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FACTORS AFFECTING *MYRICA FAYA* AITON DEMOGRAPHY IN THE AZORES

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ABSTRACT

Myrica faya (Myricaceae) is a small tree considered as an ibero-macaronesian endemic, a relic of the tethiano-tertiary flora. In the Azores *M. faya* stands are submitted to deforestation and to invasion by alien plants. In many stands density of *Pittosporum undulatum*, introduced from Australia, is higher than that of *M. faya*. In others, *Hedychium gardneranum* covers space between shrubs, impairing regeneration. Fruit production reaches $15x10^6$ fruits/ha/year, and seed bank is of the same magnitude. Male flowers and fruits are predated by *Argyresthia atlanticella*. Mature fruits are eaten by *Rattus rattus* and *Turdus merula azorensis*. In the laboratory maximum germination after 65 weeks was 50%, but in the field, less than 1% of the fruits produced seedlings. In order to preserve *M. faya* stands and the associated fauna and flora, conservation measures should be immediately enforced.

RESUMO

Myrica faya (Myricaceae) é uma pequena árvore ou arbusto considerado como um endemismo ibero-macaronésico, uma relíquia da flora tetiano-terciária. Nos Açores as formações de *M. faya* foram arroteadas ou invadidas por plantas exóticas. Em muitos locais a densidade de *Pittosporum undulatum*, originário da Austrália, é mais elevada do que a de *M. faya*. Em outros locais *Hedychium gardneranum* cobre os espaços entre os arbustos impedindo a regeneração. A produção de frutos atinge os $15x10^6$ frutos/ha/ano, e o reservatório de sementes é da mesma magnitude. As flores masculinas e os frutos são predados por *Argyresthia atlanticella*. Os frutos maduros são consumidos por *Rattus rattus* e por *Turdus merula azorensis*. No laboratório a germinação máxima após 65 semanas foi de 50%, mas no campo menos de 1% dos frutos originam plântulas. Para preservar as formações de *M. faya* são necessárias medidas de conservação imediatas.

INTRODUCTION

Myrica faya Aiton (Myricaceae), is a shrub or small tree, considered as an ibero-macaronesian endemic (Queirós, 1987). It is considered as a relic from the tethiano-tertiary flora, the vegetation that once covered Southern Europe and Northern Africa (Sunding, 1979). Drouët (1866) considered *M. faya* as a beautiful evergreen shrub or tree reaching 6 m high.

The Myricaceae include three genera and 50 species, spread throughout the Old World and the New World, generally in temperate or subtropical regions, with pollination by wind and flower reduction (Cronquist, 1981). The genera

Comptonia and *Canacomyrica* are monotypic, the remaining species belonging to *Myrica* (Cronquist, 1981). *Myrica gale* L. and *Myrica carolinensis* Miller also exist in Europe (Franco, 1971). *Myrica cerifera* L. and *Myrica pensylvanica* Loisel, both native to eastern United States are considered close to *M. faya* (Neal, 1991).

M. faya is one of the more characteristic plants of the Azores Archipelago (Drouët, 1866). It gave the name to Faial island, which formerly had a considerable cover of *M. faya*. It is also present in Madeira, in the Canary islands and in mainland Portugal (Franco, 1971), although in the latter its native status is controversial (Queirós, 1987). In the Azores, *M. faya* fossils from the Pleistocene were found (Forjaz *et al.*, 1970).

M. faya is found on all of the Azores islands and is considered as a frequent member of the coastal indigenous vegetation (Sjögren, 1973). It is found up to 600 m of altitude in dense stands, reaching 700 or 1000 m at Pico island, although without the arboreous size found in the Canary Islands and Madeira, where it is found up to 1300 m (Drouët, 1866; Sjögren, 1973, Queirós, 1987). It is present in exposed habitats on various substrates, on cliffs near the coast or on lava flows, and dry canyons over gravel or sand (Sjögren, 1984). It occurs most frequently in humid environments but does not tolerate intense cold. *M. faya* occurs on light, siliceous soils rich in organic matter, and is often associated with *Erica scoparia* ssp. *azorica* (Hochst.) D.A. Webb (Ericaceae) in the Azores, and with other *Erica* spp. in Madeira and Canary Islands (Queirós, 1987; Ashmole & Ashmole, 1989). In the Azores, Dias (1991) described the existence of several types of vegetation, of which the *Faial* is dominated by *M. faya* and *Erica scoparia* ssp. *azorica*. The plant is useful in soil development and as source of food and shelter for birds and endemic insects (Sunding, 1979; Banermann, 1966; Silva & Tavares, 1995a; Silva *et al.*, 1995).

M. faya was introduced to Hawaii by the end of the 1800's by Portuguese immigrants (Kim, 1969). In the 1950's *M. faya* was already considered a noxious weed in Hawaii, invading range lands, pasture lands and the natural forests of Hawaii, covering an area of 34000 ha (Yamayoshi, 1954; Whiteaker & Gardner, 1985). In the 1950's (Krauss, 1964) and again in the 1980's (Hodges & Gardner 1985; Gardner *et al.* 1988; Gardner & Hodges, 1990; Markin, 1990; Silva, 1992) a biological control program was developed to search for its natural enemies. Research was undertaken in Hawaii on distribution (Whiteaker & Gardner, 1985), phenology (Whiteaker & Gardner, 1987), plant-soil interactions (Turner & Vitousek, 1987; Matson, 1990), germination (Walker, 1990), seed dispersal (Larosa *et al.*, 1985; Woodward *et al.*, 1990), ecology

(Vitousek *et al.*, 1987; Vitousek & Walker, 1989; Walker & Vitousek, 1991; Aplet, 1990) and control of *M. faya* with herbicides (Cuddihy *et al.*, 1991). Vitousek & Walker (1989) studied *M. faya* demography in Hawaii and several authors evaluated the dispersion of *M. faya* by birds and other animals (Larosa *et al.*, 1985; Vitousek & Walker, 1989; Woodward *et al.*, 1990).

M. faya distribution in the Azores is being reduced as a consequence of human activities, and by the spread of alien plant species, and it is threatened with extinction in mainland Portugal (Palhinha, 1953; Sjögren, 1984; Queirós, 1987).

Several studies were performed in the Azores and Madeira including phenology (Silva & Tavares, 1995b) and associated phytophagous insects (Silva 1992; Aguiar, 1993; Silva & Tavares, 1995a; Silva *et al.*, 1995; Markin *et al.*, 1995).

In this paper, data is presented on stand structure and reproduction. Factors affecting *M. faya* demography in the Azores are discussed.

METHODS

Study sites

The present work was performed at Lombadas and Pico das Camarinhas in São Miguel island (Azores). Inland at Lombadas (550 m) *M. faya* is associated with *Pittosporum undulatum* Ventenat (Pittosporaceae) and *E. scoparia* ssp. *azorica*. *Hedychium gardneranum* Roscoe (Zingiberaceae), and *Pteridium aquilinum* (L.) Kuhn (Ptedridaceae) cover free soil between shrubs and trees. The following plants are also abundant: *Blechnum spicant* (L.) Roth (Blechnaceae), *Polygonum capitatum* D. Don (Polygonaceae), *Potentilla erecta* (L.) Räuschel (Rosaceae), *Erigeron karvinskianus* DC. (Compositae) and *Lysimachia nemorum* L. (Primulaceae). A layer of humus mainly composed of *M. faya* leaves covers a compact clay horizon.

At Pico das Camarinhas (150 m), near the coast, the following plants are abundant: *M. faya*, *P. undulatum*, *E. scoparia* ssp. *azorica*, *Festuca petraea* Guthnick ex Seubert (Poaceae), *Rubus ulmifolius* Scott (Rosaceae), *Ligustrum henryi* Hemsley (Oleaceae), and *Phytolacca americana* L. (Phytolaccaceae). A layer of humus mainly composed of *M. faya* and *P. undulatum* leaves covers an organic enriched horizon, followed by volcanic rock, exposed in many places.

At Lombadas fog is frequent, and vegetation is covered with condensation droplets, while at Pico das Camarinhas strong salt-laden winds are frequent.

Mean annual temperature in São Miguel varies from 12°C at 550 m to 17 °C at 70 m of altitude, and rain fall from 2309 to 1020 mm/year, respectively (Instituto Nacional de Meteorologia e Geofísica). The present research was developed from 1992 to 1994.

Stand structure

Transects were defined at Lombadas and Pico das Camarinhas, according to the "Quarter Centre

Method" which allows the calculation of density and dominance of various shrubs and trees in a given area (Barbour *et al.*, 1987; Haggar, 1988). At each site 25 points were defined, each separated by 20 meters. Four quadrants were defined at each point and, for each one, the distance to the nearest tree was measured, the plant was identified and its trunk perimeter measured (which was later transformed to diameter). Measurements were taken from 100 trees at each site. The density and relative dominance were calculated for each tree and shrub following Barbour *et al.* (1987).

Fruit production

Fruit drop was followed by placing twenty 0.5 m^2 trays under *M. faya* trees at each site, and collecting the material biweekly for one year. The number of fallen fruits per hectare was estimated.

Fruit predation

During the fruiting season 30 branches with fruits were collected weekly at both sites, in order to determine consumption by phytophagous insects.

During fruit drop season, ten dishes with 20 fruits each were placed at both sites with fresh fruits, dry fruits or endocarps. The dishes were analysed weekly.

The black-purple faecal pellets of a bird were collected at Pico das Camarinhas. The colour was given by the mesocarp of *M. faya* fruits. The contents of the faecal pellets were analysed using a stereo microscope. Bird species that visited *M. faya* were registered every week during field work.

Pool of seeds

The pool of seeds was evaluated by collecting 20 soil samples of 0.5 m^2 at the two places. Samples were taken before the fruiting season. For each sample, the 20 cm top layer of the soil was collected. The samples were sorted manually to separate larger particles (leaves, fruits, etc.) and sieves were used to eliminate the smaller particles. The resulting fraction including soil particles with dimensions close to those of the seeds, were sorted by direct observation. The number of endocarps in 10 m^2 of soil was calculated, and extrapolated to give the number per hectare.

Germination

Germination of seeds from fruits of different locations was determined, and compared with germination of *P. undulatum*. Fruits were collected from 30 trees per site, at Pico das Camarinhas, Lombadas and Mosteiros (western part of São Miguel, near the coast) in October/November 1992, and air dried. Four replicates of 100 fruits were used per site. The same was prepared for *P. undulatum*, for seeds collected at Pico das Camarinhas. Germination was registered for 65 weeks.

Possible allelopathic effects on *M. faya* germination were tested using leaf extracts from *M. faya* and *P. undulatum*. Leaf-extracts were prepared by placing 50 g of dried leaves

in one litre of water for 4 days (Walker, 1990). That extract was filtered and diluted in 2.5 litres of water (1 g of dry leaves in 50 ml of extract). A 1:10 dilution was also prepared. A new lot was prepared every month. Three replicates with 50 fruits each were prepared for the following treatments: fruit with distilled water, endocarp with distilled water, *M. faya* extract, pure or diluted, *P. undulatum* extract, pure or diluted. Fruits were from Pico das Camarinhas. Germination was followed for 65 weeks.

The effect of fruit digestion by *Turdus merula azorensis* was determined. Fruits were collected in October 1993 from faecal pellets or from the soil at Pico das Camarinhas. Three replicates of 50 fruits were used for the following treatments: complete fruit, endocarp, digested endocarp. Germination was followed for 45 weeks.

In all the experiments fruits were placed in Petri dishes covered with moist filter paper. Germination was defined as radicle emergence, and was considered only once for each fruit. Experiments were performed in a chamber regulated to 15 °C and a photophase of 8 hours (Maciel & Caixinhas, 1993). Position of the dishes within the chamber was randomised, and the positions changed weekly.

In another experiment 30 fruits were placed in 4 cups with soil from Pico das Camarinhas, and were submitted to Ponta Delgada climatic conditions.

Differences in number of germinated seeds between treatments were evaluated with contingency tables using χ^2-test or G-test (Scherrer, 1984).

Seedling dynamics

Seedling emergence was followed throughout the year. Forty direct observations of a 50x50 cm quadrat were made each month, and the number of seedlings per hectare was estimated.

At each site, 40 laboratory germinated seedlings of *M. faya* were planted in groups of five. Survival was compared with that of seedlings remaining in the laboratory.

RESULTS

Stand structure

M. faya density was similar at both sites but *P. undulatum* was more abundant at Pico das Camarinhas, and reached an higher density than *M. faya* (Fig. 1). *Erica scoparia* ssp. *azorica* is the third most abundant species. Remaining species were relatively rare.

M. faya was the dominant plant at Lombadas (Fig. 2), but at Pico das Camarinhas *P. undulatum* dominance was close to that of *M. faya*. The remaining species are responsible for only 1% of the dominance. Mean basal diameter of *M. faya* at Lombadas and Pico das Camarinhas was 7.2 and 6.6 cm, respectively.

Although *M. faya* dominates the Lombadas stand, no regeneration was found, since the space between shrubs is covered by *Hedychium*

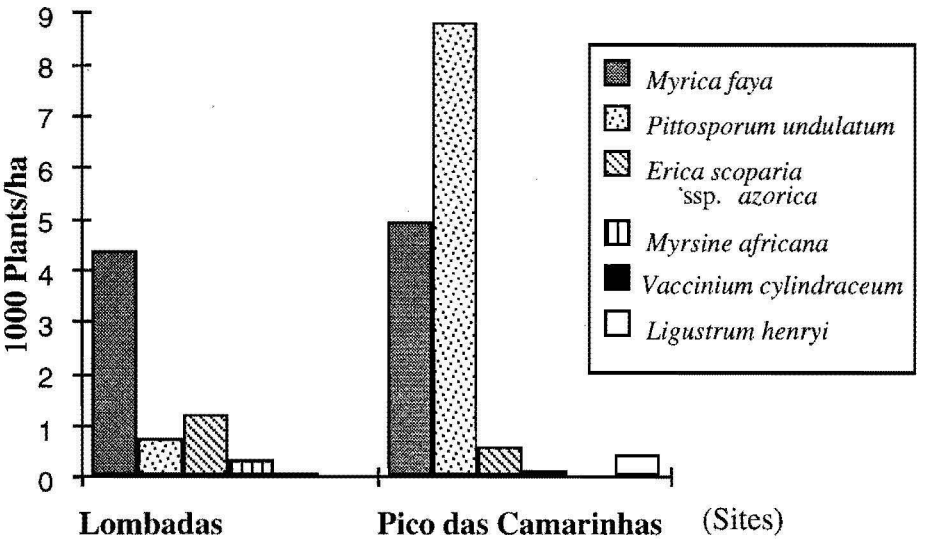

FIG. 1. Density of shrubs at two *Myrica faya* stands in São Miguel (Azores), Lombadas (550 m) and Pico das Camarinhas (150 m).

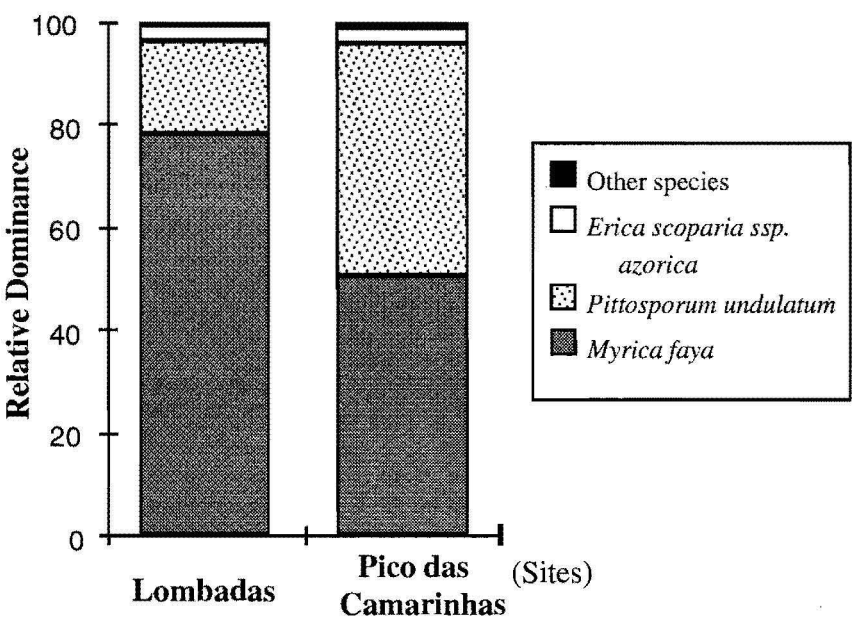

FIG. 2. Relative dominance (based on basal diameter) of various shrubs at two *Myrica faya* stands in São Miguel (Azores), Lombadas (550 m) and Pico das Camarinhas (150 m).

gardneranum and *Pteridium aquilinum*.

At Pico das Camarinhas, although *P. undulatum* had a higher density than *M. faya*, the latter still dominates this stand, since it has a higher basal diameter, and is probably older than *P. undulatum*.

Fruit production

Fruit drop occurs between September an October. Annual fruit production was 15.3×10^6 and 12.8×10^6/ha at Pico das Camarinhas and Lombadas, respectively.

Fruit predation

Less than 10% of the fruits are destroyed by *Argyresthia atlanticella* Rebel (Lepidoptera, Yponomeutidae) (Fig. 3). At Pico das Camarinhas partial destruction of endocarps and dry or fresh fruits placed in dishes at soil level was observed. The type of damage (partial fruit destruction) was that caused by *Rattus rattus* (Walker, 1990). At Lombadas the observations were affected because the fruits were covered by water, but fruit destruction was also found at that place. During fruit fall about 10% of the fruits were destroyed per week.

Between September and October 278 endocarps were found in 219 faecal pellets at Pico das Camarinhas. Percentages of faecal pellets with 0, 1 to 3 and 4 to 6 endocarps, were 26%, 72% and 2%, respectively. Body parts of several animals were also found in many faecal pellets, namely of Diplopoda and more rarely of Coleoptera, Dermaptera and Formicidae.

Only *Turdus merula azorensis* was observed feeding of *M. faya* fruits used in predation tests. Other birds, namely *Carduelis chloris*, *Erithacus rebecula*, *Fringilla coelebs*

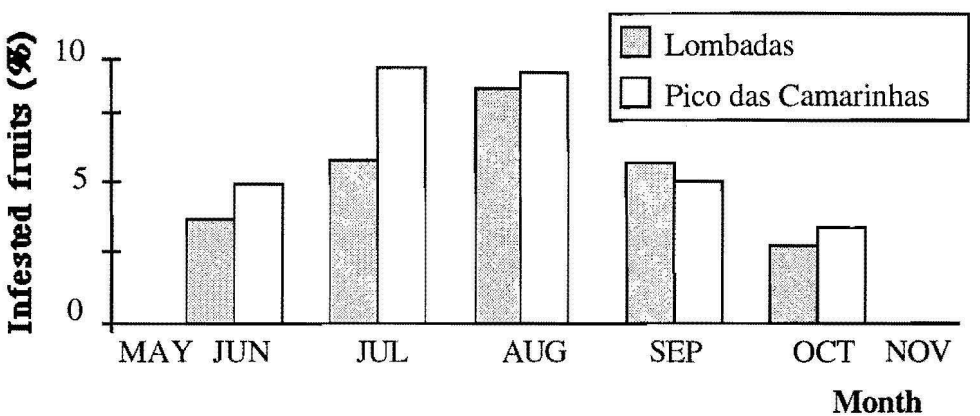

FIG. 3. Predation of *Myrica faya* fruits by *Argyresthia atlanticella* larvae, in São Miguel (Azores), Lombadas (550 m) and Pico das Camarinhas (150 m).

TABLE 1. Germination of *Myrica faya* and *Pittosporum undulatum* in São Miguel (Azores). Contingency table for fruits of different sites: Lombadas (LO), Pico das Camarinhas (PC) and Mosteiros (MO). Germination of *P. undulatum* from PC. Number of germinated seeds in 400, after 65 weeks (15°C and 8h photophase).

Myrica faya			*Pittosporum undulatum*	
LO	PC	MO	PC	
15*	106*	201*	392*	Germinated
385	294	199	8	Not germinated

*Significant differences ($p<0.001$).

moreletti, *Passer domesticus*, *Regulus regulus azoricus*, *Serinus canaria*, and *Sylvia atricapilla* visited the plant, but were not observed ingesting the fruit.

Pool of seeds

Number of endocarps for Lombadas and Pico das Camarinhas was 15.8×10^6/ha and 23.5×10^6/ha, respectively.

Germination

Significant differences in germination were found for *M. faya* fruits from different locations (Table 1, Fig. 4). Significant differences were also found between germination rate of endocarps and complete fruits (Table 2). Germination rate in the cups submitted to Ponta Delgada climatic conditions was of 20%. No significant differences were found between germination rates of digested fruits (19%) and tree collected fruits (21%) or endocarps (20%) after 45 weeks. No significant differences in germination were found when using leaf extracts from *M. faya* or *P. undulatum*. For the latter, germination was higher than that for *M. faya*, what agrees with an higher number of seedlings of *P. undulatum* found at Pico das Camarinhas.

TABLE 2. Germination of *Myrica faya* seeds from fruits or from endocarps. Contingency table for fruits from Pico das Camarinhas (Azores). Treatments: fruit with distilled water (Fr); endocarp with *Pittosporum undulatum* leaf extract, pure ($Pu_{1:1}$) or diluted ($Pu_{1:10}$); endocarp with *M. faya* leaf extract, pure ($Mf_{1:1}$) or diluted ($Mf_{1:10}$); endocarp with distilled water (En). Number of germinated seeds in 150, after 65 weeks (15 °C and 8h photophase).

Fr	En	$Pu_{1:1}$	$Pu_{1:10}$	$Mf_{1:1}$	$Mf_{1:10}$	
64*	36*	25	48	50	51	Germinated
86	114	125	102	100	99	Not germinated

*Significant differences ($p<0.05$)

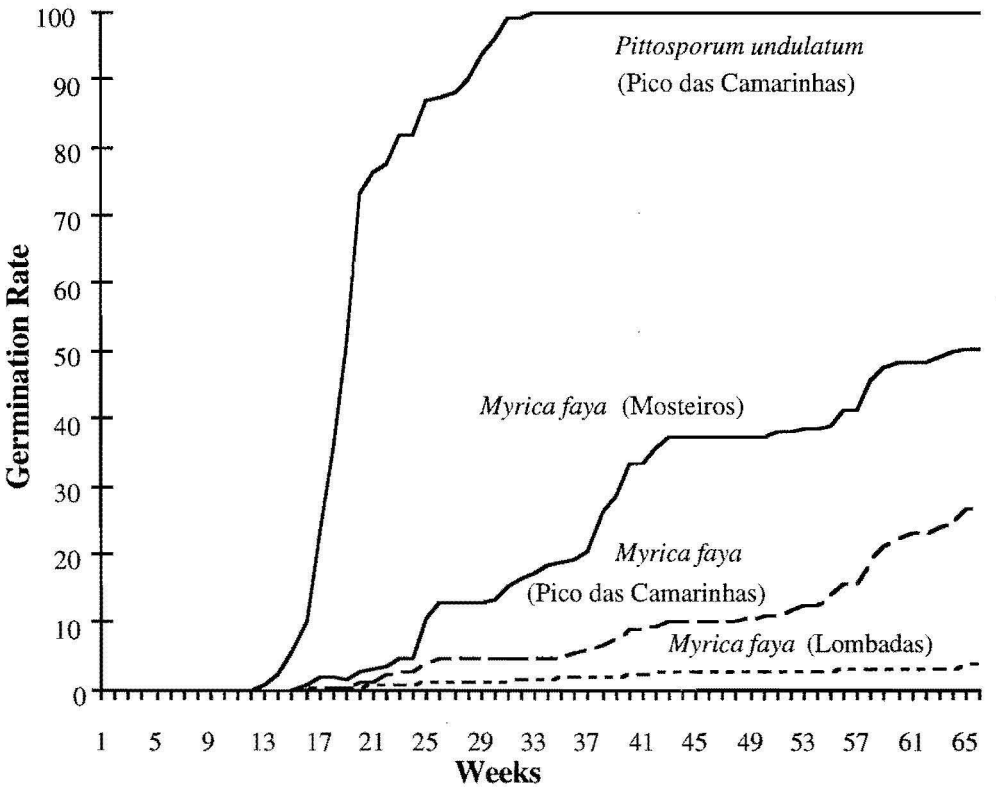

FIG. 4. Germination of *Myrica faya* seeds from three sites at São Miguel (Azores) (Lombadas, Pico das Camarinhas, Mosteiros), and seeds of *Pittosporum undulatum*. Germination rate of 400 seeds.

Seedling dynamics

A massive seedling emergence was observed in spring but no seedlings survived to the first year (Fig. 5). At Lombadas, some seedlings were found, not in the studied area, but in open sites. Some of the planted seedlings showed signs of feeding damage, while others were covered by leaf litter or uprooted (Fig. 6).

DISCUSSION

Higher densities of *M. faya* shrubs were found in the Azores as compared to Hawaii (21 to 1100 trees/ha, Vitousek & Walker, 1989; Woodward *et al.*, 1990). On the other hand fruit production was found to be higher in Hawaii ($40x10^6$ to $370x10^6$ fruits/ha/year, Vitousek & Walker, 1989). In the

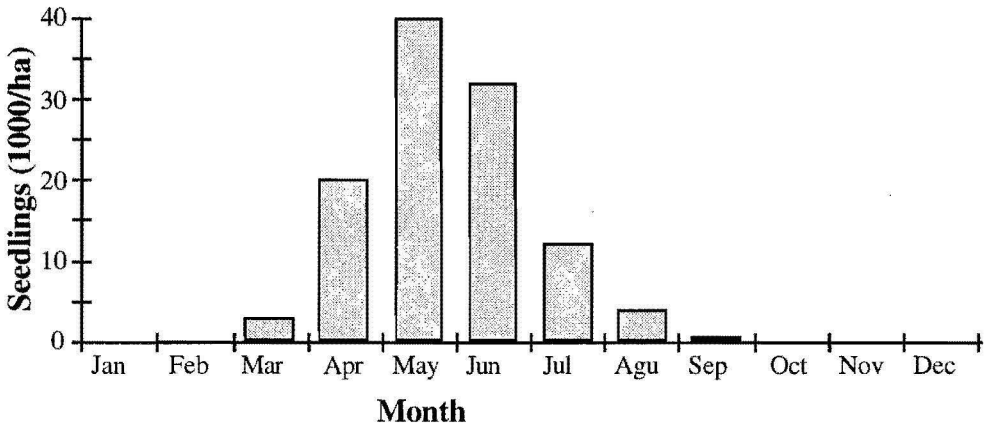

Figure 5. Abundance of *Myrica faya* seedlings along the year at Pico das Camarinhas (São Miguel, Azores).

Azores fruits are predated by insects, birds and rodents, and in Hawaii they are eaten only by pheasants and by *Rattus* sp. (Vitousek & Walker, 1989).

Since germination was not affected by *Turdus merula azorensis* digestion, this bird could function as a dispersal agent. In Canary islands *M . faya* fruits are eaten by *Turdus merula cabrerae* (Padrón, 1986). In Hawaii birds and other animals, namely *Zosterops japonicus* and *Sus scrofa,* participate in seed dispersal (Larosa *et al.*, 1985; Walker, 1990; Woodward *et al.*, 1990).

The pool of seeds at Lombadas and Pico das Camarinhas is close to the annual fruit production. This might imply that the period of residence in the soil is about a year or less. In Hawaii viable seeds were not found in the soil (Vitousek & Walker, 1989), and in the Azores, only 23,5% and 79,0% of the endocarps collected from soil were undamaged, at Pico das Camarinhas and Lombadas, respectively.

In the Azores maximum germination was about 50% while in Hawaii nearly 70 to 80% of *M. faya* fruits germinated, although in a greenhouse (Vitousek & Walker, 1989). At Lombadas space between shrubs is rapidly occupied by *Hedychium gardneranum* and *Pteridium aquilinum*, so that seedlings were only found at an open area outside the stand. According to Vitousek & Walker (1989), in very dense stands germination is impaired by low light intensity and by leaf litter. Maximum number of seedlings found at Pico das Camarinhas was about 0.3 % of fallen fruits. Seedlings at Pico das Camarinhas do not reach their first year while in Hawaii, 81% of the seedlings reach that age (Vitousek & Walker, 1989). On some open coastal areas *M. faya* regenera

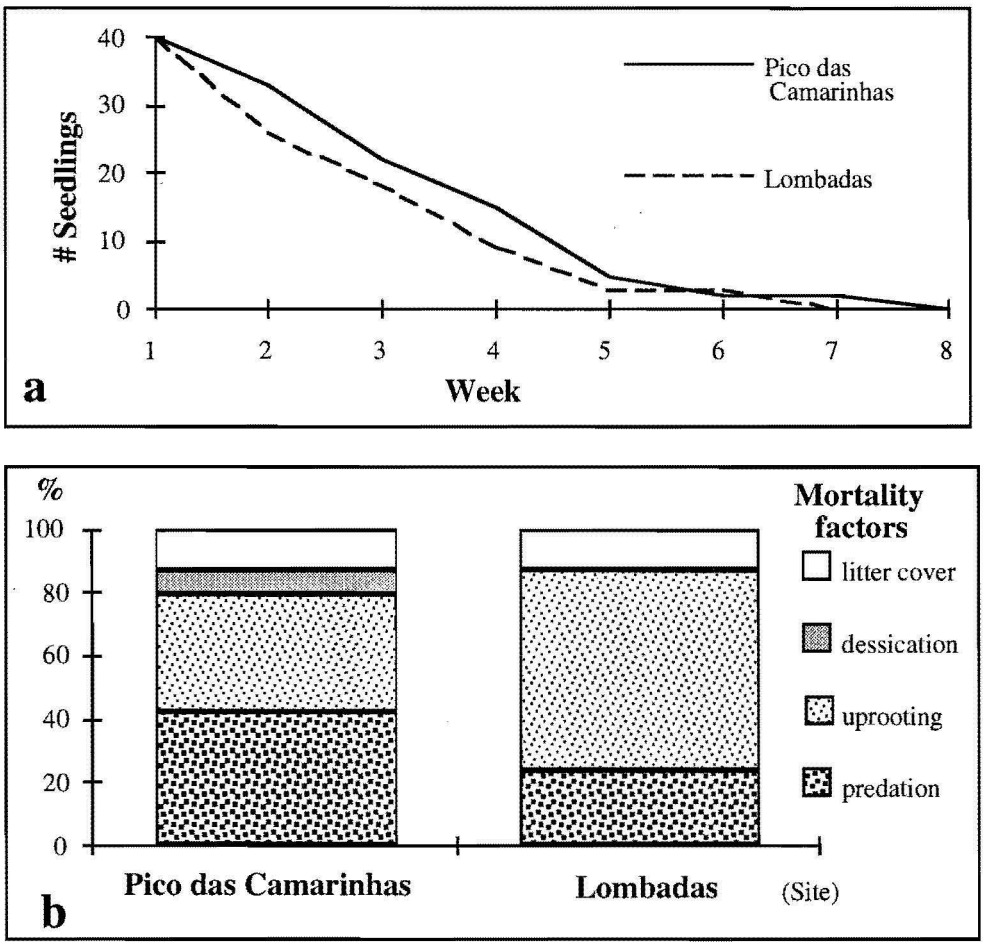

FIG. 6. a) Mortality of *Myrica faya* seedlings planted at Pico das Camarinhas (150 m) and Lombadas (550 m), in São Miguel (Azores); b) Mortality factors affecting *Myrica faya* seedlings at both sites.

tion is happening. At the Capelinhos volcano (Faial island), a thin *M. faya* stand is found with plants up to one meter height, young plants and seedlings, which are mostly found near mature plants, partially shaded or on dead *Carpobrotus edulis* (L.) N. E. Br. (Aizoaceae), in stabilised volcanic ash.

In the past *M. faya* was planted around farms to protect citrus and orange trees from wind, the wood was used in buildings and as fuel, the tannin rich bark was used to tan

leader (Drouët, 1866; Sjögren, 1984; Queirós; 1987). The fruits, edible but not appreciated, were used to prepare preserves, and the seeds were used as flour in hungry periods in the Canary islands (Ashmole & Ashmole, 1989).

The action of *M. faya*, and other native plants in facilitating infiltration of cloud water in the soil was recognised, and the fertilising effect of *M. faya* litter increases nutrient availability of the soil (Melville, 1979; Queirós, 1987). Further, *M. faya* is a source of food and shelter for birds and endemic insects (Banermann, 1966; Silva, 1992; Silva & Tavares 1995a; Silva *et al.*, 1995).

Human utilisation of this plant is now reduced, and in many lava flows below 500 m, *M. faya* was replaced by *P. undulatum*. Besides, many *Myrica/Erica* stands along the coast are now invaded by *Arundo donax*, formerly used as hedge plant, for protection against winds. At higher altitudes, *H. gardneranum* and *P. aquilinum* invade *M. faya* stands preventing regeneration.

Once, the plant was very abundant in Faial, but Drouët (1866) already mentioned that *M. faya* distribution was decreasing in that island, and in this century, *M. faya* stands were and continue to be cleared for pasture, except in rocky or highly sloped terrain. Queirós (1987) mentioned the regression of *M. faya* in the Azores as caused by human action, starting from early colonisation of the islands, and intense competition with *P. undulatum* from Australia, today naturalised in all the islands of the archipelago, and considered as invader in Jamaica, South Africa, and Australia (Cronk & Fuller, 1995).

According to Sjögren (1984), the few remaining *M. faya* stands along the coast should be preserved and protected, and Queirós (1987) stated that *M. faya* is an ibero-macaronesian endemic in extinction in mainland Portugal, that should be preserved. To preserve the *Faial*, including the associated flora and fauna, control of invasive plants is essential. On the other hand, *M. faya* stands are generally not considered as conservation sites, although Pico das Camarinhas stand was considered a CORINE biotope, and *Myrica/Pycconia* stands in Pico island were also recommended as conservation sites (Purvis *et al.*, 1993). Also, use of *M. faya* as an hedge plant should be stimulated, and other economic uses considered.

If no such measures are undertaken, lack of regeneration of *M. faya* stands will progressively lead to their reduction in the Azores. Changes in the associated entomofauna will probably occur as well as other unpredicted outcomes.

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