

AUTOECOLOGICAL NOTES OF HALIMIUM HALIMIFOLIUM AT DOÑANA NATIONAL PARK

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Abstract

Halimium halimifolium is a woody Cistaceae species occurring locally in the Western Mediterranean. At Doñana National Park (S. Atlantic coast of Spain) *Halimium halimifolium* is the main component of stable sand vegetation, growing on contrasted environmental conditions from floodable depressions to fixed dune summits although it is more abundant on the slopes of the fixed dune ridges with water table 2 to 4 m deep, where it dominates scrub composition. Together with morphological modifications (hairy leaves and twigs) it also exhibits structural and ecophysiological adaptations, controlling physiological variables under stress conditions.

Introduction

Halimium, one of the genus of Cistaceae family, is represented in Europe by 9 species of which 5 occur in West Andalucía.

Halimium halimifolium (L.) Willk. is a shrub species typical of both coastal and inland sandy soils. In Europe it is distributed on the Western of the Mediterranean basin from Italy to Portugal (TUTIN & al., 1968), it is also present in the north of Morocco. In West Andalucía it appears on the North Mountain Range of Sevilla, Aracena mountains and all over the coast from the Guadiana estuary to Algeciras (VALDÉS & al., 1987).

The main morphological characteristics of this species are the following: very branched, erect shrub up to 2 m high. Leaves elliptical or spatulated-lanceolate, white-tomentose on both surfaces, when young, greenish when mature with silvery, peltate scales and stellate hairs. Yellow flowers in numerous paniculate cymes. Five unequal sepals and 5 petals, spotted or unspotted (TUTIN & al., 1964-1980).

The broad distribution of *H. halimifolium* in Doñana National Park and its peculiar ecological behaviour have conducted to a large number of studies about this species. The aim of this contribution is to make a synthesis of the autoecology of *H. halimifolium* based on the literature and on our own work.

Study area

Doñana National Park is located in SW Spain facing the Atlantic ocean (Fig. 1). It has a mediterranean type climate with an oceanic influence. Monthly average temperatures are 9,3^o C in winter and 23,9^o C in summer. Annual rainfall lies around 600 mm. Summer drought is severe, with no precipitation (MERINO & MARTÍN VICENTE, 1981; GARCÍA NOVO & MERINO, 1993).

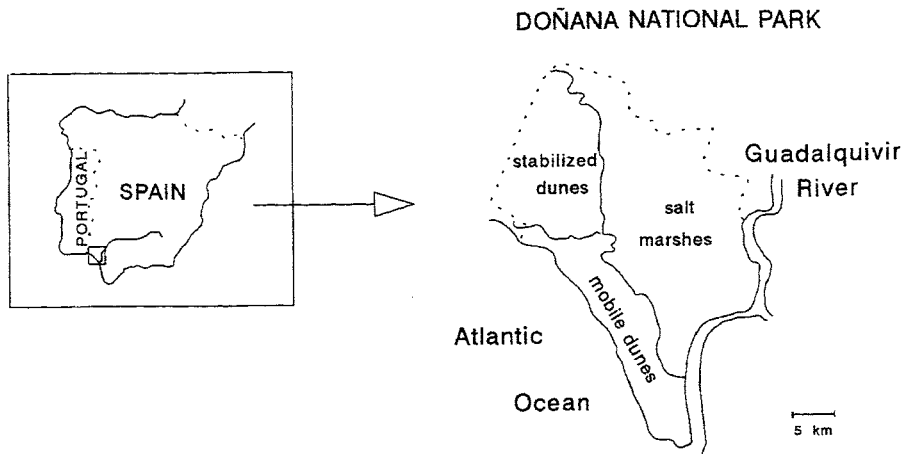


Fig. 1. Location of Doñana National Park in the Iberian Peninsula. Names and location of the three ecological units of the Park are also given.

The Park, with an extension of 77.620 Ha, includes three main ecological units: marsh, mobile dunes and stabilized sands (Valverde 1958). In fig. 1 the location of three ecological units of the Park are shown.

The mobile dune system corresponds with a sand barrier separating the marsh from the sea. It also extends over a sector of coastal plain, advancing inland from the beach (5 m/year, GARCÍA NOVO & al., 1975). There are four or five successive dune fronts between the beach and the inner boundary of the system, each separated by a flat depression (slack) from the next. *Pinus pinea* is the most abundant tree species of the mobile dune system. Pine trees grow both in dunes and slacks (local name "corral" CL). Other woody species present are *Halimium halimifolium*, *Corema album*, *Scrophularia frutescens* and *Artemisia crithmifolia*. Water table depth at the slack usually lies about 2 m in summer. The stabilized sands show a series of arched ridges (old dunes) separated by flat depressions. Three main types of scrub are found in the stabilized sands, depending on the depth of the water table (GONZÁLEZ BERNÁLDEZ & al., 1975 a, b; GARCÍA NOVO, 1977, 1979; GARCÍA NOVO & MERINO, 1993): "Monte Blanco" (MB) is located on top of the dune ridges. The vegetation is dominated by *Juniperus phoenicea*, *Halimium commutatum*, *Rosmarinus officinalis* and *Cistus libanotis*; water table summer depth is over 3 m. "Monte Negro" (MN) is located at the depressions. The vegetation is dominated by *Erica scoparia*, *Erica ciliaris*, *Ulex minor*, *Calluna vulgaris*, and *Cistus salvifolius*; water table summer depth is between 0.5-1.5 m. "Monte Intermedio" (MI) is located on the slopes of the dune ridges, the vegetation is dominated by *Halimium halimifolium* and *Ulex australis*; water table summer depth is between 1.5-3 m.

Distribution and succession

In Doñana National Park *Halimium halimifolium* is the dominant species of the scrub of the MI (average plant cover is 47.5%), but it also grows on the different sand communities on the stabilized sands from the depressions of the MN (3.8%), to the xeric areas of MB (30%).

H. halimifolium is also present on the mobile dune system (with a cover of 1.5%), behaving as a pioneer species in the first stages of colonization on the tail of the eroding dune, together with *Scrophularia frutescens* and *Artemisia crithmifolia*.

A line transect sample extending SW-NE on the stabilized sands of the Park, from the elevated drier areas to the border of the marsh along 11 Km, has shown that there is a remarkable relationship between the abundance of *H. halimifolium* and the depth of the phreatic table (see Figure 2). The correlation coefficient between *H. halimifolium* cover and depth of the phreatic level is significant with a $p < 0.0001$.

The secondary succession after fire in the stabilized sands of Doñana was studied by MARTÍN VICENTE (1982) and published in MERINO & MARTÍN (1981) and MERINO et al. (1990).

H. halimifolium does not resprout after fire, being an obligate seeder (GARCÍA NOVO, 1977).

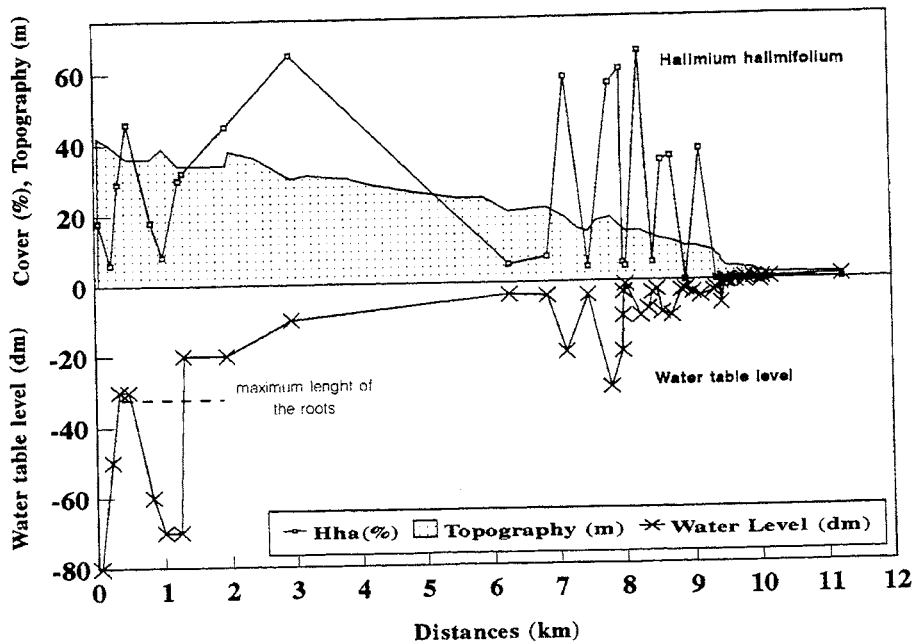


Fig. 2. Topography (m), *H. halimifolium* cover (%) and water table level (dm) on the line transect sample extending along 11 Km, on the stabilized sands of Doñana National Park.

The evolution of *H. halimifolium* is different depending on the topography (Figure 3), thus at MB plant biomass increases to a maximum close to 300 g/m², 30 years after fire and later decreases to less than 100 g/m², 100 years after fire and the relative importance of this species in the community biomass always decreases with time. At MI plant biomass always increases with time, reaching a maximum of 750 g/m², 100 years after fire and the relative importance of this species in the community biomass remains close to 50% along the succession. At MN plant biomass increases very quickly reaching 115 g/m², 5 years after fire and later remains stable, with the same amount of biomass in the mature stages, but the relative importance of this species in the community biomass always decreases with time reaching 5% in the mature stages.

The evolution of plant height is the same in the three areas (Figure 3), reaching a maximum of 70 cm (MB) and 120 cm (MI and MN) 6 years after fire, and later remaining stable. The evolution of the leaf/woody biomass ratio is also the same in the three areas showing an exponential curve with values between 1-2 in the initial stages decreasing to 0.1 in the mature stages.

The succession studies of *H. halimifolium* at the stabilized sands of Doñana show that this species has a pioneer character being able to colonize any area after fire; but in the mature stages it remains as the dominant species at the MI, decreasing its relative importance in the other areas.

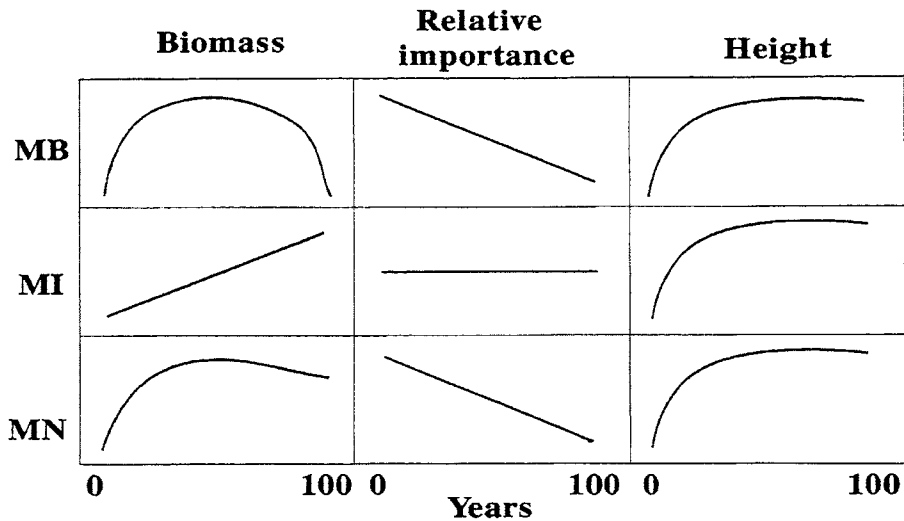


Fig. 3. Temporal changes (years after fire) of *H. halimifolium* plant biomass, relative importance of this species in community biomass and plant height in Monte Blanco (MB), Monte Intermedio (MI) and Monte Negro (MN) of the stabilized sands (modified from Martín Vicente, 1982).

Canopy structure and light extinction

The phenomorphological characters of *H. halimifolium* at the MI of the stabilized sands were studied by MERINO (in Specht, 1988).

The vertical structure of *Halimium halimifolium* was studied by destructive methods (vertical profiles of organ biomass) in four areas of Doñana National Park (DÍAZ BARRADAS, 1988; DÍAZ BARRADAS & GARCÍA NOVO, 1987a,b). The vertical profiles show (Figure 4) considerable differences depending on the water and nutrient availability, the stability of the substrate and the herbivore pressure.

MB plants have the smaller size (less than 70 cm) and lower photosynthetic and structural biomass. MI plants reach 100-120 cm height; because of the high plant cover (84%) of MI, individuals of this area must have an important vertical growth to avoid the light competition. Although plant cover is the highest at the MN (over 100%), *Halimium* plants usually grow at the border of the heath spots thus they do not suffer an important light competition. The most important factor controlling plant structure at this area is herbivore pressure (AGUILAR & al., in press); MN are smaller than MI

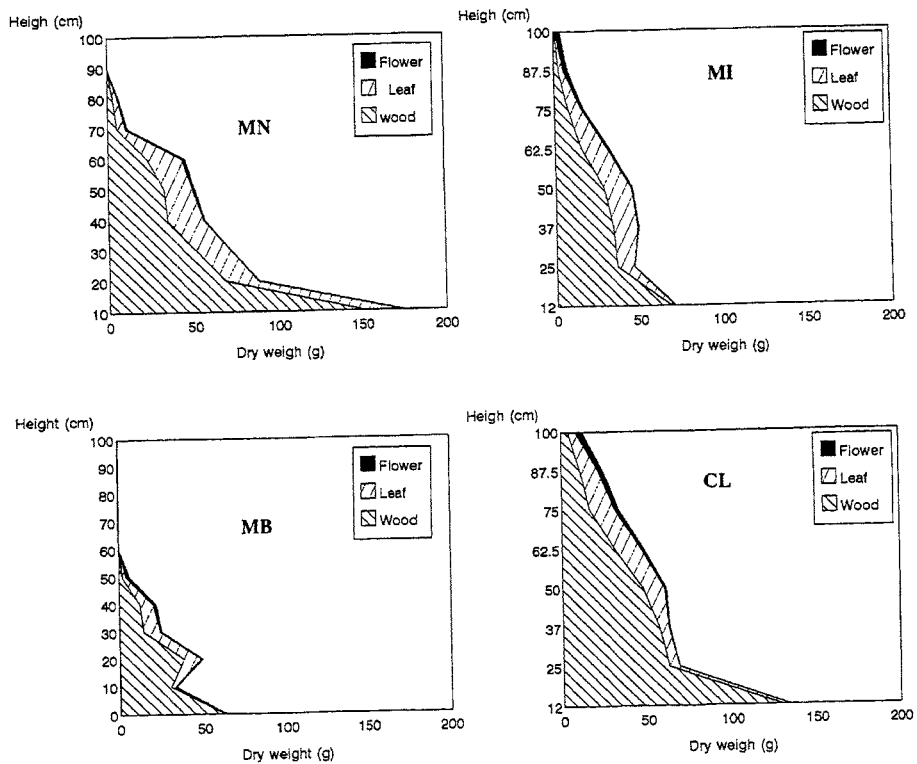


Fig. 4. Vertical profiles of organ biomass (g) of *H. halimifolium* representative shrubs in MB, MI, MN and dune slacks (CL).

plants and they have an important accumulation of biomass at the basal trunk and similar amounts of photosynthetic biomass. The CL plants have the important accumulation of structural biomass all over the vertical profile, to resist on the unstable dunar soil.

The LAI of this species shows a remarkable variability (0.61-3.5), depending on the water availability (Fig. 5). In the depressions of the MN the maximum values are obtained (2.5-3.5), while the MB presents the minimum values (0.6-0.8). In the SL of the mobile dune system the values oscillate from 1.1 in small plants to 2.1 in the larger plants. In MI the values are close to 1.0.

Significant differences were found in leaf characteristics (Fig. 5), showing MB plants the lowest surface and the highest specific leaf weight and number of leaves per shoot (these are adaptations to a xeric environment), while MN plants have the highest surface and lowest specific leaf weight. MI and CL plants present intermediate characteristics.

Light penetration within the plant canopy is determined by structural characteristics of the plant, primarily the distribution of leaf area index, stem area index and leaf and stem inclination angles. The morphological differences found in *H. halimifolium* between the different communities determine differences in the capacity of light extinction. Thus the percentage of the incident photosynthetic active radiation (400-700 nm) reaching the base of the plant oscillates between 25% at the MN and 55% at the MB, presenting both MI and SL plants intermediate values of 45%.

The analysis of leaf reflectance and leaf colour shows that *H. halimifolium* is less green and presents higher leaf reflectance, when compared with other species of mediterranean scrub. The leaves from the slack plants are significant ($p < 0.01$) more

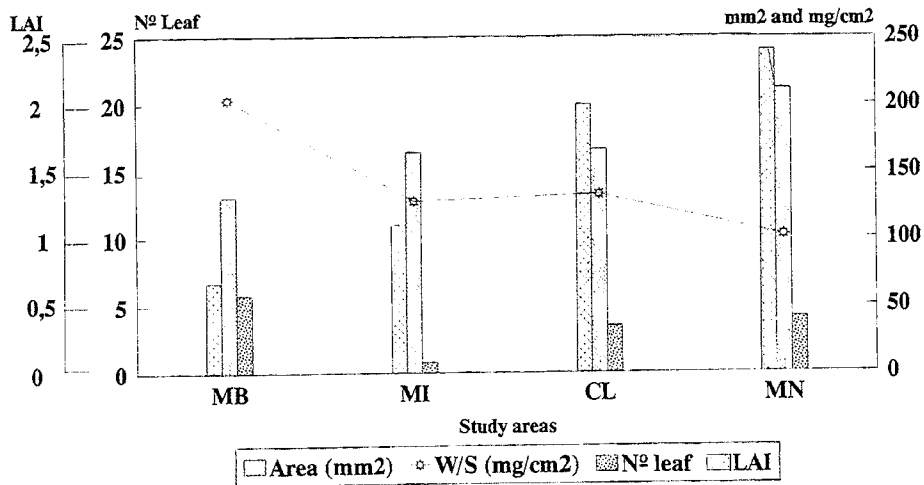


Fig. 5. Average leaf characteristics of *H. halimifolium* shrubs at the four contrasted areas, MB, MI, MN and CL: Leaf Area Index (LAI), leaf surface (mm²), Specific Leaf Weight (mg/cm²) and number of leaves.

reflectant than those from MI plants (DÍAZ BARRADAS & GARCÍA NOVO, 1988). This reduction in leaf absorbance may be considered as an adaptation to arid climates or intense radiation environments (EHLERINGER, 1981; EHLERINGER & COMSTOCK, 1987; MONTSERRAT, 1984).

Phenology

H. halimifolium presents both seasonal and interannual changes, that were described using a frequency method in permanent plants by DÍAZ BARRADAS & GARCÍA NOVO (1987, 1990).

Figure 6 represents the interannual changes of organ frequency in a representative permanent plant of *H. halimifolium* studied from 1984 to 1991, all the data correspond to the spring growing season. During the first years (1984-88) leaf frequency is always higher than woody frequency, but since 1989 the situation changes. During 1988-90 leaf and woody frequency present very close figures and since 1991 woody frequency is higher than leaf frequency. This temporal pattern is also found when individuals of *H. halimifolium* of different heights, growing in the same area are harvested and organ dry weight is measured (DÍAZ BARRADAS, 1988), and has been described by different

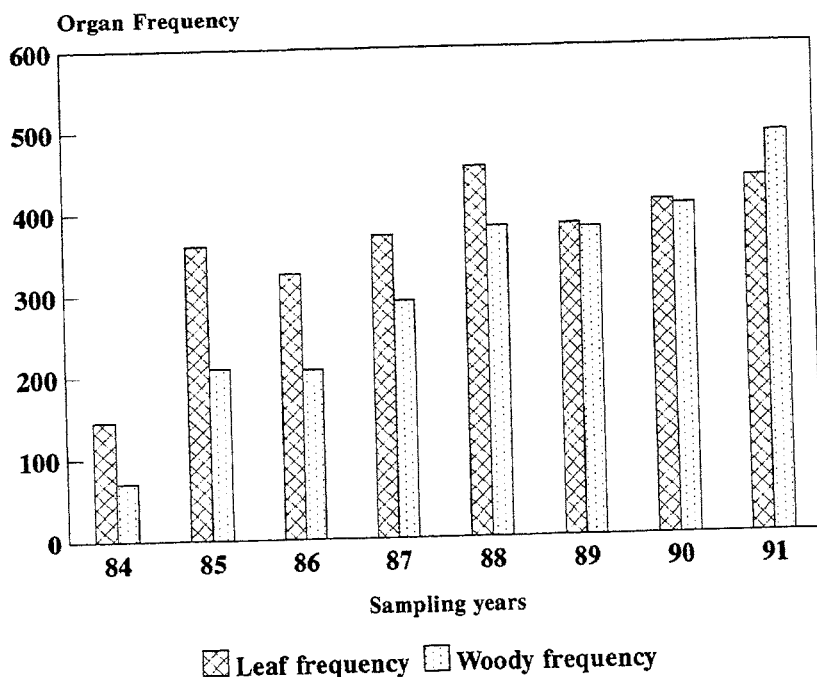


Fig. 6. Interannual changes of leaf and woody frequency of a permanent plant of *H. halimifolium* at the slack of the mobile dune system.

authors in others communities using destructive methods (like DEBUSSCHE et al., 1980 in the south of France).

Seasonal vegetative growth and leaf production were compared in four different areas of Doñana (MB, MI, MN and CL) by marking 25 shoots at the top of the previous year growth in each area, before the starting of the new growing season. Shoots were monitored monthly from February to November 1994.

Main shoot, ramifications elongation and leaf production follow the same pattern in the four studied areas, vegetative growth starts in March and ends in July (where the maximum values were measured) according to temperature and water availability. The differences appear in the intensity of growth and in the allocation of the production to main shoot or to ramifications. Vegetative growth follows a sigmoidal curve, similar to those described by MONTENEGRO et al. (1979) in Chilean matorral shrubs. Fig. 7 shows the accumulative growth of the main shoot and ramifications, the total number of leaves (both of the main shoot and ramifications) and the number of ramifications in the four studied areas. There is a temporal delay of two months between the growth of the main shoot and of ramifications. Leaf production and shoot elongation occurs simultaneously.

Flowering period is short, mainly in spring with a clear maximum in June for all the areas.

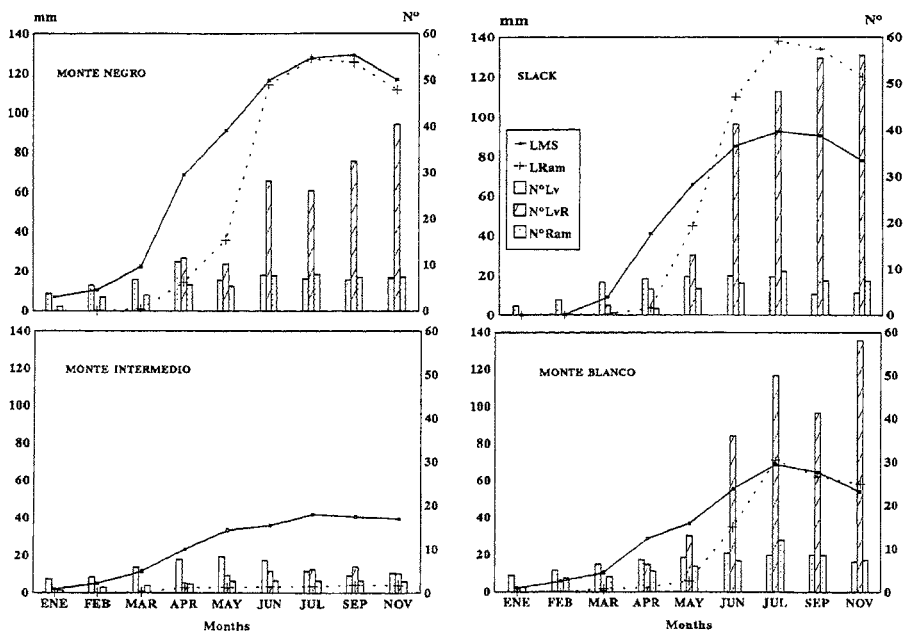


Fig. 7. Accumulative growth of *H. halimifolium*: length of the main shoot (LMS) and average length of ramifications (L_{Ram}), number of ramifications (N^oR) and number of leaves on main shoot (N^oL_v) and on ramifications (N^oL_{vR}) for each area MB, MI, MN and CL during 1994 growing cycle.

Physiology

The annual cycle of leaf water potential and leaf diffusion resistance was studied in a set of 45 marked plants, 15 in each of the three main communities, MB, MI and MN. The measurements were taken monthly in the field at predawn and midday.

During winter months water is available in all the areas because of precipitation, dew and low temperatures, avoiding the existence of very low water potentials at midday (the average is -1.8 Mpa) and the stomata remain open all day (average resistance is 4 s/cm) in the three studied areas. The differences start to appear at the end of spring, with the increase of temperatures and the end of the rainy season (see Fig. 8).

During the summer drought, mean leaf water potential for area declines dramatically to values lower than -3.9 Mpa in MI (where some individuals died) and -3.5 Mpa in MB while in MN where the water is always available the water potential decrease much less (about -2.0 Mpa). The resistance reached values higher than 67 s/cm in MI, 47 s/cm in MB and 20s/cm in MN. MERINO et al. (1976) found similar values for this species in summer months.

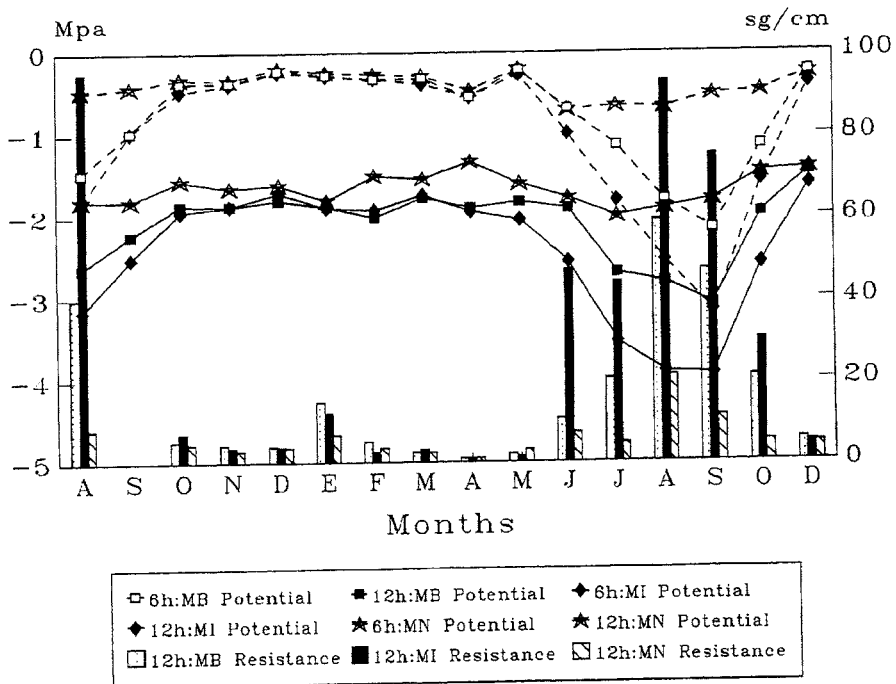


Fig. 8. Annual cycle of predawn and midday leaf water potential and leaf diffusion resistance in a set of 45 permanent plants, 15 in each of the three main communities MB, MI and MN. 6:MB, 6:MI, 6:MN: predawn leaf water potential in each area. 12:MB, 12:MI, 12:MN: midday leaf water potential. 12:MB.RESIT, 12:MI.RESIT, 12:MN.RESIT. midday leaf diffusion resistance.

MI plants were the most stressed and they presented the highest sensibility to stomatal closure during this drought period, however it is in this area where the highest *H. halimifolium* cover is found. MB plants are better adapted to a drought period than MI plants, because they are used to suffer a continuous water stress, their plant roots never reach the phreatic table and they use the soil water profile.

The close relationship between leaf water potential and soil water availability is clearly shown with the significant correlation between the depth of the water table level and the leaf water potential of *H. halimifolium* plants. The measurements were recorded in the field in nine plots with different depths of water table level at the end of June. In Fig. 9 the linear regression between water table deep and leaf water potential is shown, each point of the graphic corresponds to the average leaf water potential of 15 individuals randomly chosen in each area ($r = 0,98$, $p < 0,0001$).

Conclusions

The results of the *H. halimifolium* studies show that it is a plastic species with characters of the three Grime's models (GRIME, 1979). It can resist the competence (showing a vertical growth like occurs in MI), it can resist water stress, high summer insolation (and nutrient deficit), by controlling leaf water potential, changing leaf

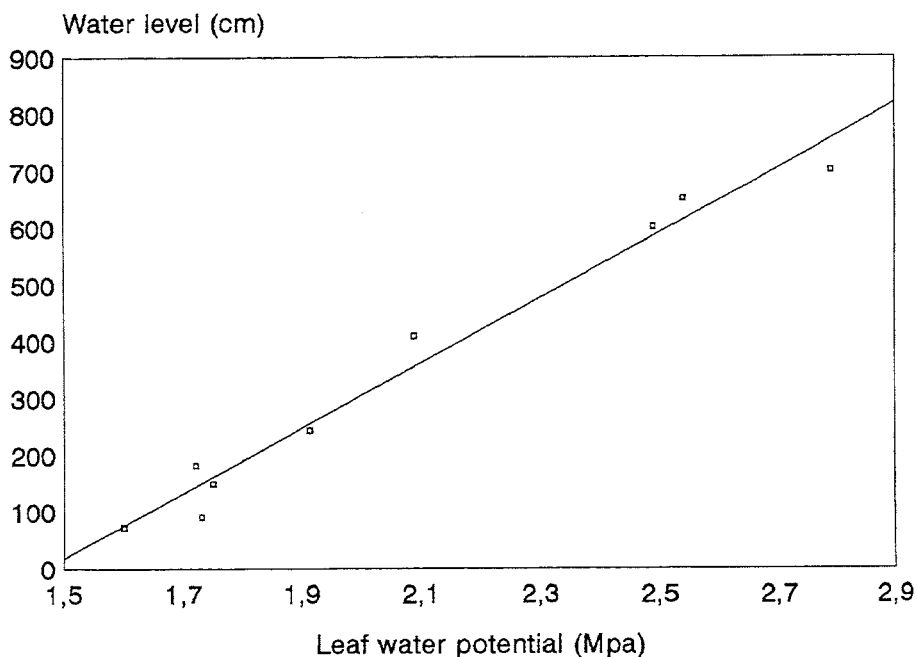


Fig. 9. Linear regression between the depth of water table and leaf water potential, each point of the graphic corresponds to the average leaf water potential of 15 *H. halimifolium* plants randomly chosen in each area.

reflectance, presenting an important accumulation of dry weigh in a basal trunk and developing a large root system. Finally it can resist some perturbation, for instance herbivore pressure, increasing its vegetative growth. All these peculiarities suggest that *H. halimifolium* has a reactive character well adapting to changes in the environment, with modifications in its canopy structure, plant elements and physiology; because of this different individuals exhibit oposite features if they grow in contrasted habitats.

The success of *H. halimifolium* in Doñana National Park emphasizes the possibilities offered to a reactive character in a changing and disturbed environment.

References

- AGUILAR SILVA, F. J., M. C. DÍAZ BARRADAS & M. ZUNZUNEGUI (1996). Growth of *Halimium halimifolium* shrub following simulated and natural browsing in Doñana National park (SW Spain). *J. Veg. Sci.* (in press).
- DÍAZ BARRADAS, M. C. (1988). *Fluctuaciones de la estructura vertical del matorral mediterráneo*. Ph.D. thesis. University of Seville.
- & F. GARCÍA NOVO (1987a). Vertical structure of *Halimium halimifolium* shrub in Doñana National Park (SW Spain). In: J. TENHUNEN, W. OECHEL, F. CATARINO & O. LANGE (eds.) *Plant response to stress*. Springer-Verlag. Berlin, Heidelberg: 531-545.
- & F. GARCÍA NOVO (1987b). The vertical structure of mediterranean scrub in Doñana National Park (SW Spain). *Fol. Geobot. Phytotax.*, **22**: 415-433.
- & F. GARCÍA NOVO, F. (1988). Modificación y extinción de la luz a través de la copa en cuatro especies de matorral en el Parque Nacional de Doñana. *Homenaje a Pedro Monserrat*. 503-516. Jaca, Huesca.
- & F. GARCÍA NOVO (1990). Seasonal changes in canopy structure in two mediterranean dune shrubs. *J. Veg. Sci.* **1**: 31-40.
- DEBUSSCHE, M., J. ESCARRE & J. LEPART (1980). Changes in mediterranean shrub communities with *Cytisus purgans* and *Genista scorpius*. *Vegetatio* **43**: 73-82.
- EHLERINGER, J. R. (1981). Leaf absorptance of Mohave and Sonoran desert plants. *Oecologia* **49**: 366-370.
- & J. Comstock (1987). Leaf absorptance and leaf angle: Mechanisms for stress tolerance. In: J. TENHUNEN; W. OECHEL, F. CATARINO & O. LANGE (eds.). *Plant response to stress* Tenhunen. Springer-Verlag. Berlin, Heidelberg.
- GARCÍA NOVO, F. (1977). The effects of fire on the vegetation of Doñana National Park. *Proc. Symp. Environm. Cons. Fire Fuel Manag. Medit. Ecosyst.*: 318-325.
- (1979). The ecology of dune vegetation of Doñana National Park. In: R. L. JEFFRIES & A. J. DAVY (eds.). *Ecological Processes in Coastal Environments*: 571-592.
- , RAMÍREZ DÍAZ, L. & A. TORRES MARTÍNEZ (1975). El sistema de dunas de Doñana. *Nat. Hisp.*, **5**. ICONA.
- GARCÍA NOVO, F. & MERINO, J. (1993). Dry coastal ecosystems of southwestern Spain. In: E. VAN DER MAAREL (ed.). *Dry coastal ecosystems*: 349-362. Elsevier. Amsterdam.
- GONZÁLEZ BERNÁLDEZ, F., F. GARCÍA NOVO & L. RAMÍREZ DÍAZ (1975a). Analyse factorielle de la végétation des dunes de la Reserve Biologique de Doñana (Espagne). I. Analyse numerique des donnees floristiques. *Israel J. Bot.* **24**: 106-117.
- , F. GARCÍA NOVO & L. RAMÍREZ DÍAZ (1975b). Analyse factorielle de la végétation des dunes de la Reserve Biologique de Doñana (Espagne). II. Analyse d'un gradient du milieu. Etude speciale du probleme de la non-linearite. *Israel J. Bot.* **24**: 173-182.

- GRIME, J. P. (1979). *Plant strategies and vegetation processes*. Wiley & Sons, Chichester.
- MARTÍN VICENTE, A. (1982). *Sucesión tras el fuego del matorral de las arenas estabilizadas de la Reserva Biológica de Doñana*. Ph. D. thesis. University of Seville.
- MERINO, J., F. GARCÍA NOVO & M. SÁNCHEZ DÍAZ (1976). Annual fluctuation of water potential in the xerophitic shrub of Doñana Biological Reserve (Spain). *Oecol. Plant.*, **11**: 1-11.
- & A. MARTÍN VICENTE (1981). Biomass, productivity and succession in the scrub of the Doñana Biological Reserve in SW Spain. In: H. A. MOONEY & N. S. MARGARIS (eds.): 63-71. *Productivity in mediterranean ecosystems*. Dr. Junk Editors.
- , M. P. MARTÍN, A. MARTÍN & J. MERINO (1990). Successional and temporal changes in primary productivity in two mediterranean scrub ecosystems. *Acta Oecol.* **11**: 103-112.
- MONTENEGRO, G., M. E. ALJARO & J. KUMMEROW (1979). Growth dynamics of Chilean matorral shrubs. *Bot. Gaz.* **140**: 114-119.
- MONTSERRAT, P. (1984). Dinámica de las zonas áridas. *Seminario sobre zonas áridas*. 75-89. Instituto de Estudios Almerienses.
- SPECHT, R. L. (ed.) (1988). *Mediterranean-type ecosystems a data source book*. Kluwer Academic Press. Dordrecht, Boston, London.
- TUTIN & al. (1964-1980). *Flora Europaea 1-5*. Cambridge University Press.
- VALDÉS, B., S. TALAVERA & E. FERNÁNDEZ GALIANO (eds.) (1987). *Flora vascular de Andalucía Occidental 1-3*. Ketres Editora. Barcelona.
- VALVERDE, J. A. (1958). An ecological sketch of the Coto Doñana. *Br. Birds* **51**: 1-23.

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