from rainforest.

The genus *Dendrocnide* (family Urticaceae) is represented in Australia by three rainforest species, the largest being *D. excelsa* (Wedd.) Chew (Francis, 1955). This species is a large tree growing to about 40 metres in height and occurs in sub-tropical, dry and littoral rainforests, particularly in areas disturbed by cyclones or clearing (Floyd, 1977). *D. excelsa* has been recorded from coastal scrubs from Tathra near Bega (southern New South Wales) to Imbil (south-eastern Queensland) (Floyd, 1977). The leaves of this plant are large, alternate, simple, cordate, dull green in colour and measure 10-30 cm long with a petiole 2.5-15.0 cm long. The abaxial (lower) surface is more or less glabrous. Both surfaces possess a sparse covering of rigid, stinging hairs (c. 1.5 mm long), which become fewer in number or disappear from the surfaces of old leaves on larger trees. The stinging hairs are more prominent on the primary and secondary veins than on the other leaf surfaces. The stems and petioles possess stinging hairs as well as normal, non-stinging hairs. Details of the chemistry and stinging effects of these hairs have been provided by Petrie (1906) and Francis (1955).

During December 1978, the author noticed the leaves of numerous, young *D. excelsa* plants partially skeletonized in a rainforest at Bellingen, north-eastern New South Wales (30°27'S, 152°53'E). No leaf-feeding insects were found on any of the stinging trees (1-3 m high) during several surveys of this rainforest community and it was presumed that the feeding had occurred during the evening or at night by nocturnal herbivores. The author has since noticed similar feeding damage to the leaves of stinging trees in the Lamington National Park (28°15'S, 153°02'E) and Mt. Tamborine (27°58'S, 153°11'E) areas of south-eastern Queensland but was

again unable to discover the organisms responsible for the damage. At all sites, there did not appear to be any deaths of plants (or even severe retardation of growth) as a result of the feeding damage, although one to several, heavily skeletonized leaves per plant had already discoloured and withered. Not all leaves per plant had been attacked. Opportunity to study some aspects of invertebrate herbivory on *D. excelsa* leaves did not arise until December 1983, and these observations are provided below.

Table 1. Number of *Diphucephala* beetles counted on the leaves of one plant of *Dendrocnide excelsa* (Wedd.) Chew on 26 December 1983, at Mt. Glorious, south-eastern Queensland, Australia

Leaf No.	Adaxial	Abaxial	Total	Leaf No.	Adaxial	Abaxial	Total
1	5	2	7	11	1	0	1
2	2	3	5	12	6	0	6
3	6	0	6	13	11	5	16
4	28	7	35	14	1	0	1
5	9	7	16	15	10	2	12
6	9	2	11	16	14	4	18
7	7	2	9	17	5	1	6
8	15	1	16	18	12	4	16
9	9	3	12	19	1	0	1
10	8	1	9	20	2	0	2

Totals Adaxial = 161, Abaxial = 44, Both surfaces combined = 205

Mean ± S.D. Adaxial = 8.1 ± 6.3, Abaxial = 2.2 ± 2.2, Both surfaces combined = 10.3 ± 8.3

Observations

On 26 December 1983 (c. 1130-1245 hrs, Eastern Australian Standard Time), 3 km north of Mt. Glorious, south-eastern Queensland (c. 27°25'S, 152°50'E), large numbers of an unidentified *Diphucephala* species (near *D. pygmaea* Waterhouse) (Scarabaeidae: Melolonthinae) (Figs. 2, 3) were observed feeding on the living tissues of a young *D. excelsa* plant (0.8 m high, with four main branches from near ground level). The plant possessed 29 leaves, of which 20 (69%) were occupied by the *Diphucephala* beetles. On one leaf, an adult of *Hoplostines viridipennis* Blackburn (Coleoptera: Chrysomelidae), a species usually found feeding on nettles, *Urtica* spp. (Urticaceae) (Hawkeswood, 1983, pers. obs.; 1987), was resting and did not feed during the observation period. The lower leaves of the young *D. excelsa* tree, which were the largest (i.e. c. 18-26 cm long, excluding length of the petiole), were more severely attacked than leaves situated towards the top of the plant. The number of beetles per leaf were counted; both adaxial and abaxial leaf surfaces were examined (Table 1). In the majority of the severely damaged leaves, the margins of the lamina, from the tip (apex) towards the petiole had been attacked first (Fig. 1). In other leaves, random damage had occurred. Estimates of the percentage leaf destroyed for all leaves possessing beetles at the time of observation were also undertaken (Fig. 4). The beetles fed on the leaf tissues between the veins but did not attempt to feed on the primary and secondary veins possessing stinging hairs (Figs. 2, 3). The majority of beetles were feeding on the largest leaves which were the ones most severely attacked. Feeding resulted in skeletonization of the leaf (Fig. 1). Large amounts of beetle excreta (black pellets, c. 1 mm long) littered the unaffected leaf surfaces and uneaten portions of leaves between areas of skeletonization (Fig. 2). An average of one or two pairs of beetles per leaf were mating on the adaxial leaf surfaces in semi-shade. If disturbed, some beetles rolled from the leaf where they were feeding or resting, underwent flight before hitting the ground and flew around the plant for up to about 10 seconds before returning to another leaf with other *Diphucephala*. Other beetles remained feeding on leaf tissues despite movements of the leaf on which they were resting, while others ceased feeding upon disturbance and remained motionless with their bodies raised by extension of all legs. Close examination indicated that the major veins had not been attacked (Figs. 2, 3) and stinging hairs were not chewed. When on the leaves, the beetles wandered over the hairs without effect. A return visit was made two days later to the same site but there were fewer beetles and feeding damage did not appear significantly greater than previously. A third visit was made three days later but no beetles were encountered on the plant nor any others.

Discussion

The first published record of beetle herbivory on Australian stinging trees appears to be that of the natural history notes of O'Reilly (1940), writing about his early life as a pioneer in the dense rainforests of the McPherson Range on the New South Wales-Queensland border. He writes about a beetle associated with the leaves of the gympie nettle (*Dendrocnide moroides* (Wedd.) Chew, Urticaceae) – "There is a small insect which lives exclusively on gympie leaves, devouring them stings and all; we don't know his name, but we call him the He-man beetle;

Fig. 1 Photograph of a portion of the *Dendrocnide excelsa* plant taken on the third day at Mt. Glorious, Queensland, showing the extent of feeding damage to the leaves.

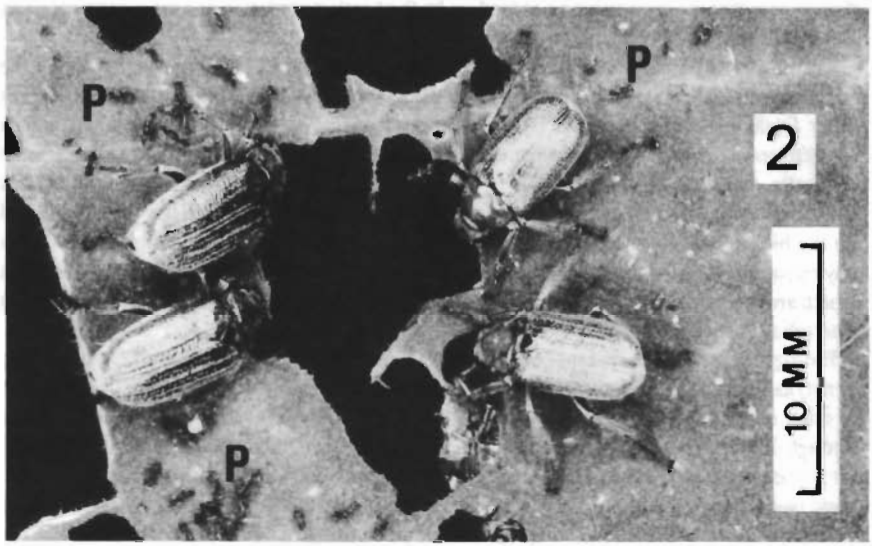

Fig. 2. Four *Diphucephala* beetles feeding on the lamina (adaxial) of a *Dendrocnide* leaf. Faecal pellets (p) can be clearly seen resting on the leaf. Note feeding occurs between the major veins.

he seems to have found the ideal formula for hot meals at all hours."! Although there is no description enabling identification of the insect in O'Reilly's book, it is probable that his "He-man beetle" is the same *Diphucephala* species from Mt. Glorious. Field observations on herbivory in the McPherson Range would be valuable for comparisons.

The vernacular name gympie nettle is usually referred to *D. moroides,* but occasionally (and incorrectly) to the related species, *D. excelsa;* from plant specimens at the Queensland Herbarium, Brisbane, it appears that *D. moroides* does not occur in the McPherson Range, so it is most likely that O'Reilly is referring to *D. excelsa,* (which is known correctly as the giant stinging tree).

From the observations presented here, it is significant that the majority of beetles, i.e. 161 out of the total 205 counted (78.5%) were found feeding on the *adaxial* surface of leaves (Table 1)(χ^2 = 66.8, critical value = 10.83, $p<0.001$). It is hypothesized here that feeding is more easily facilitated on the upperside of the leaves, rather than the underside, because the abaxial surface not only possesses stinging hairs but also a moderately dense covering of normal, simple, cellular hairs. Many of the beetles on the underside of leaves had previously been on the adaxial surface but after chewing through the leaf, had fallen or lost balance and had clung to uneaten leaves and other leaf tissues. The percentage of leaves chewed at the time of observation varied from 1-50% (Fig. 4) with the majority of leaves sustaining leaf material loss of 5-30%. Feeding did not result in the death of any leaves. Although the initial appearance of the beetle on *D. excelsa* leaves was not observed, it was apparent from the feeding observations on 26 December that the beetles had only recently emerged because the feeding damage was only recent. It would thus appear that the total duration of feeding by the beetle population as a whole is very short (i.e. 5-7 days).

The ability of this *Diphucephala* species to feed on the leaves of a host plant avoiding the stinging hairs during feeding is surprising, since recent observations have suggested that most other *Diphucephala* species are obligate flower feeders, either devouring petals, stamens (pollen) and/or nectar of their particular host plants (e.g. *D. affinis* Waterhouse from Western Australia, which feeds on the petals of *Hibbertia* (Dilleniaceae) and the pollen of *Acacia* (Mimosaceae), Hawkeswood, 1989). Unfortunately though, not enough has been published on the biology of *Diphucephala* for valid and meaningful comparisons to be made on the phylogeny and behaviour of this rainforest species with those of the other members of the genus which are predominantly found in dry sclerophyll forests, woodlands and heathlands of eastern Australia (Hawkeswood, 1975-1989, pers. obs.).

Biologists in the past have tended to regard thorns, prickles, and/or hairs (whether stinging or not) as adaptations by plants for protection against mechanical/physical damage by herbivores or other animals, which have the potential of severely damaging or killing the plants, either through direct feeding or by trampling. In the author's opinion, this hypothesis can only be valid for higher animals with some degree of learning capacity which after initial contact, learn to avoid plants which are harmful, especially those with stinging hairs. However, few studies have examined the effectiveness of stinging hairs on potential grazing animals. In Australia, the Urticaceae are the principal group which contain plants with stinging hairs. The genus *Dendrocnide* in particular would be an ideal starting point for such studies in this country, since apart from the published record of a horse being severely "stung" (Francis, 1955), there have

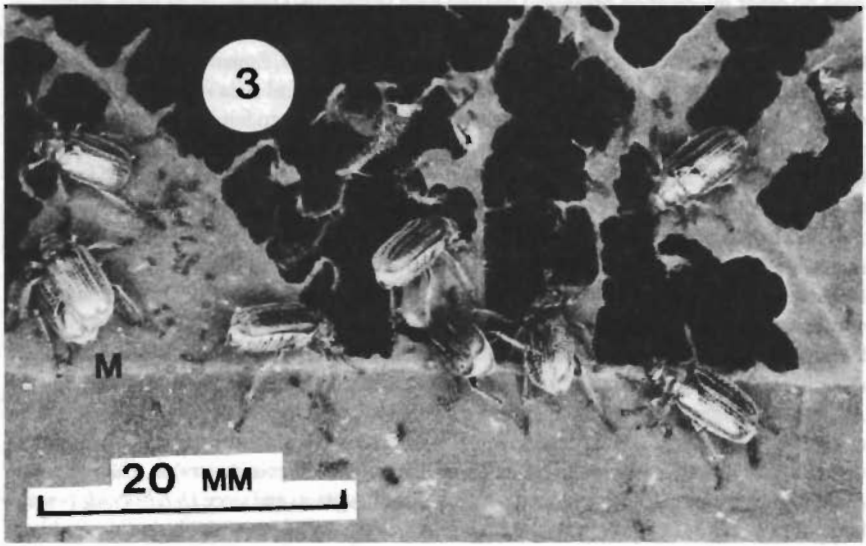

Fig. 3. Wider view of a *Dendrocnide* leaf showing gregarious feeding and attempted mating (m) of *Diphucephala* sp. on the upper leaf surface.

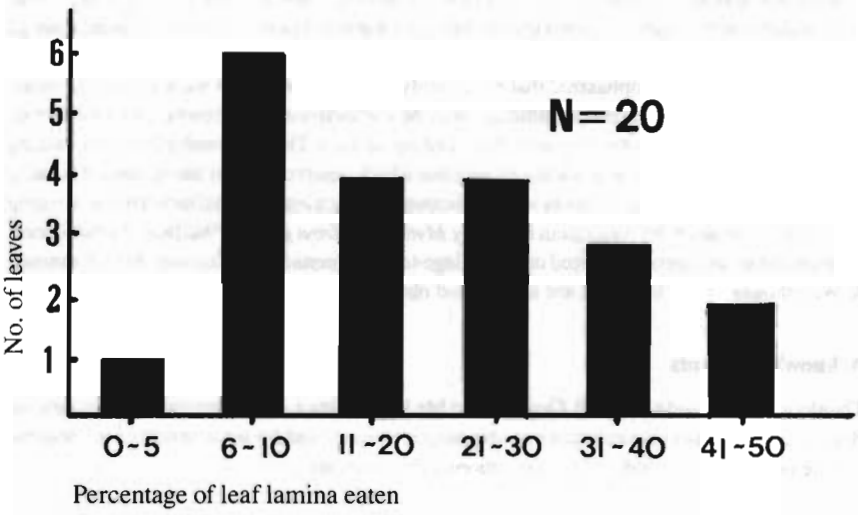

Fig. 4. Histogram showing the relationship between the percentage of leaf lamina eaten (arranged in six classes) and the number of leaves in each class.

been no other information presented dealing with vertebrate/*Dendrocnide* relationships.

Dendrocnide, other stinging trees, and the Urticaceae in general, are widely distributed in tropical countries of the world, especially Indonesia, Malaysia, Sumatra, Borneo and Papua New Guinea. Since the stronghold of *Dendrocnide* is in tropical Asia where over 30 species occur, it is highly likely that the Australian species, which are endemics and closely related to each other, have resulted from an ancestral species which migrated across the land bridge between Australia and Asia in the Cretaceous Period, some 65-100 million years B.P. However, this Indo-Malayan bridge is believed to have broken up at the end of the Cretaceous, about 50 million years B.P., thereby removing the most readily available means for plant and animal migration between the two land masses. It is interesting to note the limited speciation of *Dendrocnide* in Australia compared to that in Asia. Only one species, *D. excelsa*, reaches the cool temperate rainforests of southern New South Wales, while the other two are restricted to the sub-tropical rainforests of southern Queensland and northern New South Wales. The factors affecting speciation in this genus are not known with any certainty but it is most likely that the Australian *Dendrocnide* have adapted to a different suite of phytophagous animals than their counterparts in Asia. For instance, some of the most prominent animals of rainforest communities in Asia are arboreal primates, which are absent from Australia. These animals feed extensively on the fruits, flowers and leaves of various plants and since *Dendrocnide* possess large, fleshy, edible, drupaceous, aggregate fruits, these would be particularly susceptible to feeding damage by monkeys (as well as birds and possibly bats). Some *Dendrocnide* possess stinging hairs on the fruits in addition to stems and leaves (e.g. *D. excelsa*) to protect against fruit-eating animals. However, the adaptations of *Dendrocnide* are not apparently effective against invertebrate foragers such as the *Diphucephala* species on *D. excelsa*, although there is no evidence at this stage to suggest that the beetles are able to kill plants (or even leaves) through their destructive feeding.

Clearly it should be emphasized that even highly evolved adaptations such as stinging hairs, which are effective against certain animals, may be ineffective against others, and therefore do not secure total protection for the plants from feeding damage. The relationship between stinging trees and beetles reported here is a fascinating one which deserves further study, since it is likely that additional invertebrate foragers will be discovered which are also unaffected by the stinging hairs. (The larvae of the Australian butterfly *Mynes geoffroyi guerini* Wallace (Lepidoptera: Nymphalidae) are reported to feed on the foliage of *Dendrocnide* (McCubbin, 1970; Common & Waterhouse, 1981) but there are no detailed observations published on this relationship).

Acknowledgements

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Summary

Observations are provided on destructive leaf-feeding of the Giant Stinging Tree, *Dendrocnide*

excelsa (Wedd.) Chew (Urticaceae) by a *Diphucephala* species (near *D. pygmaea* Waterhouse) (Coleoptera: Scarabaeidae: Melolonthinae), a rain-forest scarab beetle from Mt. Glorious, south-eastern Queensland, Australia. Larger leaves were found to be more severely attacked than smaller leaves and although feeding damage was destructive (i.e. most leaves sustained removal of 5-30% of total leaf tissues), no leaves were killed. Other behavioural observations on the *Diphucephala* beetles are provided. The adaptations of *Dendrocnide* against herbivory are discussed; it appears doubtful whether the stinging hairs afford any protection from herbivory by the scarab beetles. The general lack of published data on herbivory of *Dendrocnide* is highlighted.

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