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Pyrrolizidine alkaloid-related pharmacophagy in neotropical moths (Lepidoptera)

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Abstract. Baiting tests with pure pyrrolizidine alkaloids (PAs) in Costa Rica, French Guiana, and Peru attracted more than 1,000 ctenuchid and arctiid moths representing 98 species. In combination with literature data on the attractivity of dry PA-containing plants, more than 200 moths species pharmacophagous for those substances can be assumed to exist in the neotropics, which is higher than the numbers hitherto recorded from the Old World tropics. The need for more comprehensive surveys in the neotropics for an evolutionary understanding of PA-related pharmacophagy is emphasized.

Key Words. Arctiidae, Ctenuchidae, pharmacophagy, secondary plant substances, non-nutritional insect-plant relationships, unpalatability, mimicry.

Introduction

The syndrome of pharmacophagy where insects actively search for and take up secondary plant substances independent of their nutritional requirements and use them to increase their fitness (Boppré 1984, cf. Boppré 1996) has been documented for several insect taxa, particularly with respect to pyrrolizidine alkaloids (PAs). In the Lepidoptera, for example, nymphalid butterflies of the Danainae and Ithomiinae sequester PAs gathered by (male) adults from withering or dry plants of PA-containing plants and subsequently use these substances for their own defence (Brown 1984) and as precursors for the biosynthesis of male pheromones (for reviews see Boppré 1986, 1990, 1995).

With respect to moths, baiting tests with pure PAs in several parts of the Old World tropics have shown that PA-related pharmacophagy of adult Lepidoptera occurs in at least 10 genera of the Noctuoidea from the Afrotropical as well as from the Oriental region (cf. Boppré 1990). From the New World tropics, hitherto only a few reports on the attraction of moths to dry material of several PA-containing plants exist (e.g., Jörgensen 1913, Moss 1947, Beebe 1955), and pure PAs have rarely been used as baits (but see Pliske 1975). This paper presents results of pilot field tests on the attractivity of purified PAs for moths from three different sites in the neotropical region.

Material and methods

Field work was carried out at Sirena, Peninsula de Osa, Puntarenas, Costa Rica, from 19

to 26 February 1989 (dry season), during a period of four weeks in September/October 1989 (dry season) at different locations near Saül and St. Elie, French Guiana, and at Pakitza Biological Station, Parque Nacional del Manu, Madre de Dios, Peru, from 28 September to 18 October 1991 (end of dry season). Sirena is located in slightly disturbed coastal primary forest, Saül (300 m) and St. Elie (40-60 m) are in areas of upland rainforest, and Pakitza is situated in an alluvial floodplain of the upper Manu river covered by undisturbed primary forest at 340 m elevation.

Plastic dishes (10 x 7.5 cm) containing 50-200 mg of PAs were exposed for varying periods of at least two to four hours both during day and night. PA-baits were made from purified methanol extracts of ripe seeds of *Crotalaria scassellatii* (Fabaceae) collected in Kenya, East Africa. In addition, pure monocrotaline (Aldrich) and heliotrine extracted from *Heliotropium europaeum* (Boraginaceae) was used. At Pakitza dried plants of locally occurring *Heliotropium indicum* (Boraginaceae) were tested in comparison with the pure chemicals.

Almost all moths landing on the PA-dishes and plant material, respectively, were collected for subsequent identification; a few (less 10%), however, escaped particularly at times of many specimens arriving at the same time. Males were checked for the presence of eversible abdominal coremata and externally visible androconial organs. Our tentative determination and classification of the specimens is based on Hampson (1898) and Draudt & Seitz (1915-1917).

Results

The purified PA-extracts proved to be attractive for a large number of diurnal as well as nocturnal species of moths in all three habitats. Attracted specimens landed at the dishes, enrolled their proboscides, applied fluid onto the bait material and reimbibed it with dissolved compounds as has been described and illustrated for several Old World pharmacophagous moths and butterflies (Boppré 1986). The same behaviour could also be observed at the dried *Heliotropium* used in Pakitza which also attracted many moths (cf. Beebe & Kenedy 1957, Pliske 1975).

All moths collected at the PA-baits belong to the families Ctenuchidae (= Syntomidae) and Arctiidae in the Noctuoidea, most of which show aposematic coloration and represent (co-)mimics of aculaete Hymenoptera or otherwise distasteful insects (cf. Draudt & Seitz 1915-1917, Beebe & Kennedy 1957). In total, 1,019 specimens were collected, representing at least 98 species in more than 26 genera. All samples show a strong male-bias, both at the purified PAs and at the *Heliotropium*, and females were only recorded for a few species. In many species, males possess spectacular abdominal coremata or other conspicuous androconial organs.

At Sirena, a total of 140 specimens representing 21 species were recorded which are listed in table 1. Only 24 females were found, and 15 species were represented by

males exclusively. In 13 species, the males possess conspicuous abdominal androconial organs mostly in form of extrusible brushes of hair-like scales (coremta) or pneumatically eversible tubes. In two *Episcepsis* species, the males possess no abdominal coremata but instead patches of hair-like scales inside a pouch along the anal margin of the upperside of the hindwing.

At Pakitza, a total of 796 specimens representing at least 54 species were recorded at PA-sources. Eight species only were represented by females, and, again, males of many species possess conspicuous abdominal or alar androconial organs. Proper identification of many taxa is still pending, and detailed results will be published elsewere (Häuser & Boppré in prep.).

In French Guiana, 83 specimens representing at least 25 species were recorded. Females were found only in three species, and most males show coremata or other androconial organs. The spectra of species collected at the three different localities show hardly any overlap. Only *Desmotriche ursula* and *Episcepsis lenaeus* were found in Pakitza as well as in Sirena. At all three localities, however, a considerable number of further arctiid and ctenuchid taxa occured that have never been observed at PA-sources previously.

Discussion

The attractivity of baits made of pure PAs for many species of Arctiidae and Ctenuchidae clearly shows that previous reports about the attraction to wilted *Heliotropium*, *Eupatorium*, and other plants in the Neotropics (Jörgensen 1913, Moss 1947, Beebe 1955, Pliske 1975) can be attributed to PA-related pharmacophagy. During a period of more than ten months spent at seven different sites in Panama, Venezuela, Trinidad, Guyana, and Ecuador, Pliske (1975) attracted 140 species of Ctenuchiidae and 36 Arctiidae with dry *Heliotropium* spp. and other PA-containing plants (including *Tournefortia* (Boraginaceae), *Eupatorium* (Asteraceae), and *Crotalaria* (Fabaceae)). At Simla on Trinidad, 9 of 13 species of Ctenuchidae studied by Beebe & Kenedy (1957) would be attracted to dry *Heliotropium*. With a few exceptions, none of the species recorded by these authors appear in our own records from Costa Rica, French Guiana, and Peru.

Considering the data from the literature in addition to our own results reveals at least 200 species of neotropical Ctenuchidae and Arctiidae that can been recognized as being pharmacophagous towards PAs. Even though the available information must still be considered as being far from comprehensive, it is obvious that the diversity of PA-related pharmacophagy among New World moths is much larger than in the Old World.

Regarding the biological function(s) of the ingested PAs in neotropical Ctenuchidae and Arctiidae much is still open to speculation. Aposematic coloration and life-style typical for many of the taxa (cf. Draudt & Seitz 1915-1917, Beebe & Kenedy 1957, Blest 1964) might indicate storage of PAs for protection, which has been demonstrated for a variety of

Old World taxa (for references, see Hartmann & Witte 1995). This assumption is further supported by the finding that a large number of neotropical ctenuchids and arctiids have been shown to be distasteful for several vertebrate and invertebrate predators (Beebe & Kennedy 1957, Blest 1964, Watson 1980).

Any additional use of PAs known from other insects, e.g., as precursors for pheromone biosynthesis or as a morphogenetic factor (Boppré 1986) must remain speculative at present, but the frequent occurence of eleborate androconial organs could be interpreted also in that context. Histological studies of a few Ctenuchidae have shown that these organs indeed are equipped with or connected to glandular tissue (Barth 1953). However, in the Old World not all PA-pharmacophagous species possessing androconial organs utilize PAs as pheromone precursors (Boppré, unpubl.).

Perspectives

Additional data from different seasons and other habitats are required for a comprehensive list of PA-pharmacophagous neotropical moths. A comparison of related species which do or do not utilize PAs but occur sympatrically should permit conclusions about the ecological parameters responsible for the evolution of pharmacophagy, which, however, must probably await further systematic revisions and phylogenetic studies of neotropical Arctiidae and Ctenuchidae. We continue to work along those lines and would certainly be grateful for the communication of any observations on relations between insects and PA-containing plants.

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Table 1: List of moths species attacted to purified PAs at Sirena, Costa Rica, during 19. - 26. February, 1989. N = total number of specimens collected; d/n: d = attracted by day, n = attracted by night; ♀ = females attracted; cor = abdominal coremata present.

Ctenuchidae	N	d/n	♀	cor
Aclytia punctata Btlr.	4	n		+
Correbia lycoides Wkr.	6	n		+
Correbidia cf.continentalis Drt.	1	n		
Desmotricha ursula Cr.	1	n		
Episcepsis lenaeus Cr.	6	n		
Episcepsis cf.*redunda* Schs.	4	n		
Eucereon pseudarchias Hmps.	16	n	+	+
Eucereon punctatum Guér.	33	n		+
Eucereon varians Wkr.	11	n		+
Eucereon sp.	3	n	+	
Loxophlebia sp.	1	d		
Loxophlebia sp.	4	n		
Napata leucotelus Btlr.	1	d		
Sphecosoma sp.	4	d		
Sphecosoma sp.	1	d		
Arctiidae				
Agoraea semivitrea Rthsch.	14	n	+	+
Baritius haemorrhoides Schs.	2	n		+
Halisidota sp.	4	n	+	
Halisidota sp.	11	n	+	
Halisidota sp.	10	n	+	
Hemihyalea sp.	3	n		+