

Pharmacophagy in grasshoppers?

Zonocerus attracted to and ingesting pure pyrrolizidine alkaloids

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Abstract

Zonocerus elegans has been found to be attracted to pure pyrrolizidine alkaloids and to ingest them. This finding makes the species likely to be pharmacophagous; also, it might provide means of controlling *Zonocerus*, and it indicates the importance of olfaction for localizing and recognizing host-plants in grasshoppers.

Introduction

Many plants having pyrrolizidine alkaloids (PAs) as secondary substances in common, when withered, are known to attract certain butterflies and moths which ingest PAs by applying a fluid via their proboscises onto the dry plants and reimbibing it (details and refs. in Pliske, 1975; Boppré, 1978, 1984a).

In the course of baiting Lepidoptera in open *Acacia* bushland in the Hluhluwe area of Zululand (Natal, Rep. of South Africa) in February/March 1981, adults of both sexes of the Elegant Grasshopper, *Zonocerus elegans* (Thunb.) (Orthoptera: Pyrgomorphidae), were attracted to and fed on withered (air-dried) whole plants of *Heliotropium steudnerii* (Vatke) (Boraginaceae), displayed as baits on 20 × 30 cm white cotton gauze on the ground. Also, plastic Petri dishes (diameter, 86 mm) containing unquantified methanol extracts of air-dried plant material of various species of *Senecio* (Asteraceae), *Heliotropium*, and *Crotalaria* (Fabaceae) and placed in the field after evaporation of the solvent, invariably attracted *Zonocerus* adults which tried to ingest the PA-containing residue.

The grasshoppers approached the plant material and the extracts respectively by walking upwind in

a direct manner over distances of at least 3 m, while moving their antennae vigorously. They reacted best when there was sunshine. If the *Heliotropium* had been covered with gauze, *Zonocerus* tried eagerly to reach the plant. Similarly, if the dishes were covered with gauze, they tried to bite through it. Empty gauze bags and empty dishes put out as controls were never visited. Thus, the behaviour exhibited by *Zonocerus* is clearly chemically mediated.

Because *Z. elegans*, like *Z. variegatus* (L.), is an aposematic species, the latter being known to feed on a great variety of plants, including so-called poisonous ones (Bernays *et al.*, 1975; Toye, 1982 and refs. therein), and to store noxious secondary plant substances including PAs (Bernays *et al.*, 1977), we tested whether attraction to *Heliotropium* and extracts of PA-plants is due to PAs alone. The experiments were conducted in November/December 1982, when there were only nymphal stages (15–25 mm long) of *Z. elegans* available.

Firstly, six dishes containing either heliotrine (H) or a mixture of senecionine and fuchsisenecionine (SF) respectively, in amounts of 50 and 100 mg, and two empty ones (controls) were placed at distances of 20–200 cm apart on the ground in a straight line perpendicular to the wind direction. *Zonocerus*

nymphs climbing onto the dishes were counted for 1 h 14 times within two weeks. All dishes were visited by *Zonocerus* but not by any other Orthoptera abundant in the area. The baited dishes attracted a total of 470 specimens, while only five came to the controls. Mean numbers of visits per hour were 6.5 for H-, 11.4 for SF-dishes, and 0.7 for controls. The nymphs at the pure PA-sources behaved as the adults at withered *Heliotropium* and at crude extracts. The insects walked rather slowly towards the dishes, climbed onto the gauze cover and stayed there for a few minutes, waving their antennae up and down and trying to get into the dishes while slowly moving forward. Often, they finally entered a nearby grass plant and stayed there next to the dish. Uncovered dishes were entered by *Zonocerus* which spent up to 15 min trying to feed from the thin crystalline PA-layer before continuing their walk around the rim or moving on to a nearby blade of grass. During the few visits at control dishes, however, the nymphs did not wave their antennae and remained motionless for the most part.

Secondly, glass fibre discs (Whatman GF/A; diameter, 21 mm) were impregnated with 10 mg of heliotrine in methylenchloride or with this solvent alone (controls), then dried and exposed pairwise (one baited, one control) by pinning them 5 cm apart of each other in the grassland (up to 2 cm

above the soil). Nine such tests were done at irregular intervals (not more than one per day) for the same periods, lasting from 1 to 4 h (depending upon weather conditions and the arrival time of the first *Zonocerus*). All baited discs were finally partly eaten by 1–3 nymphs at a time, while seven out of nine controls remained completely untouched (Fig. 1). The mean percentages eaten were 35.8 (range, 15.9–74.9) from baited discs, and 0.63 (range, 0–5.4) from the controls ($p < 0.01$, Wilcoxon matched pairs signed rank test, two-tailed).

In summary the results demonstrate that both adults and nymphs of *Z. elegans* are (i) capable of detecting PAs of different chemical structure over a distance and that pure PAs elicit (ii) upwind walks and (iii) ingestion. It has to be emphasized that all tests were done in a resident population of *Zonocerus*, i.e. PAs lured the insects away from their food plants. How strongly PAs stimulate *Zonocerus* is also impressively shown by the fact that PAs were ingested on the ground although *Zonocerus* usually feeds on the tips of plants only. In the disc tests, nymphs often mounted the holding pin and were found sitting motionless 5–6 cm above the baited disc.

The observations reported here demonstrate that *Z. elegans* searches for and ingests PAs independently from the consumption of food; thus, it is most

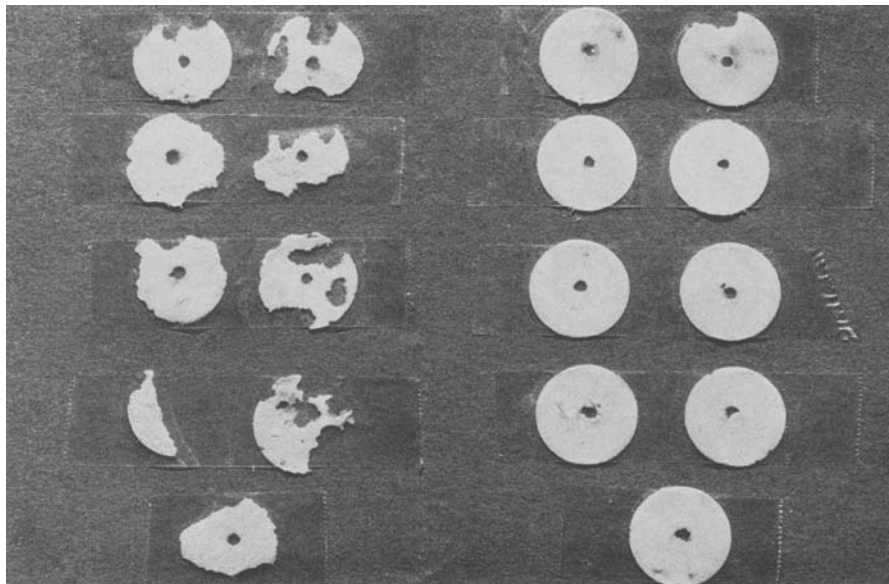


Fig. 1. Glass fibre discs impregnated with 10 mg of heliotrine in methylenchloride (left) and with methylenchloride only (right) after being exposed to *Zonocerus elegans* in the field.

likely a pharmacophagous species (Boppré, 1984b). However, the biological significance of PA-uptake by *Zonocerus* is not yet completely clear and is therefore the subject of ongoing studies. Obviously, PAs are not cues for locating/identifying food plants. Since *Zonocerus* store PAs (Bernays *et al.*, 1977), are strongly aposematic and not attacked by predators, it is probable that PAs contribute to the chemical protection of the species. Additional, and perhaps even more significant, functions of PAs for *Zonocerus* are possible or even likely, as appears to be the case in other insects associated with PA-containing plants. Several unrelated groups of Lepidoptera utilize PAs as precursors of male pheromones (refs. in Boppré, 1978, 1984a); moreover, in the arctiid genus *Cretonotos*, these plant chemicals in addition regulate specifically the growth of the androconial organs (Schneider & Boppré, 1981; Schneider *et al.*, 1982). We intend to investigate whether PAs also have effects on the development and/or reproduction of *Zonocerus*, since for the sister species of *Z. elegans*, *Z. variegatus*, it has been suggested that its increased abundance in Nigeria may be due to the ever-increasing spread of *Chomolaena* (= *Eupatorium*) *odorata* (Toye, 1974) – *Chomolaena* species are known to be rich in PAs (refs. in Smith & Culvenor, 1980).

The strong behavioural responses to PAs might be applicable for controlling *Zonocerus* in areas where it occurs as a pest. Furthermore, our observations demonstrate the importance of olfaction for localizing and recognizing plants; this had not been clearly established so far (Uvarov, 1977), except to demonstrate that *Schistocerca* can react to grass odours by upwind movements (Haskell *et al.*, 1962; Moorhouse, 1971). Laboratory experiments, combined with further field studies, are expected to provide more details on the aspects discussed above.

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Zusammenfassung

Pharmacophagie bei Heuschrecken? Zonocerus wird von reinen Pyrrolizidin-Alkaloiden angelockt und nimmt sie auf

Zonocerus elegans wird von reinen Pyrrolizidin-Alkaloiden angelockt und nimmt sie auf. Dieser Befund macht es wahrscheinlich, daß die Art pharmacophag ist; ausserdem könnte er neue Möglichkeiten zur Kontrolle von *Zonocerus* eröffnen und gibt Hinweise auf die Bedeutung des Geruchs für die Lokalisation und Erkennung von Wirtspflanzen bei Heuschrecken.

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