PHENOLOGICAL CYCLES OF *MYRICA FAYA* AITON (MYRICACEAE) IN THE AZORES ISLANDS

By L. SILVA [1] & J. TAVARES [1]

With 4 figures

ABSTRACT. The phenological cycles of *Myrica faya* AITON, 1789 (Myricaceae) were followed, weekly, at to sites in São Miguel Island (Azores), from October 1991 to October 1993. Data collected until this date support the following conclusions:

1) Flushing is reduced or inexistent from December until April. Net leaf production, per shoot, per year, is 16 leaves near the coast and 12 leaves at 550 m. Average growth rate at the tip of the shoots is about 7 cm/year. Leaf fall extends along the entire year.

2) Male flowering occurs between April and June/July, but female flowering extends until July/August. Green fruits and red fruits appear from May/June until September/ October, while purple fruits are found from July until October/November. Fruit drop extends between September and november.

3) Leaf damage, caused by phytophagous insects peacks during summer and autumn, but leaf mines are rare. Several factors, including strong winds near the coast and a disease causing dark spots on the leaves, may affect their lifetime, while a fungus attacks meristems. Male flower damage and fruit damage, caused by phytophagous insects, occurs in May and between June and September, respectivelly.

INTRODUCTION

Myrica faya AITON, 1789 (Myricaceae), a shrub or small tree that has been considered as an Ibero-Macaronesian endemic (QUEIRÓS, 1987), was introduced to Hawaii at the end of the 1800's, by portuguese immigrants. In the 1950's *M. faia* was already considered a noxious weed, invading rangelands, pasturelands and the natural forests of Hawaii. In the 1950's (YAMAYOSHI, 1954; KRAUSS, 1964) and later, in the 1980's (HODGES & GARDNER, 1985; GARDNER *et al.*, 1988; GARDNER & HODGES, 1990, MARKIN, 1990), a biological control program was activated in order to search for its natural enemies. At the same time,

[1] Universidade dos Açores, Departamento de Biologia, 9500 Ponta Delgada, Açores, Portugal

 ISSN 0870-3876

many studies were performed, in Hawaii, regarding distribution (WHITEAKER & GARDNER, 1985), phenology (WHITEAKER & GARDNER, 1987), plant-soil interaction (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).

Surprisingly, in the Azores, *M. faya* distribution is being reduced (QUEIRÓS, 1987) in consequence of human activities (destruction of the natural forest for pastures and industrial forest) and by the spread of invading exotic species (i. e. *Pittosporum undulatum* VENTENAT, Pittosporaceae and *Hedychium gardneranum* SHEPPARD, Zingiberaceae).

In the Azores, since 1991, a survey and testing of *M. faya* natural enemies is underway, as well as studies on phenology, germination, and ecology.

The present work, summarizes the results of the studies regarding the phenological cycles of *M. faya* in the Azores.

METHODS

Data was collected every week from October 1991 until October 1993, at two sites in São Miguel Island (Azores): Lombadas (inland, at 550 m of altitude) and Ferraria (near the coast, at 150 m altitude), the two places were chosen because of expected differences in rain fall, with higher levels at Lombadas. Thirty trees were observed at each site, for the following parameters, every week:

- Leaf flushing, using an index weigthing the proportion of trees in the following categories: 0 - without new leaves, 1 - few, 2 - some, or 3 - many new leaves; the index was calculated using the formula: F = P0x0 + P1x1 + P2x2 +P2x3, where P0 to P3 are the above mentioned proportions; Flushing at the two study sites, was compared using a KOLMOGOROV-SMIRNOF non-parametric test (SHERRER, 1984);

- Leaf damage caused by phytophagous insects, using an index weigthing the proportion of trees in the following categories: 0 - no damage, 1 - less than 25% of damaged leaves, 2 - less than 50% of damaged leaves, 3 - less than 75% of damaged leaves, 4 - from 75% to 100% of damaged leaves; the index was calculated using the formula:

LD = P0x0 + P1x1 + P2x2+ P3x3 +P4x4, where P0 to P4 are the above mentioned proportions; KENDAL correlation (SHERRER, 1984) was calculated between flushing and leaf damage for the two study sites;

- Leaf damage caused by weather agents or by pathogens;

- The number of plants in each of the following phenological stages: vegetative, male flowering, female flowering, immature fruiting, and mature fruiting;

- Proportion of shoots with damaged male flowers or fruits;

- Diseases affecting the trees.

Leaf fall and fruit drop were follwed by placing twenty 0,5 x 1 m trays at each site, and collecting the material biweekly. Fruit drop at the two study sites was compared using the U-test, from WILCOXON-MANN-WHITNEY (SHERRER, 1984).

Annual leaf production, growth rate at the tip of the shoot and basal diameter growth were also recorded, by measuring and counting 40 marked shoots and 10 tree trunks at each site. Differences between study sites were checked with a t-test (SHERRER, 1984).

RESULTS AND DISCUSSION

Flushing (Fig. 1) was reduced or inexistent between December and April, increasing in Spring and decreasing in Autumn. No differences seem to exist between the two sites (KOLMOGOROV-SMIRNOV, p=0.19).

On the other hand, in Hawaii, leaf flushing was found to be more active in June, but the patterns over the entire year differed at the driest and warmest site (WHITEAKER & GARDNER, 1987) where a correlation with precipitation was found. The same didn't happened at our two study sites, since the peaks of activity coincide with the lowest precipitation period: from July until September (Fig. 2). This phenophase was not allways present in the two studied places while in Hawaii it was almost never absent.

Different patterns of leaf fall were found at one site in Hawaii due to the high concentrations of SO_2 of vulcanic origin (WHITEAKER & GARDNER, 1987). In the Azores (Fig. 3), leaf fall was also influenced by environmental factors, since at Lombadas a peak was found in November, while at Ferraria leaf fall was maximal in April and was associated with strong, salty winds near the coast. Burning of the leaves at Ferraria, caused by the strong winds carrying salt water, begins in November, the majority of the exposed leaves being damaged.

At Lombadas, another agent damages the leaves, a disease causing dark spots surrounded by a lighter halo. The number of leaves affected by the disease, probably caused by a fungus, was reduced during Spring and Summer months, but increased during late Autumn and Winter months. Although no fruiting bodies were ever found over the spots, the disease was very similar to that found in North Carolina and Venezuela, associated with *Myrica* sp., caused by *Septoria* sp. (SMITH & GARDNER, personal communication). Another disease, caused by *Ramularia destructiva* PHILLIPS & PLOWRIGHT, that kills the tip of the shoots (twig blight), already mentioned by GARDNER & HODGES (1990), is found throughout the year at Lombadas, being very rare at Ferraria. This is probably connected with the fact that Lombadas is a wetter place than Ferraria, due to precipitation and frequent fog, keeping the surface of the leaves almost permanently wet.

In Hawaii, flowering showed maximum activity in June and peaks of immature fruiting followed in August and September, while maximum mature fruiting was seen in November. In Hawaii, these phenophases showed simmilar patterns at all the studied sites

and seemed to follow an annual cycle that is endogenously controled and/or initiated by consistent annual environmental cycles such as daylength (WHITEAKER & GARDNER, 1987). At no time of the year were any of these phenophases completely absent, what contrasts with what we found in the Azores, where the phenophases appear only in well defined moments (Fig. 4). In the Azores, the phenophases and their peaks of activity were found during the following periods: male and female flowering from April to August, with a peak in May/June; immature fruiting from May to November with a peak in August; and mature fruiting from July to December, with a peak in September/October. The given peaks of activity coincide roughly with those for Hawaii. The constant presence of all the phenophases in Hawaii, may be related with a longer daylength, throughout the year, when compaired with daylength in the Azores islands, located at higher latitudes.

An identical discussion applies to fruit drop, since it follows the pattern of mature fruiting. In Hawaii, fruiting was heaviest at the warmest and driest site and lightest at the cooler and wettest site (WHITEAKER & GARDNER, 1987). This agrees with what happened in the Azores (Fig. 3), since fruiting was heaviest at Ferraria, a dryer place than Lombadas (a significant difference was found with the U-test from WILCOXON-MANN-WHITNEY), and suggests that *M. faya* is not well adapted to reproducing in cold and/or extremely wet habitats. This also agrees with the upper altitudinal limit given by QUEIRÓS (1987) and SJÖGREN (1973), for the distribution of *M. faya* in the Azores, respectively 600 and 500 meters. Meanwhile, in the Azores maximum fruit drop occurs in September/October, but in Hawaii the peak is in November (WHITEAKER & GARDNER, 1987).

Annual growth rate at the tip of the shoot was 7,1 cm/year at Ferraria and 6,2 cm/year at Lombadas, although no significative differences were found ($t = 0.9$, $p = 0.36$).

On the other hand, net leaf production per year was 16 leaves/year at Ferraria and 12 leaves/year at Lombadas, this difference being significative ($t = 2.3$, $p = 0.023$).

Basal diameter growth was 4,4 mm/year at Lombadas and 1,0 mm/year at Ferraria, and this was a significative difference ($t = 4.8$, $p < 0.001$), while in Hawaii radial growth was between 6,7 (WHITEAKER & GARDNER, 1987) and 12 mm/year (VITOUSEK & WALKER, 1989).

Leaf consumption by phytophagous insects (Fig. 1), which, according to SILVA (1992) consists mainly on the larval stages of *Ascotis fortunata azorica* PINKER, 1971 (Lep., Geometridae), begins in Spring and is maximal during Summer and Autumn, ceasing in Winter. A positive correlation was found between flushing (Fig. 1) and leaf consumption (KENDAL correlation was 0,9 at Ferraria and 0,7 at Lombadas). Leaf mines caused by *Caloptilia aurantiaca* (Lep., Gracillariidae) are rare, and were found between February and November.

Male flower damage (Fig. 4) caused by *Argyresthia atlanticella* REBEL, 1940 (Lep., Yponomeutidae), begins in April and is maximal in May or June, and is followed by some fruit damage.

CONCLUSIONS

The main conclusions of the present work are as follows:

- In Hawaii, flowering and fruiting occur throughout the year, while in the Azores, these phenophases are restricted to well defined periods of the year;
- In the Azores, several environmental agents (weather agents, phytophagous insects and diseases), affect different organs of the plant, in well defined periods of the year.

ACKNOWLEDGEMENTS

Funding for this study was provided by the University of the Azores and by the Cooperative National Park Resources Studies Unit (CPSU), of the University of Hawaii at Manoa. Special thanks are due to Dr. Clifford W. Smith of the CPSU for his support and coordination of this program.

REFERENCES

APLET, G. H.:

1990. Alteration of earthworm community biomass by alien *Myrica faya* in Hawai'i. *Oecologia*, 82: 414-416.

CUDDIHY, L. W., G. L. SANTOS AND C. P. STONE:

1991. Control of firetree (*Myrica faya* Aiton) with herbicides in Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, National Park Service, *Technical Report* 82, 42 pp.

GARDNER, D. E., G. P. MARKIN AND C. S. HODGES, JR.:

1988. Survey for potential biological control agents for *Myrica faya* in the Azores and Madeira. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, National Park Service, *Technical Report* 63, 18 pp.

GARDNER, D.E. & C. S. HODGES, JR.:

1990. Diseases of *Myrica faya* (firetree, Myricaceae) in the Azores, Madeira and Canary Islands. *Plant Pathology*, 39: 326-330.

HODGES, JR., C. S. & D. E. GARDNER:

1985. *Myrica faya* : Potential biological control agents. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, National Park Service, *Technical Report* 54, 37 pp.

KRAUSS, N. L. H.:
1964. Insects associated with Firebush (*Myrica faya* Aiton). *Proceedings, Hawaiian Entomological Society*, 18(3): 405-411.

LAROSA, A. M., C. W. SMITH AND D. E. GARDNER:
1985. Role of Alien and Native Birds in the Disseminatioin of Firetree (*Myrica faya* Ait.-Myricaceae) and Associated Plants in Hawaii. *Pacific Science*, 39(4): 372-378.

MARKIN, G. P.:
1990. Insect Survey of potential Biological control agents of *Myrica faya* in the Azores and Madeira Islands. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, National Park Service, *Technical Report* 75, 26 pp.

MATSON, P.:
1990. Plant-Soil interactions in primary succession at Hawaii Volcanoes National Park. *Oecologia*, 85: 241-246.

QUEIRÓS, M.:
1987. *Myrica faya. in* Fernandes, A. & R. B. Fernandes (ed.), Iconographia Selecta Florae Azoricae, Secretaria Regional da Educação e Cultura da Região Autónoma dos Açores, 1(2): 17-24.

SCHERRER, B.:
1984. *Biostatistique*. Gaetän Morin Editeur, Québec, Canada, 850 pp.

SILVA, L.:
1992. Contribuição para o estudo da Bioecologia de *Ascotis fortunata azorica* Pinker (Lep., Geometridae). *Boletim da Sociedade portuguesa de Entomologia*, Suplemento 3 (2): 337-346.

SJÖGREN, E.:
1973. Recent changes in the vascular flora and vegetation of the Azores Islands. *Memórias da Sociedade Broteriana*, 22: 1-113.

TURNER, D. R. & P. M: VITOUSEK:
1987. Nodule Biomass of the Nitrogen-Fixing Alien *Myrica faya* Ait. In Hawaii Volcanoes National Park. *Pacific Science*, 41(1-4): 186-190.

VITOUSEK, P. M., L. R. WALKER, L. D. WHITEAKER, D. MUELLER-DOMBOIS & P. A. MATSON:

1987. Biological invasion by *Myrica faya* alters ecosystem development in Hawaii. *Science*, 238: 802-804.

VITOUSEK, P. M. & L. R. WALKER:

1989. Biological invasion By *Myrica faya* in Hawai'i: Plant Demography, Nitrogen Fixation, Ecosystem Effects. *Ecological Monographs*, 59(3): 247-265.

WALKER, L. R.:

1990. Germination of an invading tree species (*Myrica faya*) in Hawaii. *Biotropica*, 22(2): 140-145.

WALKER, L. R. & P. M. VITOUSEK:

1991. An invader alters germination and growth of a native dominant tree in Hawai'i. *Ecology*, 72(4): 1449-1455.

WHITEAKER, L. D. & D. E. GARDNER:

1985. The Distribution of *Myrica faya* Ait. in the State of Hawaii. Cooperative National Park Resources Study Unit, University of Hawaii at Manoa, National Park service. *Thecnical Report* 55, 31 pp.

WHITEAKER, L. D. & D. E. GARDNER:

1987. The Phenology and Stand Structure of *Myrica faya* Ait. in Hawaii. Cooperative National Park Resources Study Unit, University of Hawaii at Manoa, National Park service. *Thecnical Report* 62, 20 pp.

WOODWARD, S. A., P. M. VITOUSEK, K. MATSON, F. HUGES, K. BENVENUTO, & P. A. MATSON:

1990. Use of Exotic Tree *Myrica faya* by Native and Exotic Birds in Hawai'i Volcanoes National Park. *Pacific Science*, 44(1): 88-93.

YAMAYOSHI, H. T.:

1954. *Myrica faya survey District of Hamakua, Hawaii.* Unpublished report on file, Hawaii Dept. of Agriculture, Honolulu, 3 pp.

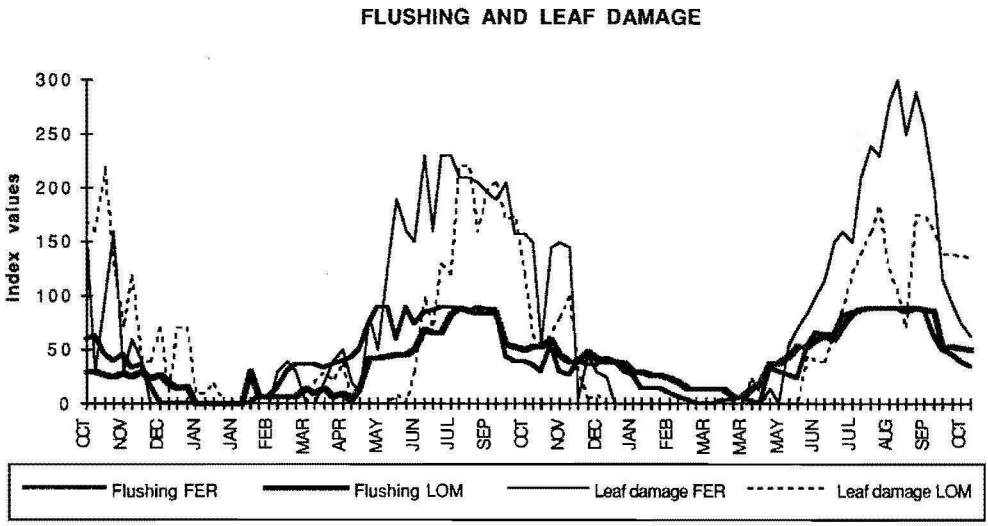

Figure 1 - Flushing and Leaf Damage of *Myrica faya* at two sites in São Miguel (Lombadas, LOM; and Ferraria, FER). Data from October 1991 to October 1993.

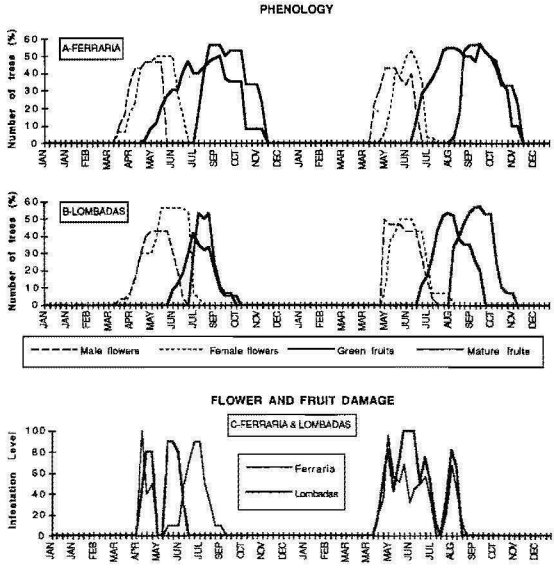

Figure 2 - Mean Temperature (A), Relative Humidity (B), and Rain Fall (C), at Ponta Delgada (PD, 50 m, average from 30 years) and Lagoa do Congro (PE, 550 m, average from 3 years), two meteorological stations, that are expected to be the closest to the study sites, respectively Ferraria and Lombadas. Data from "Instituto Nacional de Meteorologia e Geofísica" and "Posto Experimental de Culturas de Altitude".

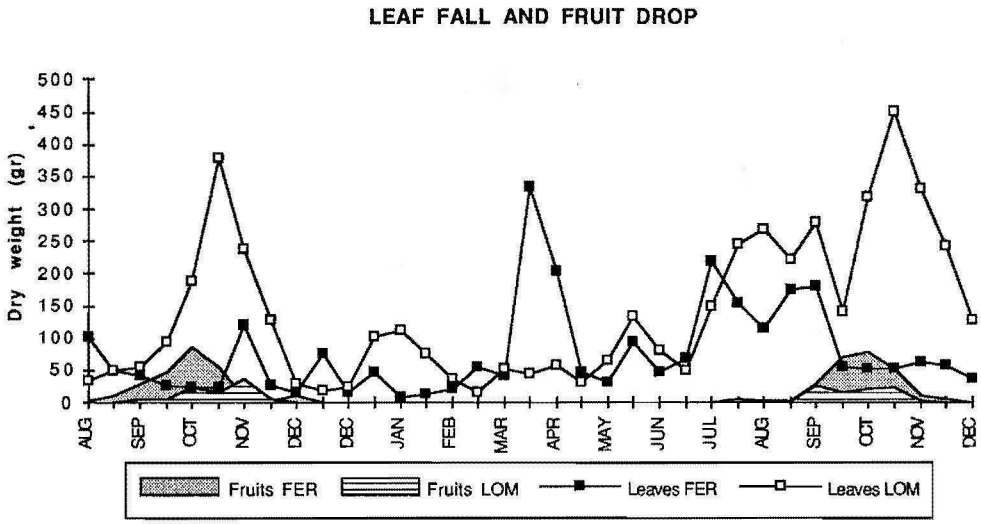

Figure 3 - *Myrica faya* Leaf litter and Fruit drop, collected in twenty litter traps, placed at two sites in São Miguel (Lombadas, LOM; and Ferraria, FER). Data from August 1992 to November 1993.

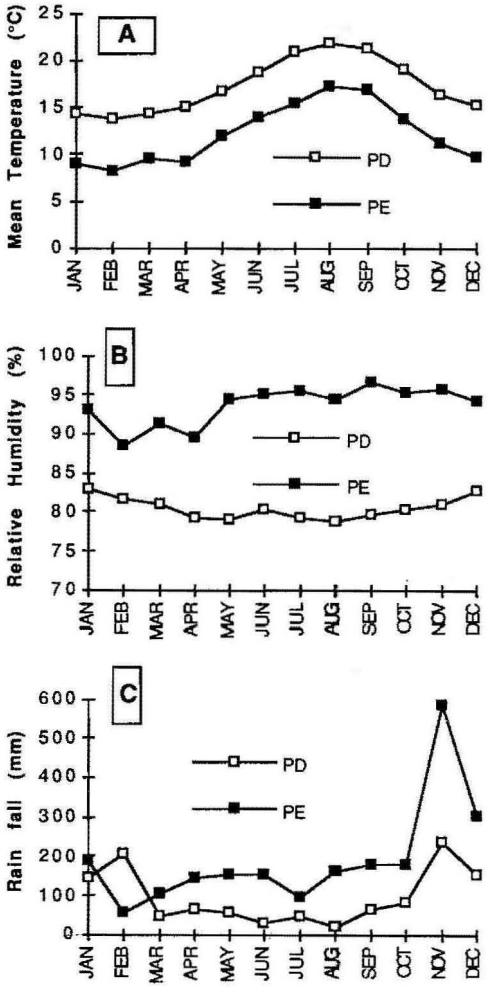

Figure 4 - *Myrica faya* phenolology, flower and fruit damage at two sites in São Miguel (Lombadas and Ferraria). Percentage of trees in the following phenophases: male flowering, female flowering, immature fruiting, and mature fruiting. (A) Phenophases at Ferraria; (B) Phenophases at Lombadas. (C) Percentage of the shoots with male flowers or fruits infested by *Argyresthia atlanticella* (Lep. Yponomeutidae). Data from January 1992 to December 1993.