Journal of the Lepidopterists' Society
44(3), 1990, 156–162

INTERACTION OF *PYRAUSTA PANOPEALIS* (PYRALIDAE) WITH A NEWLY-REPORTED HOST, THE ENDANGERED MINT *DICERANDRA FRUTESCENS* (LABIATAE)*

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ABSTRACT. *Dicerandra frutescens* (Labiatae), an endangered mint endemic to Florida, is a previously unrecorded food plant for *Pyrausta panopealis* (Pyralidae). *Pyrausta panopealis* tolerates the plant's terpene-based defenses, which it uses to its own advantage. As a defensive response, the larva regurgitates fluid containing pulegone, the principal terpene within its foliar diet. Preliminary findings indicate that the oral discharge has anti-insectan activity.

Additional key words: food plant, chemical defense, terpenes, defensive regurgitation, silk.

Pyrausta panopealis (Walker), a pyralid of the *phoenicealis* species group, is distributed pantropically (Munroe 1976). Its sole previously recorded larval food plant is *Hyptis capitata* Jacquin (Labiatae) in Puerto Rico (Schaus 1940). Although Schaus lists the species as *phoenicealis*, current understanding of the two species (Munroe 1976) indicates that the Puerto Rican record is actually *panopealis*. We here report a new larval host of *P. panopealis*, the endangered scrub balm, *Dicerandra frutescens* Shinners (Labiatae), and also examine some aspects of the moth's behavior in light of its host's phytochemistry.

D. frutescens is a low-growing shrub, flowering in August–September. It is endemic to the sand pine scrub habitat of Highlands County in central Florida (Kral 1982, Huck 1987). Due to its limited distribution of probably no more than 100 ha (M. Deyrup, pers. comm.), *D. frutescens* has been declared a federally endangered species (Code of Federal Regulations 1988). As is typical for mint plants, damage to the foliage of *D. frutescens* results in emission of a strong terpenoid odor. Twelve monoterpenes responsible for the fragrance of the plant have been characterized. These chemicals are concentrated in glandular capsules, distributed over the entire leaf surface (Eisner et al. 1990).

MATERIALS AND METHODS

During 17–21 October 1989 at the Archbold Biological Station, Lake Placid, Florida, USA, we examined one of the more extensive remaining

* Paper no. 97 in the series *Defense Mechanisms of Arthropods*. Paper no. 96 is Mason et al., *Naturwissensch.* (in press).

stands of *D. frutescens* plants. In a subplot covering about 40 m^2 that we inspected in detail, 25 mid- to late-instar larvae of a pyralid (Fig. 1D) were found. These were collected and reared to adults (Fig. 1A), which were identified as *P. panopealis*. An adult was also collected when it was flushed from a *D. frutescens* patch. Voucher specimens of the adults are deposited in the Cornell University Insect Collection, lot #1184.

To determine if *P. panopealis* larvae consume the terpene-bearing capsules of *D. frutescens*, foliage was prepared for scanning electron microscopy. Three chewed leaves, each from a different larva, were frozen by rapid immersion in liquid Freon 22 (jacketed by liquid nitrogen) and immediately freeze-dried. [Freon 22 is preferable to Freon 12 for this purpose, because as a hydrochlorofluorocarbon (rather than a chlorofluorocarbon), it degrades environmentally more quickly, supposedly before reaching the upper atmosphere.]

When disturbed by pinching with forceps, *P. panopealis* caterpillars writhe vigorously, coating themselves and their immediate environs with vomit. To determine whether the egested fluid contains the food plant's terpenes in unaltered form, vomit was obtained from a last instar larva collected on 4 February 1990 at the Archbold Station and transported to Cornell where it was allowed to consume fresh *D. frutescens* foliage. The larva was disturbed on a chilled depression slide, and its regurgiated fluid was collected with calibrated microcapillary tubes. A capillary tube containing ca. 0.4 μL of fluid was stored in a capped reaction vial at −78°C, and its contents were examined directly, without solvent, by gas chromatography (Attygalle & Morgan 1988). Instrumentation included a Hewlett Packard 5890 series II gas chromatograph equipped with a solid sample injector and a J & W Scientific DB1 30 m × 0.25 mm capillary column held at 40°C for 5 min then ramped up to 200°C at 10°C/min. Foliage fed to the larva supplying the vomit sample was itself analyzed for terpene content as previously described (Eisner et al. 1990).

To determine whether larval regurgitated fluid has anti-insectan potential, it was tested for topical irritancy using a cockroach scratch bioassay (Eisner et al. 1976, 1990). In this assay, a fluid sample is applied to the integument of decapitated roaches (last instar nymphs of *Periplaneta americana* (L.), Blattidae), and the delay to onset of leg-scratching of the stimulated site is timed to provide the criterion of irritancy. Active samples usually produce scratching in less than 30 sec. Due to the limited quantity of vomit available from the single *P. panopealis* that was "milked", only one application could be performed. The single sample (ca. 0.1 μL) was applied with a microcapillary tube to one side of the fifth abdominal tergite of a roach. As a control, a comparable

volume of distilled water was applied shortly thereafter to the opposite side of the same tergite.

OBSERVATIONS AND RESULTS

The solitary larvae of *P. panopealis* construct a loose, silken retreat, in which they incorporate *D. frutescens* leaves, including those upon which they feed (Fig. 1B, C). Only after persistent prodding with forceps did the caterpillars leave their enclosures. Individual strands of the webbing were densely beset with tiny fluid droplets (Fig. 1E).

In the field there was some tendency for larvae to feed upon leaves of branches bearing recently senesced blossoms (Fig. 1B). However, both field and laboratory observations showed that they are capable of consuming foliage of non-flowering branches as well. Scanning electron microscopic examination of the three leaves that were being eaten by larvae indicated that *P. panopealis* fully consumes the terpene-containing glandular capsules (Fig. 1F).

Gas chromatographic analysis of the oral effluent of the larva revealed the presence of a single major terpene, pulegone. Pulegone was also found to be the principal monoterpene in the leaves upon which the larva had fed.

The vomit of the *P. panopealis* larva proved irritating in the cockroach scratch test. Application of the fluid elicited vigorous scratching at 19 sec, unlike the control, which failed to induce a response.

DISCUSSION

Plant terpenes commonly have anti-insectan properties. This is true for the scrub balm's terpene mixture and its major components, including pulegone (Eisner et al. 1990). A diet of 0.2% pulegone (fresh *D. frutescens* foliage is ca. 1.0% pulegone) adversely affects the development and reproduction of the generalist lepidopteran *Spodoptera eridania* (Cramer) (Noctuidae) (Gunderson et al. 1985). The pulegone-rich oil of pennyroyal, *Mentha pulegium* (L.) (Labiatae), is an antifeedant with high toxicity for larval *Spodoptera frugiperda* (J. E. Smith) (Noctuidae) (Zalkow et al. 1979).

P. panopealis is undeterred by the mint's chemical defense. It ingests the glandular capsules, and must therefore be exposed to its host's terpenes, both orally and enterically. Beyond its tolerance of the plant's chemicals, *P. panopealis* evidently uses the compounds for its own benefit: the single pulegone-laden oral discharge sample that we tested had anti-insectan properties. By the same *Periplaneta* assay used to test the vomit, pulegone itself has been shown to be irritating (Eisner et al.

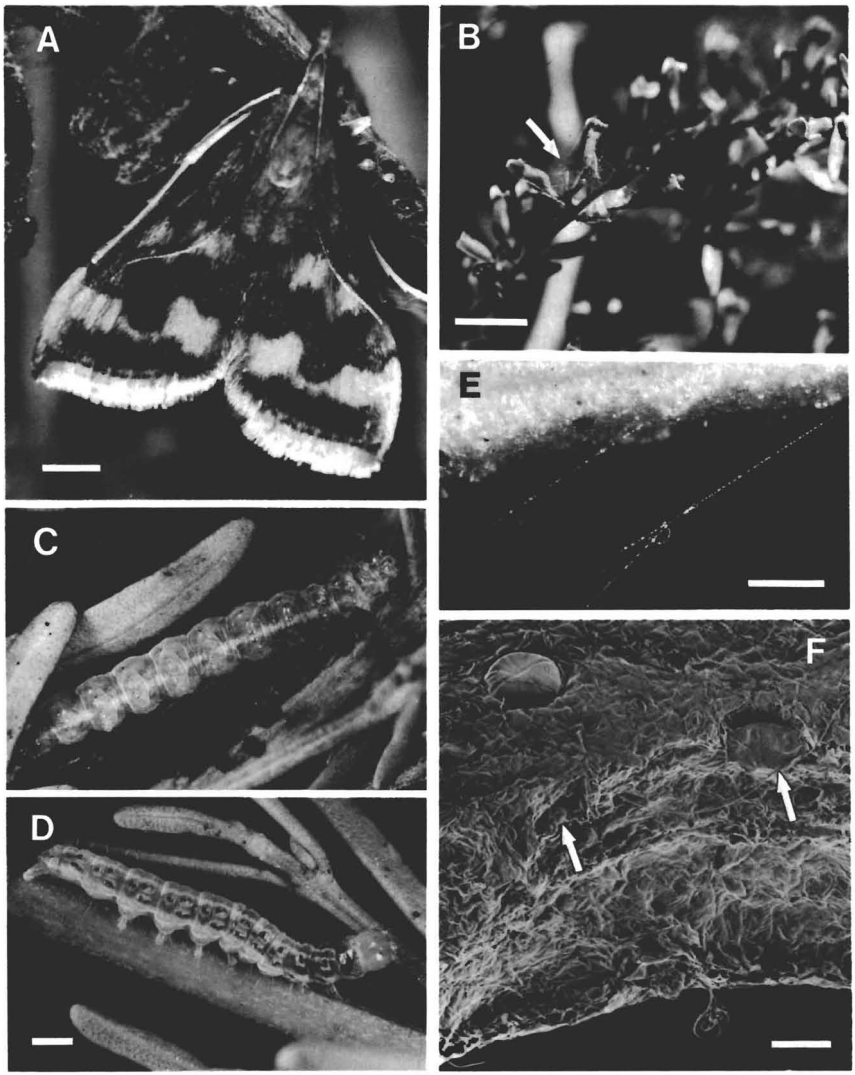

FIG. 1. *Pyrausta panopealis* and its host plant *Dicerandra frutescens*. A, Adult female (brownish purple, markings golden yellow); B, Larva within silken enclosure (arrow) on branch with senesced flowers; C, Enlarged view (ventral) of larva in enclosure; D, Larva (pale green, stripes greenish yellow, tubercles black) removed from enclosure; E, Anchoring threads of larval enclosure. Note fluid droplets on threads; F, Scanning electron micrograph of chewed leaf margin. Note intact (upper left) and ruptured glandular capsules. Arrows point to chewed margin of capsules. Scale bars: (A) 1 mm; (B) 1 cm; (D) 1 mm; (E) 0.5 mm; (F) 50 μm.

1990). Defensive regurgitation of diet-derived materials has been documented for other larval Lepidoptera as well (Common & Bellas 1977, Eisner et al. 1980, Peterson et al. 1987).

Terpene tolerance is likely characteristic of the majority of the congeners of *P. panopealis*, for they too are specialists on Labiatae (Munroe 1976). One possibility is that these mint-feeders possess an enzymatic means of detoxifying dietary terpenes. Induction of cytochrome P-450 dependent monooxygenases, glutathione transferases, and 1-naphthyl acetate esterase has been implicated in terpene degradation by lepidopterans (Yu 1986). A survey of the midgut aldrin epoxidase activity (an indicator of cytochrome P-450 dependent oxygenase activity) of 58 species of larval lepidopterans reports high activity invariably associated with the ingestion of host plants containing monoterpenes (Rose 1985).

Hyptis, the labiate genus upon which *P. panopealis* had previously been reported to feed, occurs within both the New and Old World tropics (Mabberley 1987). *Hyptis* may therefore potentially serve as a host over much of the range of *P. panopealis*. At least two species of *Hyptis* are sympatric with *D. frutescens* (Vander Kloet 1986). *Hyptis* and D. *frutescens* share a minimum of five monoterpenes (Luz et al. 1984, Tanowitz et al. 1984, Malan et al. 1988, Eisner et al. 1990). The shared chemistry may well play a role in the use of both mint genera by *P. panopealis*, particularly if the terpenes, either singly or in combination, have ovipositional or phagostimulatory activity for the moth. Monoterpenes are known ovipositional stimulants (Fatzinger & Merkel 1985, Hanula et al. 1985, Leather 1987) and phagostimulants (Harborne 1988) for lepidopterans.

The use of silken enclosures by larval lepidopterans is common and likely provides protection against certain predators, parasitoids, and abiotic factors. However, to our knowledge, presence of fluid droplets on the strands of such retreats has not been previously reported. These droplets may enhance the webbing's defensive function. They could act physically as an adhesive or chemically as a deterrent, depending on their specific properties. Defensive placement of droplets on silken strands has been noted in certain chrysopids, where such droplets are spaced along the egg stalk and act to repel ants (Eisner 1970, fig. 16B).

A minor point concerns the chemical composition here reported for *D. frutescens* leaves. We previously noted for spring foliage the presence of *trans*-pulegol and pulegone as the main terpene constituents of the plant (Eisner et al. 1990). The analysis of winter foliage reported here did not detect trans-pulegol. This may well reflect seasonal variation in the terpene composition of *D. frutescens*, a phenomenon reported for other mints (Cabo et al. 1987, Holm et al. 1988).

ACKNOWLEDGMENTS

This work was supported in part by NIMH (to S.R.S.) and NIH (to K.D.McC.) predoctoral traineeships and grants AI-02908 and AI-12020 from NIH. We thank Dr. Athula B. Attygalle for advice on chromatographic technique, Maria Eisner for electron microscopy, Dr. John G. Franclemont for identification of the moth, and the staff of the Archbold Biological Station for help and hospitality.

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Received for publication 12 March 1990; revised and accepted 12 June 1990.