Insect frugivory in *Juniperus phoenicea* (L.) (Cupressaceae) in Cabrera island (Balearic Archipelago)

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In the present paper, the variation among individuals of *Juniperus phoenicea* in the incidence of frugivorous insects is examined in Cabrera island during 1992 and 1993. The proportion of seeds that are damaged is determined, and whether the number of cones (structures equivalent to the fleshy fruits of the angiosperms) infested by insects is associated with cone size (diameter) is also examined. A great variability in the proportion of "fruits" that are infested is found, representing from 3% to 50% of the crop. The larva of the frugivorous insect (a microlepidopteran of the family Gelechiidae not yet identified) feeds upon the pulp of the fruit and only rarely (<3% of the cases) damages the seeds. Cone diameter does not have any influence on the intensity of attack. Larger fruits do not necessarily have more seeds and are not more infested than small fruits. In 1993, fruit infestation was greater than in 1992 possibly because cones take about two years to mature and, thus, those collected in 1993 had been exposed to moth infestation for a longer period.
Keywords: Juniperus phoenicea, *Cupressaceae, frugivorous insects, Gelechiidae, reproductive losses, Cabrera, Balearic Islands.*

FRUGIVORIA D'INSECTES EN *JUNIPERUS PHOENICEA* (L.) (CUPRESSACEAE) A L'ILLA DE CABRERA (ARXIPELAG BALEAR). En el present treball s'examina la variació entre individus de savina (*Juniperus phoenicea*) en la incidència d'insectes frugívors (que mengen la polpa i/o llavors dels fruits) a l'illa de Cabrera durant els anys 1992 i 1993. Es determina quina proporció de llavors són atacades, i també es vol conèixer si el nombre de gàlbuls (estructures equivalents als fruits de les angiospermes) atacats pels insectes està associat amb llur mida (diàmetre del gàlbuls). Es troba que hi ha una gran variabilitat en la proporció de "fruits" atacats, representant d'un 3% a un 50% de la collita. La larva de l'insecte depredador (un microlepidòpter de la família Gelechiidae que encara no ha pogut ésser identificat) menja la polpa que envolta les llavors, i sols en rares ocasions (en <3% dels casos) es menja també aquestes. El diàmetre dels gàlbuls sembla no tenir cap efecte sobre la intensitat d'atac. Fruits més grans no tenen necessàriament més llavors i tampoc estan més o menys atacats que fruits petits.

En 1993, el percentatge d'atac per insectes fou més elevat que en 1992 possiblement degut a que els gàlbuls estan gairebé dos anys a madurar, i per tant, els del 1993 varen estar més temps exposats a l'atac de la falena sobre l'arbre.

Paraules clau: Juniperus phoenicea, *Cupressaceae, frugivoria per insectes, Gelechiidae, pèrdues reproductives, Cabrera, Illes Balears*

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Introduction

Insects are potential destroyers of large quantities of reproductive structures in many species of plants (see reviews in Crawley, 1989; 1992), and have the capacity of limiting plant recruitment (Louda, 1982a,b). The insects that feed upon the fruits (either on the pulp or the seeds), in particular, have received attention for a long time and in different kinds of ecosystems (e.g. Janzen 1971, Breedlove & Ehrlich, 1972. De Steven, 1981; Auld, 1986; Andersen, 1989; Evans *et al.*, 1989).

Regardless of, or in addition to, their demographic effect on plant population dynamics, insects may also act as selective factors if they discriminate between plant phenotypes and promote individual variation in reproductive losses (Harper, 1977). A particular plant attribute such as fruit crop size (e.g. Jordano, 1987; Traveset, 1994), number of seeds per fruit (e.g., Garrison & Augspurger, 1983; Herrera, 1984), or fruit size (e.g., Hare, 1980) may be selected due to the pressure exerted by insects that interact with it (frugivorous insects, in this case).

Even though junipers are widely distributed and are abundant in many habitats, their interaction with insects has been hardly examined. As far as we know, there are only two studies that examine the effect of insects on the reproductive success of this group of plants (Roques *et al.* 1984; Fernandes and Whitham, 1989).

In the present paper, we examine such effect in *Juniperus phoenicea* (L.), a species of juniper commonly found in the Balearic Islands. Our objectives were the following:

1) to document the variation among individual plants in the incidence of insects in the fruits,

2) to evaluate what proportion of seeds are damaged by insect larvae,

3) to determine whether fruit infestation is associated with fruit size, and

4) to know whether the intensity of fruit damage by insects increases significantly from one year to the next since maturing fruits are on the plants for about two years.

Study site

The study was carried out in the island of Cabrera, south of Mallorca (Balearic Islands), during the autumn of 1992 and 1993. Cabrera island is about 1130 ha and has a maximum elevation of 172 m. The vegetation is mediterranean scrubland, dominated by *Pistacia*

lentiscus, Phillyrea spp., Olea europaea, Juniperus phoenicea, Cistus spp., Rosmarinus officinalis and *Erica multiflora. Pinus halepensis* is very abundant at the northeast of the island (see Rita i Bibiloni, 1993, for more information on the vegetation of the area).

Mean temperature ranges from 8ºC (in January) to 34ºC (in August). Total annual precipitation averages 380 mm (calculated for the period 1950-1971), ranging from 193 to 555 mm. Most (43.8%) of such rain falls between September and November. A detailed description of the climate of Cabrera island and surrounding islets can be found in Guijarro (1993).

Study organisms

Juniperus phoenicea (L.) (Cupressaceae) is a monoecious (functionally subdioecious in most populations, according to Jordano, 1991) shrub/small tree that can reach up to 8 m in height. It is distributed all around the Mediterranean Basin, reaching also the Canary Islands, and is abundantly found in the Balearics (Bonafé, 1979). Following the taxonomic nomenclature used by Palau (1976), the species most commonly found in the island of Cabrera, and the one studied here, is J. phoenicea var. turbinata (Guss.) Parl.

The female strobili (fleshy cones or "fruits" or "berries", hereafter) are functionally analogous to angiosperm fleshy fruits. The strobili are dark-red when ripe and measure 8-14 mm in diameter; they reach full size about a year after pollination, and mature during the following year (Roques *et al.* 1984). Important seed dispersers of junipers are birds of the genus *Turdus* (see Jordano, 1993), although carnivores might also act as major dispersers in some regions. In the island of Cabrera, although *Turdus* appear to be the main fruit consumers of this plant (Traveset, pers.obs.), the fruits are also eaten by genets *(Genetta genetta)* and by an endemic lizard, *Podarcis lilfordi* (Lacertidae), which pass the seeds intact through their intestines (Traveset, 1993).

The berries are attacked by different species of insects which oviposit on them at different times of cone development, and have different life cycles. Roques et al. (1984) found four species of lepidopterans, one coleopteran and one himenopteran infesting the fruits in France and in Corsica Island. In the island of Cabrera, we have found only one species of microlepidopteran that belongs to the family Gelechiidae (but is not yet identified) the larva of which appears to infest the fruit during the first year of cone development, remaining inside it until the following one. All insect exit holes appear on the berries collected in 1993. In only one ocassion we found an exit hole in 1992 which suggests that there might be another species of insect, with a different life cycle, attacking the fruits of this plant.

Methods

On September 19, 1992, a total of 30 fruits were randomly collected from each of 10 haphazardly chosen individuals scattered in Cabrera island. The cones were placed in paper bags and taken to the laboratory to be dissected. For each dissected fruit, we

recorded: (1) fruit diameter, (2) the number of seeds in it, (3) whether it was infested by larvae and (4) how many seeds had been damaged.

On September 24 of 1993, we collected 50 fruits from each of other 10 individuals chosen haphazardly from the areas where we had collected in 1992. We could not use the same individual plants because most of the labels placed were damaged by sheep that graze freely in the island. The variables recorded for each dissected fruit were the same as in 1992, except for fruit diameter.

The data were analyzed performing an analysis of variance, using the proportion of fruits damaged per plant as the dependent variable and plant as the main effect. The proportions were normalized using the angular transformation before the analysis. Also, a correlation analysis was executed in order to find associations between fruit size, number of seeds and fruit infestation.

Results

Table 1 shows the incidence of insect larvae in the fruits of *J. phoenicea*. There was a great variation among plants, the proportion of cones infested ranging from 3.3% to 50%. In 1993, the proportion of fruits attacked was significantly greater than in 1992 ($F_{1,18}$=8.46, P<0.01) and also varied from 3.3% to 48%.

The moth larvae were observed to feed upon the pulp of the fruit, and only occasionally (2.75 % of the cases) had damaged the seeds (usually only one seed per cone). Fruit infestation was not associated with fruit diameter in 1992 (Figure 1). The number of seeds per fruit did not appear to be correlated with fruit diameter either (r=0.02, P>>0.05, n=300). This implies that even if fruit infestation was related to fruit size and larvae were preying upon the seeds, they would not be killing more seeds when infesting larger fruits. Fruit diameter differed significantly among plants ($F_{9,290}$=32.9, P=0.0001), being on average 10.4 ± 6.4 mm and ranging from 9.2 to 11.6 mm. The mean number of seeds per fruit was 6.4 ± 1.0 (s.d.) and also differed significantly among plants ($F_{9,290}$=27.3, P=0.0001, in 1992, and $F_{9,489}$=32.6, P=0.0001 in 1993).

Discussion

A broad inter-individual variation in fruit infestation by moths was observed

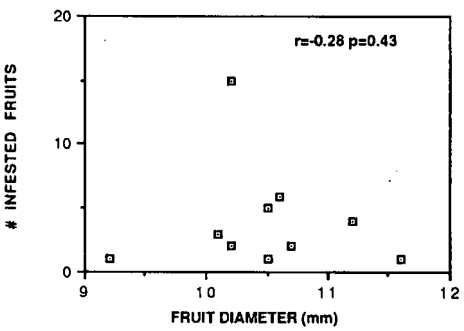

Fig. 1. Relation between fruit size and number of fruits damaged by insects. N=10 plants. Data from 1992.
Fig. 1. Relació entre mida del fruit i nombre de fruits danyats per l'insecte. N=10 plantes. Dades del 1992.

in *J. phoenicea,* representing from 3% to 50% of the crop. A great variance in the levels of attack (6.7% - 83.9%) was also reported by Roques *et al.* (1984) from some French populations. Either factors intrinsic to the plant (plant size, fecundity, etc.) or extrinsic to it (position of the individual in the habitat, etc.) may be responsible for such variance, as it has been found in other species (e.g., Roitberg & Prokopy, 1982; Courtney & Manzur, 1985; Jordano, 1987; Traveset, 1994). In the present system, fruit size did not appear to be associated with the number of infested cones, and thus, it is an intrinsic factor that does not influence insect attack. This is possibly because the adult moth begins ovipositing when the cones are still developing (at least most of them are), so it has no much opportunity to choose among fruit sizes.

As also reported by Roques *et al.* (1984), the number of seeds damaged by insect larvae is very low. These authors found that only two of the five species of insect frugivores of *J. phoenicea* had a direct influence reducing the number of viable seeds. In the present study, we observed that the larvae feed upon the soft, fibrous pulp, and only rarely (in <3% of the infested fruits) damage the seeds, which probably have a too hard seed coat for them.

The number of attacked fruits was greater in 1993 than in 1992. This suggests that the moth keeps ovipositing even when fruits have begun maturing. However, the possibility exists that some larvae present in the cones dissected in 1992 were still too small to be detected and thus were missed when recording fruit infestation.

Even though insects did not seem to represent a great loss in the reproductive success of *J. phoenicea* because of the low proportion of seeds damaged, they may be more important reducing the potential number of viable seeds dispersed since fruits that have been damaged and bear exit holes rot soon and are not attractive to birds (Traveset, pers. obs.). Such fruits usually remain on the branches for a long time without ever being dispersed.

Year	*Fruits dissected per plant*	*Plants*	*% Fruits infested X ± S.D.*	*C.V.*
1992	30	10	13.3 ± 14.1	106.0
1993	50	10	29.2 ± 13.1	44.9

Table 1. Infestation by moths of *J. phoenicea* fruits in Cabrera island during the two years of the study. (C.V.: coefficient of variation).
Taula 1. Atac dels fruits de J. phoenicea *pel microlepidòpter a l'illa de Cabrera durant els dos anys d'estudi. (C.V.: coeficient de variació).*

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