Orsis, 8: 121-126 (1993)

Response of Mediterranean grassland species to changing rainfall. A reply to Figueroa and Davy

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Key words: Mediterranean annuals, temporal changes, dehesa.

Resumen. *Respuesta de especies pratenses mediterráneas a cambios en la precipitación. Una réplica a Figueroa y Davy.* Se han revisado los resultados publicados por Figueroa & Davy en el *Journal of Ecology* (vol 79: 925-941, 1991) sobre la relación entre las variaciones en frecuencia de las especies de pastos mediterráneos del W de España y la precipitación, debido a que sus resultados contradicen los de otros autores que también han estudiado estas relaciones en otros pastos mediterráneos. La causa de esta contradicción estriba en que los datos de precipitación utilizados por Figueroa & Davy contienen muchos errores. Cuando se utilizan los datos correctos los resultados son concordantes con los de los otros autores.

Abstract. The results of a paper of Figueroa & Davy in the *Journal of Ecology* (vol 79: 925-941, 1991) on the relationships between changes in species frequency and rainfall in a Mediterranean grassland of W Spain have been revised, because they do not agree with the results of other authors that have studied this relationships in other Mediterranean grasslands. The lack of agreement is the result of the inaccuracies contained in the rainfall data used by Figueroa & Davy. When the correct rainfall data are used, the results agree with those of the other authors.

Introduction

Recently, M.E. Figueroa and A.J. Davy have published a paper in the *Journal of Ecology* (1991) on the relationships between changes in species abundance and rainfall in a Mediterranean grassland in W Spain. Using a long series of data (11 years) on species frequency in a dehesa grassland in Alía (Cáceres), and rainfall data from the meteorological station of Guadalupe (Cáceres), the authors show that winter rainfall and the rainfall over the whole growing season are good predictors of the abundance of a considerable number of species (25%), better than autumn and spring rainfall. These results do not fit with other studies on Mediterranean grasslands of California (Duncan & Woodmansee, 1975; Pitt & Heady, 1978), Australia (Rossiter, 1966), Israel (Naveh, 1982) and Spain (Ortega & Fernández Alés, 1987). All these authors find better relationships between species abundance and seasonal rainfall (specially with autumn and spring rainfall) than with annual rainfall.

Hobbs & Mooney (1985), Marañón (1985) and Fernández Alés (1991) have shown that, in Mediterranean annual grasslands, only a small part of the seed bank emerge as seedlings, and almost all of them emerge during the first month after the first autumn rains, with many of them dying in this time of the year. Mortality is very low during winter and spring, and almost all survivors die at the end of the spring, after producing seeds. This means that the botanical composition and species abundance in the grassland are determined during the germination and seedling emergence period, remaining constant during the rest of the growing season (Heady, 1958; Ortega & Fernández Alés, 1987). Thus, the distribution and abundance of rainfall during this critical period (autumn) will be a paramount factor in determining the abundance of the species in the grassland (Bartolome, 1979; Ortega & Fernández Alés, 1987). Since autumn rainfall is not correlated with winter or total rainfall (Figueroa & Davy, 1991), the set of processes described cannot explain the relationships found by Figueroa & Davy.

The objective of this study is to revise the data of Figueroa & Davy, in order to investigate the causes of the lack of agreement between the results of these authors and the results of the other studies cited above.

Methods and results

The first matter investigated is the effect of data transformation on the results of the correlation between plant frequency and rainfall, since the correlation coefficient r is not invariant to logarithmic transformations. In order to test for the effect of the transformation used, the non transformed frequency data for the most abundant species (the only plant data available from Figure 2 of Figueroa & Davy, 1991) have been correlated with the total rainfall over the whole growing season (Figure 1 in Figueroa & Davy, 1991), and the results compared with the ones published by Figueroa & Davy using log-transformed plant frequency data (tables 1, 2, 3, 4 and 5 in Figueroa & Davy, 1991). The results (Table l) show that the number of species showing significant correlation increases from 7 to 10 when using non transformed data. Thus, it can be concluded that data transformations are not the responsible for the discrepancies detected.

The second matter investigated is the existence of errors in the data. The revision of the rainfall data used by Figueroa & Davy has shown that there are some inaccuracies in them. Thus, the data on annual precipitation in Guadalupe meteorological station used in figures 1 and 3 by Figueroa & Davy (Figure la), do not fit with the data provided by the Spanish Meteorological Institute for Guadalupe station (Figure lb), nor with the data from Alía station (figure lc,), that lies closer to the study area.

In view of such discrepancies, the non transformed plant frequency data has been correlated with the rainfall data from Alía Meteorological station. This station has been selected because it has no missing data, as it happens with Guadalupe station (Figure 1). Product-moment correlation coefficients (n=ll) were calcula-

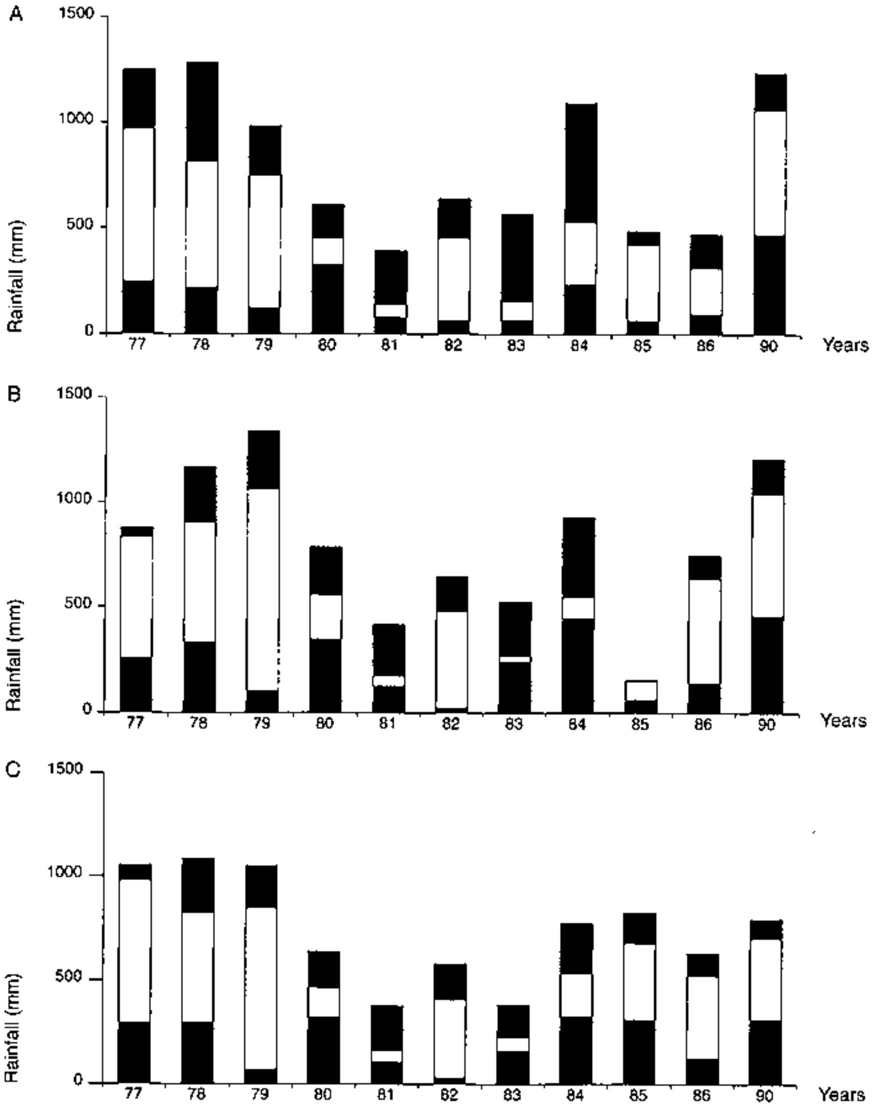

Figure 1. Total rainfall during the growing season (October-May) at two meteorological stations close to the study area of Figueroa & Davy, for the years in which plant frequency was recorded. Separate seasonal components: (■) Autumn (October-November), (□) winter (December-February), (■) Spring (March-May). A. Data from Figueroa & Davy (1991) for Guadalupe station. B. Data provided by the Spanish Meterological Institute for Guadalupe Station. This station has missing data (months in which rainfall was not recorded) in 1983, 1984, 1985 and 1986. The number of months with missing data each year are marked at the top of the bar, in brackets. C. Data provided by the Spanish Meteorological institute for Alía Station, closer to the study area than Guadalupe and with no missing data.

ted between the total frequency of each species and total rainfall during the whole growing season and over autumn (October, November), winter (December, January, February) and spring (March, April, May).

The results (Table 2) show that, when considering the rainfall data of Alía instead of the ones provided by Figueroa & Davy, the number of species exhibiting significant correlation with rainfall over the whole growing season falls from 10 to 6. The most striking differences are found when comparing the correlations with the seasonal rainfall (Table 2). Thus, while Figueroa & Davy find that the largest number of species are significantly correlated with winter rainfall, the correlations with Alía rainfall data show that much more species are related with the autumn precipitation (7) than with the winter (1) and spring (O) one. Thus, it can be concluded that the grasslands studied by Figueroa & Davy behave as the other Mediterranean grasslands, and that the differences found by these authors were related with the inaccuracies in the rainfall data.

Table 1. Correlations of transformed and non transformed plant frequency with the accumulated rainfall over the growing season (October - May). Data of transformed plant frequency and rainfall from Figueroa & Davy (1991). Coefficients with an asterisk are significant for $p< 0.05$.

Species	Transformed	Not transformed
Vulpia bromoides	0.78*	0 81*
Anthoxanthum aristatum	0.59	0.62*
Aira cariophyllea	0.63*	0.68*
Poa bulbosa	0.58	0 61*
Chaetopogon fasciculatus	0.23	0.16
Ornithopus compressus	0.90*	0.92*
Trifolium glomeratum	0.78*	0.81*
Trifolium campestre	0.70*	0.70*
Trifolium arvense	0.61*	0.62*
Trifolium gemellum	0.46	0.51
Tolpis barbata	0.72*	0.83*
Leontodon taraxacoides	0.16	0.28
Hipochaeris glabra	-0.20	-0.08
Chamaemelum mixtum	0.10	-0.04
Logfia gallica	0.41	0.42
Tuberaria guttata	0.52	0.69*
Plantago bellardi	0.57	0.58
Euphorbia exigua	-0.05	0.28

Conclusions

The lack of agreement between the results of Figueroa & Davy and the results of other studies made in other Mediterranean grassland is related with the inaccuracies in the rainfall data used by the former authors. When the correct rainfall data are used, this lack of agreement disappear.

In any case, it should be noted that the number of species correlated with rainfall over the whole growing season is almost as high as when considering only autumn rains. Since many of the studies cited above have established the relationships between species abundance and rainfall grouping the species into families, or have used short series of data, it would be very interesting that these authors reconsider their results with the proper rainfall data, in order to check the relative importance of total and autumn rainfall in determining species abundance.

Table 2. Correlations of non transformed plant frequency with accumulated rainfall of Alía meteorological station. Growing season, October-May; Autumn, October-November; Winter, December-February; Spring, March-May. Coefficients with an asterisk are significant for $p< 0.05$.

	Accumulated rainfall			
Species	Growing season	Autumn	Winter	Spring
Vulpia bromoides	0.82*	0.64*	0.59	-0.08
Anthoxanthum aristatum	0.63*	0.62*	0.34	0.11
Aira cariophyllea	0.71*	0.21	0.68*	-0.13
Poa bulbosa	0.48	0.66*	0.23	-0.16
Chaetopogon fasciculatus	0.26	-0.13	0.35	-0.10
Ornithopus compressus	0.63*	0.55	0.35	0.22
Trifolium glomeratum	0.50	0.72*	0.14	0.15
Trifolium campestre	0.81*	0.60*	0.50	0.25
Trifolium arvense	0.78*	0.75*	0.41	0.20
Trifolium gemellum	0.50	0.56	0.17	0.35
Tolpis barbata	0.35	0.51	0.14	-0.07
Leontodon taraxacoides	0.34	-0.10	0.39	0.07
Hipochaeris glabra	-0.11	-0.39	0.11	-0.19
Chamaemelum mixtum	0.10	-0.16	0.09	0.37
Logfia gallica	0.07	0.61*	0.26	0.17
Tuberaria guttata	0.29	-0.05	0.33	0.05
Plantago bellardi	0.58	0.05	0.52	0.30
Euphorbia exigua	0.47	0.12	0.50	-0.22

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Manuscript received on December 1992