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Insect Symbionts of Some Mexican Cycads in Their Natural Habitat

Insect pollination of the Mexican cycad *Zamia furfuracea* L. fil. has been established by Norstog and Fawcett (1989a). They have shown that the snout weevil *Rhopalotria mollis* Sharp is an obligate pollinator of *Z. furfuracea* and completes its entire reproductive cycle in the pollen cones of the cycads studied at the Fairchild Tropical Garden (FTG). Tang (1987) has shown insect pollination of *Z. pumila* L. by *R. slossoni* Schaeffer and *Pharaxonotha zamiae* Blake. By contrast, recent wind tunnel experiments show that while airborne pollen does preferentially settle on the same regions of certain cycad species (Niklas & Norstog 1984, Norstog 1987), the cone morphology of most species does not favor direct wind pollination of ovules.

This paper presents evidence that similar beetles were observed in cones of wild Mexican populations of *Z. furfuracea* and also in cones of species of the other two Mexican cycad genera in their natural habitats. The symbiosis described by Norstog and Fawcett (1989a) is similar to that in naturally occurring stands of *Z. furfuracea, D. califanoi* De Luca Sabato & Vázquez Torres, *D. edule* Lindl., and *D. spinulosum* Dyer. This symbiosis is widespread among natural populations of cycads.

During recent field work on these species in Mexico, both snout weevils and languriid beetles were found associated with male cones. The weevil found in field-collected *Z. furfuracea* male cones was *R. mollis,* a pollen-eating languriid beetle (*Pharaxonotha* sp.) was also found. The beetles were collected on 17 August 1988 from dehisced cones of *Z. furfuracea* plants growing among coastal vegetation on stabilized sand dunes in southern Veracruz. A few weeks earlier, at time of pollen release, hundreds of beetles were seen on the male cones.

The weevil found on *Dioon califanoi* was *R. bicolor* Voss (Fig. 1); *Pharaxonotha* was also present. The beetles were collected 25 February 1989 on dehisced, dry male cones. The beetles were dead, but the larvae in pupa cases were alive at the time they were preserved in alcohol; these were probably in diapause. *Dioon califanoi* is found in a matorral-like, deciduous, tropical thorn-forest with a highly pronounced dry season, and the plants are on steep metamorphic rock hills in northern Oaxaca at 1650 meters elevation.

The weevil on *D. edule* male cones was a *Rhopalotria* sp., different from both those present on the other two cycad species. The larvae, pupa cases, and weevils were collected from male cone debris on 8 February 1989. These plants grow on deciduous tropical-thorn forest on limestone hills in central Veracruz at 500 m elevation on tropical rendzina soil. Abundant larvae were found in larva cases in the microsporophylls.

Languriid beetles were found exclusively on *Ceratozamia mexicana* Brongn. male cones (Fig. 1). The insects arrive as soon as the cone is mature and begins to open and release pollen, and they lay eggs between the sporangia and feed on pollen and sporophyll tissue. Over 5300 beetles were counted from a single male cone. The insects were collected on 10 March 1989 from *C. mexicana* cones releasing pollen. On later-dehisced cones both eggs and larvae were found between the microsporangia; also, there were fewer numbers of beetles. The *C. mexicana* site is in tropical montane rain-forest on basalt hills with dark, humus rich soils at 1300 m elevation in central Veracruz.

It has been shown (1986) that *Zamia furfuracea* (Norstog *et al.* 1986) and *Z. pumila* (Tang 1987) do not produce viable seed if insects are excluded from the female cones.

The study of Norstog and Fawcett (1989a) described the life cycle of *Rhopalotria mollis,* a weevil of Mexican origin, that is associated with male and female cones of *Z. furfuracea,* also of Mexican origin and under cultivation at FTG. *Zamia furfuracea* has been cultivated in Florida for some decades, and it is well known that large quantities of field-collected plants from Veracruz, Mexico have been imported to the U.S.A. over the past years for landscape architecture (Gilbert 1984, Vovides 1986). It is very probable that larvae and pupae have been introduced with these plants on dried cone debris on which they overwinter for several months (diapause). This cycad species is currently raised in large quantities from seed by the wholesale nursery trade in south Florida. This practice has probably resulted in a large enough cultivated population of *Z. furfuracea* to enable *R. mollis* to become naturalized. Part of the life cycle reported by Norstog and Fawcett (1989a) involves a diapause stage of the larvae in male-cone debris which persists until the next coning cycle, hence also the next insect reproductive cycle.

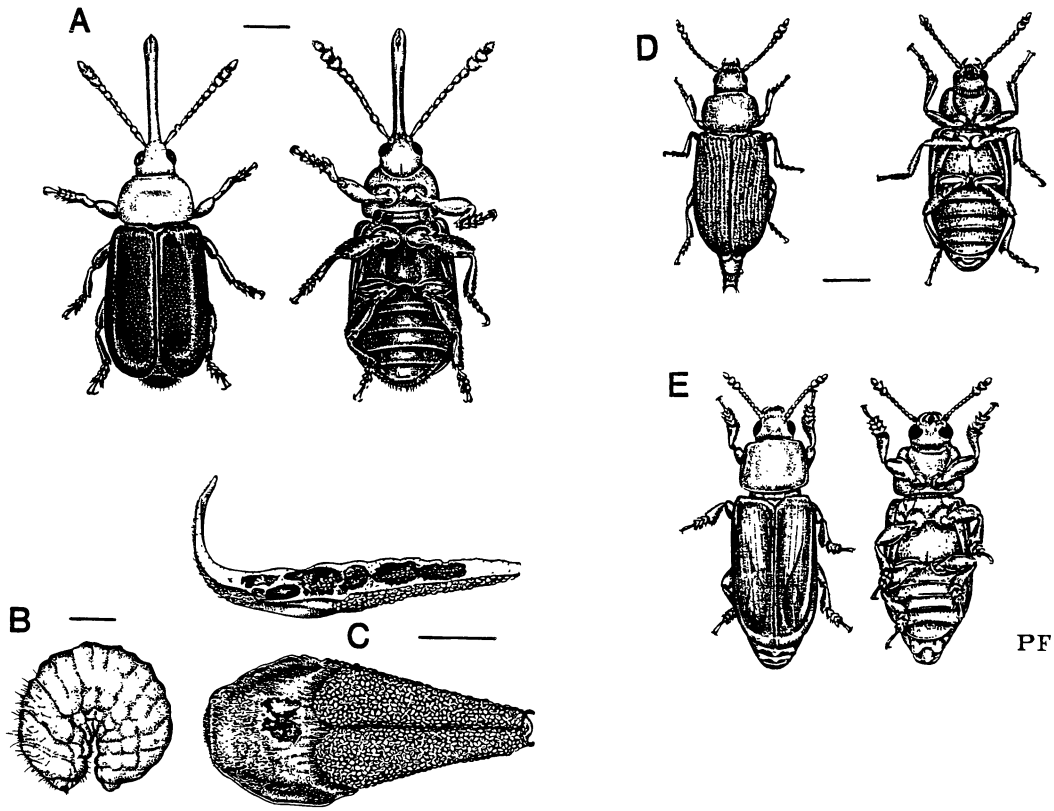

FIGURE 1. A. Dorsal and ventral views of *Rhopalotria bicolor* from microsporophylls of *Dioon califanoi*. B. Larva of *R. bicolor*. C. Longitudinal section and abaxial view of microsporophylls of *D. califanoi* showing insect tunnels. D. Dorsal and ventral views of *Pharaxonotha* sp. from microsporophylls of *Dioon califanoi*. E. Dorsal and ventral views of *Pharaxonotha* sp. from microsporophylls of *Ceratozamia mexicana*. Scale: all bars = 1 mm.

The weevils found on *D. edule* and *D. califanoi* appear to have a life cycle resembling that of *R. mollis* as described by Norstog and Fawcett (1989a) in that tunnels, larvae, and pupa cases have been found in the microsporophylls as well as diapause larvae which overwinter and come out during the next coning season (Fig. 1). O'Brien (pers. comm.) reported a repeated annual emergence of *Rhopalotria* weevils from a dried male *D. edule* cone he kept in a box for six to seven years. Vovides (1988) found thousands of weevils (*Rhopalotria* sp. nov.) and languriid larvae in a dehiscing male cone of *D. spinulosum* in its natural rain-forest habitat.

Pharaxonotha zamiae appears to be a co-pollinator of *Z. pumila* along with *R. slossoni* (Tang 1987). Though *Pharaxonotha* appears to be a pollen eater, by doing so it may help to scatter pollen widely. This is accomplished by the breaking up of sporangia by the beetle, thus covering the largely sporophyll tissue-eating weevils and itself with pollen that can be carried to the female cones (Fawcett, pers. comm.). Both *Rhopalotria* and *Pharaxonotha* belong to beetle families that appear to be exclusively associated with cycads and that coevolution has occurred at the family level over a very long period of time, probably predating that of the angiosperms.

Insects and cycads are much more intimately and mutually interrelated than has been reported earlier for any insect-cycad interaction. The pollinators thus far studied are host specific. *Rhopalotria mollis,* the pollinator of *Z. furfuracea* is not found on the native, Florida *Z. pumila* which is pollinated by *R. slosonii,* and *vice versa.* It has been noted that most cultivated cycads at FTG and other botanic gardens do not

produce seed unless hand pollinated, even though synchronous coning of closely associated male and female plants occurs.

Rampant habitat destruction and illegal collecting of cycads in Mexico and other countries where cycads are native has given rise to the thought that botanic gardens could play an important role in cycad conservation. This could be accomplished by maintaining and propagating living collections of cycads and eventually reintroducing them where they have been depleted in the wild. Unfortunately, as Norstog and Fawcett (1989b) point out, if the specific pollinators of the cycads in question are not also conserved, reintroduction of the cycads into the wild will be futile and they will not be saved from extinction. Thus, the pollinators must also be collected, identified, and maintained. For this reason field studies of cycad pollination have a high priority, before natural cycad populations are wiped out.

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