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Influences of *Quercus ilex rotundifolia* on the herb layer at the El Pardo forest (Madrid)

A multivariate approach to community structure, diversity and environmental factors

by

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The aim of this work was a preliminary survey of the influences of *Qu. ilex rotundifolia* on the herb layer. The El Pardo area was selected owing to its lack of agricultural interventions.

El Pardo woodland has belonged to the spanish Crown since the Middle Ages and has been mainly used both as hunting ground as for firewood and charcoal production. It is now under the Patrimonio Nacional del Estado and has some aspects of a nature reserve.

Unlike the other *Quercus ilex* woodlands on flat ground in Central W and SW Spain, there is no historical record of any agricultural use of this land.

In the flat area under consideration, the *Quercus* trees are 15 or 20 meters apart looking very old (crown diameter 4-5 m, heigth 7-8 m.). The herb layer may be included in the *Helianthemion* alliance of the phytosociological classification (RIVAS GODAY and FERNÁNDEZ GALIANO, 1956). The physiognomy of the vegetation is "savanoid". The scattered trees are the vestiges of the much more dense climax forest. There is no apparent regeneration of *Quercus ilex* by seed in the area examined.

The herb layer is grazed mainly by fallow deer *(Dama dama)* which are extremely abundant in the forest and rabbits *(Oryctolagus cuniculus)*. These two animals, especially the fallow deer, may be considered as the dominant vertebrates from the point of view of influence on vegetation. After the paper by RIVAS GODAY and FERNÁNDEZ GALIANO (1956) was published, rabbit pressure on vegetation has probably diminished strongly. Rooting by wild boar *(Sus scrofa)* and grazing by red deer *(Cervus elaphus)* are only of occasional occurrence. Sheep and cattle are excluded from the area but, the floristical composition of vegetation under heavy fallow deer grazing and trampling, strongly resembles the semi-natural pastures under *Quercus ilex* scrub in other nearby "dehesas" on siliceous soil grazed by sheep.

The soils of the area have been classified on the map of the Instituto Nacional de Edafología y Agrobiología (1966) as "suelos pardos no cálcicos" (brown non-calcic). The samples examined here (0-10 cm) may be considered as lighty acidic. The pH, C/N and V data indicate that the humus may be considered as "mull forestal mesotrófico" (mesotrophic forest mull), tending to oligotrophy. Although, the saturation percentage values (V) are in general not too low, the total cation exchange capacity (T) and the sum of exchangeable bases (S) are small, in agreement with the low organic matter and sandy texture of the soil. The cation exchange capacity in the area examined depends more on humus than on clay content. The humus of the samples with the highest C/N values could be considered as "Moder arenoso" (sand mull). The data on pH, total N exchangeable cations, etc. may be deduced from the adjoined graphs. A typical texture of the soil examined is: sand (> 0.02 mm) 87.4 %, silt (0.02-0.002 mm) 8 %, clay (< 0.002 mm.) 4.6 %.

The macroclimate may be described as continental mediterranean, with the average annual rainfall being about 500 mm. Climate conditions are very similar to those of the area near Madrid.

Semi-natural pastures under *Quercus ilex*, *Q. suber* and *Q. "lusitanica"* are encountered very frecuently in W and SW Spain. Only in the Badajoz Province are there about 700.000 Hectars of this kind of vegetation. *Quercus ilex rotundifolia* is considered the dominant tree in various climaxes of most Central Spain, but its natural distribution has been very much reduced by agriculture.

The industrial applications of *Q. ilex* have diminished enormously in the last years. Even in the "dehesa" areas, it appears that the trees hinder the utilization of agricultural machinery both in cereal farming as in the operations of improvement of pastures. As most "dehesas" are on semi-arid oligotrophic soils, some Spanish agriculturists think that the scattered *Quercus* trees may have a beneficial influence on the pastures. These influences are believed to be both microclimatical (radiation and wind decrease) and nutritional (cation mobilization from deep soil layers). Favourable effects on humification by comparison with pine species have been detected (Velasco y Albareda, 1966). In addition, the fruits of the W and SW tree populations are yet important in pig fattening. The leaves are eaten by sheep and cattle mainly in the cold season and are also a part of the diet of game animals.

Owing to the extremely short period during which the identification of all the individual plants for detailed quantitative studies may be practised, only one tree could be considered in detail. Nevertheless, we think that the results obtained are susceptible to generalization to a range of conditions characterized mainly by soil oligotrophy.

METHODS.

The tree studied grows in the place called "Cruz del Gallego" and was selected because, unlike most of the trees, at the moment, it had not been recently pruned. The neighbouring ground is flat and relatively indisturbed and the crown shape fairly regular.

A "a priori" inspection of the various types of previsible influences of the *Quercus* trees on the herb layer may result in an impressive list of both correlated and uncorrelated effects. At least the following influences may be foreseen:

1. Radiation interception (short wave during day hours long wave during night period, with effects on temperature, evapotranspiration, soil moisture and photosynthesis).
2. Rainfall interception (complicated effects depending on rain intensity.
3. Effects on wind (with further effects on temperature and evapotranspiration).
4. Root competiton.
5. Possible effects of organic active substances (both from roots and litter).
6. Effects of litter humification and mineralization (interaction with soil factors).

7. Cation mobilization by the tree (incorporation of mineral elements from deep soil layers and by rain).
8. Effects of the tree as atraction center for animals (vertebrates, insects, etc., with accumulation of products from other parts of the ecosystem).

Vegetation composition may be considered as a resultant or integration of very many environmental factors. The approach used was to study in detail the floristical composition of the herb layer along four transect lines. 5 quadrats (only 4 in South direction) (60 × 60 cm.) subdivided in 16 square sub-units where laid and the "shoot frecuences" of all the species present counted. The first quadrat was almost in contact with the trunk and the others followed 2 meters apart in the 4 directions mentioned.

73 plant species where detected and therefore, data obtained consisted of 73 species × 19 quadrats × 16 subunits = 22,192 single data of presence-absence.

All species recorded less than in 2 quadrats were not considered in the analysis. The records of *Poa bulbosa* were also suppressed owing to the difficulty of determining the frecuencies when the leaves were in dry condition and very inconspicous.—As a result, 54 species were considered.

A correlation matrix was computed between the frequencies of the 54 species (Seal, 1954) and the matrix subjected to principal component analysis, obtaining the eigenvalues and the eigenvectors and loadings of every species. Coordinates were attributed to every quadrat by multipliyng the loadings for every component by the standarized frecuencies and adding these values.

In the center of every quadrat a soil sample (o — 10 cm.) was obtained by means of a steel cylinder of 10 cm. diameter and 10 cm. height. The samples were air dried, screened (2 mm.) and homogenized and the following analysis performed:

Organic matter (Schollenberger, 1945), total nitrogen (Kjeldahl, modified by Irion, 1951), pH (saturated paste according to Hernando and Sánchez-Conde, 1954; Beckman potentiometer), cation exchange capacity and exchangeable cations (after Mehlich, 1948).

A correlation matrix of physico-chemical environmental data was computed and subjected to principal components analysis by means of the same procedures as for the floristical data (Seal, 1964).

The solar radiation was expressed in relative values of the maximal radiation possible (in the absence of clouds) received by the different quadrats during the period of march 1 to june 30 (main growing season of the herbaceous species considered).

The values were estimated from: a).—Shadow of the *Quercus* tree given by formula

$$l = L \cot h$$

where l = Lengh of the projected shadow, L = height of the obstacle (height of the different parts of the crown), h = sun height (h at noon may be obtained by astronomical tables). For computation at different day times formula $\sin h = \sin \lambda \sin \delta + \cos \lambda \cos \delta \cos H$, may be used. (In which λ is the latitude, δ sun declination and H the hour angle).

b) Actual plotting of tree shadow (determined at hourly intervals during a cloudless day) on graphs and extrapolation to the other days of the period considered.

c) Radiation intensity was taken to be proportional to cos φ, φ being the angle of the beam to the surface.

The relative values obtained represent mainly the proportion of the times without tree shading taking into account the intensity and daily and seasonal changes of radiation intensity.

The values obtained for the places never reached by the shadow were checked with radiation tables (Turc, 1961) with very good agreement.

Diversity was computed by means of Shannon's (1948) information formula

$$H = - \Sigma p_i \log p_i ,$$

using decimal logarithms.

RESULTS AND DISCUSSION.

a) *Physico-chemical data.*

As expected, these data show a great number of correlations.—Many of the measured factors tend to vary together.

Table I shows the correlation coefficient between the factors measured. Inspection of radiation data and floristical analysis demonstrated that the quadrats may be considered as two separate populations owing to the marked discontinuity of both radiation an floristical data (fig. 3). This is due mainly to the limited displacement of the shadow of the tree on the ground giving rise to two markedly distinct populations of quadrats, that we will call the "sunny" and the "shaded" populations. Owing to this fact, correlations matrices were also computed within each of these quadrats populations (table 2, table 3).

The three tables contain a number of correlations that are easily interpretable. Besides the obvious correlation between the distance from the tree trunk with radiation, distance is negatively correlated with pH, Ca^{++}, K^{+} and S (sum of exchangeable cations), organic matter, Mg^{++} and V (percentage of base saturation). These correlations may be explained by the fact that in this sandy siliceous soil the main source of bases is the *Quercus* litter.—Changes in soil acidity, amount of exchangeable bases and organic matter depend on distance to the tree zone. Analysis data like organic matter, pH V, N, Ca^{++}, Mg^{++}, K^{+} and S are correlated positively; the reasons being the importance of the debris as source of both cations and organic matter.—Organic matter is the main component of the exchange capacity in this soil with low clay content.

The interdependence of V and N reflects both the degree of humification and base saturation of organic matter.

Correlations between radiation and other factors are analogous to those between distance from the tree and those factors. Radiation is negatively correlated with N and positively with Na^{+}, these relations are not apparent for the distance to the tree. Many of the correlations between radiation and chemical properties are no doubt indirect, owing to the relationships between radiation and distance to the tree.

Due to the complexity of the inter-relations of the physicochemical factors, a correlations matrix between the following values: Radiation, organic matter, pH, N, C/N, H^{+}, Ca^{++}, Mg^{++}, K^{+}, Na^{+}, S, T (total cation exchange capacity) and V was computed and subjected to principal components analysis. The results are shown in table 4.

The first component represent a very important direction of variation and it is correlated with S (sum of exchangeable cations), Mg^{++}, N, Ca^{++}, K^{+}, pH and V, and negatively with radiation. Figure 1 shows the relationships between this physico-chemical components and the distance from the tree.—This relationship is similar to the ones obtained between S, Mg^{++}, organic matter, etc., and distance to the tree. In general, exchangeable cations, pH, N and saturation % tend to increase when going closer to the tree.

The second component is related mainly to T (total cation exchange capacity) and H^{+}, that tend to vary together and represent a direction of variation independent of that accounted by the first component.

TABLE 1.

CORRELATION MATRIX OF PHYSICO-CHEMICAL DATA AND FLORISTICAL VECTORS, WHEN ALL QUADRATS ARE CONSIDERED. Components 1 to 3 represent the result of principal component analysis of the species frequencies matrix. Only the correlation coefficients significant at the 0.05 level have been represented. Coefficients significant at the 0.01 level are in **bold type.**

	Component 2	Component 3	Radiation	Distance from tree.	O. matter	pH	Diversity	N	C/N	H	Ca	Mg	K	Na	S	T	V
Component 1	—	—	.90	.85	—.49	—.57	.84	—.45	—	—	—	—.51	—.74	—	—.51	—	—
Component 2		—	—	—	—	—	—	—	—.53	—	—	—	—	—	—	—	—
Component 3			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Radiation				.88	—.55	—.56	.69	—.52	—	—	—.47	—.62	—.74	—.46	—.62	—	—.56
Distance from tree.					—.53	—.61	.67	—	—	—	—.60	—.57	—.70	—	—.67	—	—.52
O. matter						.52	—	.82	—	—	.72	.61	.61	—	.75	—	.56
pH							—	.45	—	—	.56	.65	.69	.52	.68	—	.63
Diversity								—	—	—	—	—.44	—.74	—	—	—	—
N									—.73	—	.69	.72	.62	—	.77	—	.52
C/N										—	—	.53	—	—	—.46	—	—
H											—	—	—	—	—	.78	—.83
Ca												.71	.55	—	.93	—	.58
Mg													.74	—	.91	—	.64
K														—	.74	—	—
Na															—	—	—
S																.46	.65
T																	—

TABLE 2.

CORRELATION MATRIX OF PHYSICO-CHEMICAL DATA AND FLORISTICAL VECTORS, WHEN THE 10 QUADRATS OF THE "SHADED" POPULATION ARE CONSIDERED.

Same symbols as in table 1.

	Component 2	Component 3	Radiation	Distance from tree.	O. matter	pH	Diversity	N	C/N	H	Ca	Mg	K	Na	S	T	V
Component 1	—	.74	—	—	—.67	—	—	—	—	—	—	—	—	—	—	—	—
Component 2		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Component 3			.71	—	—	—	.72	—.68	.64	—	—	—	—	—	—	—	—
Radiation				—	—	—	—	—	—	—	—	—.64	—	—	—	—	—
Distance from tree.					—	—	—	—	—	—	—.67	—	—	—	—	—.66	—
O. matter						—	—	.80	—	—	—	—	—	—	—	—	—
pH							—	—	—	—	—	—	—	—	—	—	—
Diversity								—.71	—	—	—	—	—	—	—.67	—.88	—
N									—.80	—	—	—	—	—	—	—	—
C/N										—	—	—	—	—	—	—	—
H											—	—	—	—	—	.82	—.88
Ca												.68	.72	—	.93	.69	—
Mg													.68	—	.89	—	—
K														—	.81	.73	—
Na															—	—	—
S																.66	—
T																	—

TABLE 3.

CORRELATION MATRIX OF PHYSICO-CHEMICAL DATA AND FLORISTICAL VECTORS, WHEN THE 9 QUADRATS OF THE "SUNNY" POPULATION ARE CONSIDERED.

Same symbols as in table 1.

	Component 2	Component 3	Radiation	Distance from tree.	O. matter	pH	Diversity	N	C/N	H	Ca	Mg	K	Na	S	T	V
Component 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Component 2		—	—	—	—	—	—	—	—.69	—	—	—	—	—	—	—	—
Component 3			—.68	—	—	—	.75	—	—	—	.77	.72	—	—	.78	—	—
Radiation				—	—	—	—	—	—	—	—	—	—	—	—	—	—
Distance from tree.					—	—	—	—	—	—	—	—	—	—	—	—	—
O. matter						—	.86	.73	—	—	.84	.73	—	—	.85	—	—
pH							—	.67	—	—	—	.76	—	—	—	—	—
Diversity								.81	—	—	.94	.81	—	—	.91	—	.71
N									—.66	—	.88	.85	—	.74	.93	—	.67
C/N										—	—	—	—	—	—	—	—
H											—	—	—	—	—	.86	—.82
Ca												.77	—	—	.97	—	.72
Mg													—	.80	.90	—	.67
K														—	—	—	—
Na															.71	—	—
S																—	.72
T																	—

TABLE 4.

LOADING FACTORS OF THE PHYSICO-CHEMICAL VARIATES FOR THE 5 COMPONENTS FROM THE ANALYSIS OF THE CORRELATION MATRIX.

Physico-chemical factors	Components				
	I	II	III	IV	V
Radiation	—.740	.022	—.381	—.066	—.234
Organic matter	.814	.092	—.025	—.116	—.377
pH	.766	—.110	.367	.001	.140
N	.854	.084	—.368	.214	—.190
C/N	—.577	.171	.618	—.472	—.181
H	—.334	.934	.028	.085	.009
Ca	.827	.171	—.124	—.371	—.215
Mg	.889	.070	—.124	—.124	.245
K	.814	.203	.165	.110	.379
Na	.531	.047	.441	.514	—.367
S	.974	.152	—.076	—.215	—.005
T	.300	.945	—.023	—.060	.005
V	.739	—.622	.064	—.173	—.080

TABLE 5.

EIGEVALUES OBTAINED IN THE ANALYSIS OF THE CORRELATIONS MATRIX OF PLANT SPECIES.

Component	Eigenvalue	% of variation accounted	Cumulative % of variation accounted
1	14.84498	27.5	27.4
2	7.20272	13.3	40.8
3	6.12710	11.3	52.2
4	4.39251	8.1	60.3
5	3.22021	5.9	66.3

TABLE 6.

LOADING FACTORS OF THE PLANT SPECIES FOR THE 5 FIRST COMPONENTS OF THE CORRELATION MATRIX OF FLORISTICAL DATA.

Species	Component				
	1	2	3	4	5
Andryala sp.	.168	.887	.190	—.086	.159
Anthemis arvensis	—.241	—.289	.452	—.068	—.367
Anthriscus vulgaris	—.455	—.046	—.502	.397	.231
Aphanes microcarpa	.779	— 474	.105	—.096	.159
Arenaria leptoclados	.561	—.278	.346	.269	.487
Biserrula pelecimus	.603	.662	—.010	—.088	—.073
Bromus madritensis	—.602	—.136	.536	.248	—.016
Bromus mollis	—.338	—.533	.412	—.202	.150
Bromus tectorum	—.293	—.324	.721	—.004	.063
Carduus tenuiflorus	—.536	—.074	—.392	.313	.196
Centaurea sp.	—.596	.191	—.525	.368	.207
Cerastium cf. semidecandrum	.832	—.374	—.125	—.022	.174
Corynephorus fasciculatus	.556	—.014	.268	.688	.090
Crepis virens	.471	.106	—.100	.190	—.408
Diplotaxis catholica	.303	.402	.294	.483	—.147
Erodium cicutarium	—.405	.127	.065	—.219	.394
Filago minima	.652	—.333	—.011	.294	.030
Galium murale	—.139	—.474	.495	—.301	.151
Geranium molle	—.730	—.417	.417	—.191	.023
Tuberaria guttata	.948	.032	—.113	—.051	.049
Herniaria cinerea	.384	.340	.050	—.185	.209
Hipochaeris glabra	.324	.860	.125	—.077	.001
Hordeum murinum	—.502	—.071	—.505	.419	.115
Leontodon rothii	.401	.666	.440	.193	.194
Lithospermun apulum	.625	—.056	.220	.222	.346
Mibora minima	.754	—.162	—.320	—.285	—.292
Myosotis stricta	—.224	—.070	.477	.021	—.035
Nardurus maritimus	.186	—.271	.532	.431	—.151
Ornithopus compressus	.003	—.419	.248	—.207	.449
Plantago lagopus	—.408	.487	.357	—.221	.125
Plantago psyllium	—.072	.561	.146	—.018	—.009
Polycarpon tetraphyllum	—.036	.732	.290	—.023	.057
Sanguisorba muricata	.468	—.429	—.110	—.189	.358
Rumex angiocarpus	—.206	— 312	.447	.010	—.381
Sagina apetala	.658	—.222	—.280	.077	—.105
Scleranthus ruscinonensis	.156	.291	.318	.098	.046
Sedum rubrum	.457	—.398	—.028	—.271	.442
Silene colorata	.476	.074	.358	.628	.163
Spergula pentandra	.474	—.212	—.394	—.365	—.138
Spergularia rubra	.680	.140	—.276	.014	—.174
Stellaria media	—.728	—.162	—.368	.247	.258
Tillaea muscosa	.692	—.187	—.366	—.321	—.069
Tolpis barbata	.371	.142	.102	—.293	.661
Trifolium arvense	.788	—.156	—.206	—.310	.088
Trifolium gemellum	.243	.606	.201	—.078	.228
Trifolium glomeratum	.455	—.249	.444	.503	—.148
Trifolium suffocatum	.956	.064	.035	—.117	—.012
Trifolium striatum	—.258	.155	.019	—.082	.072
Trifolium tomentosum	.490	—.266	.204	.413	.458
Urtica urens	—.321	.015	—.603	.407	.222
Veronica arvensis	.225	—.132	.090	.359	—.416
Veronica verna	.778	—.179	—.087	.456	—.175
Vulpia ciliata	.946	—.014	—.134	.005	—.101
Vulpia sciuroides y V. uniglumis.	.274	—.061	.552	—.421	—.233

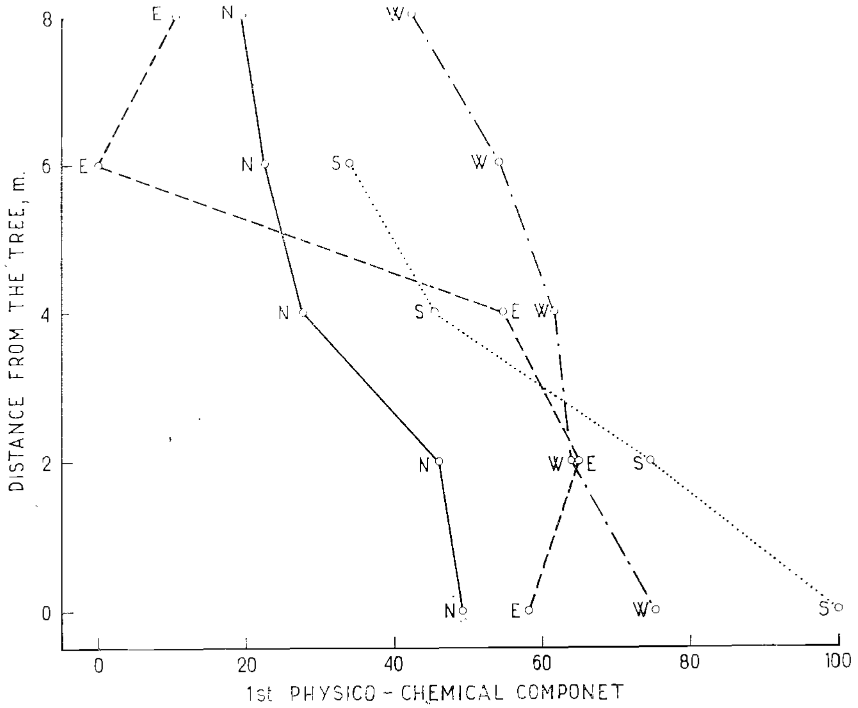

Fig. 1.—Relationship between the first principal component from the correlation matrix of the physico-chemical data and the distance from the tree.

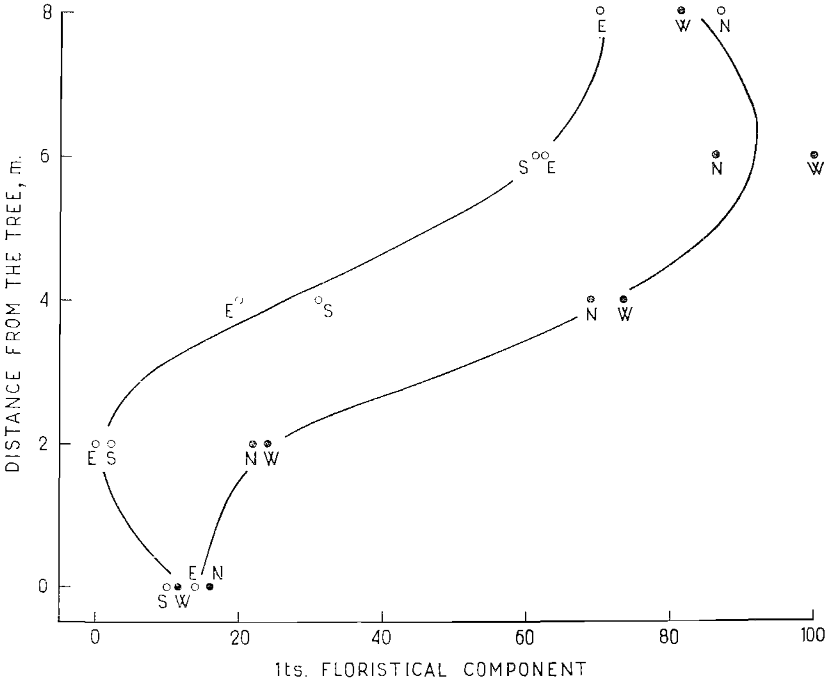

Fig. 2.—Relationship between the first principal floristical component and the distance from the tree. It is apparent the sigmoid shape of the curves and the distinctictness of the relationship for the quadrats on the South and East transects (open circles). This discrepancy is maximal for the intermediate values of the distance.

The third component partly reflects a direction of variation related with C/N (carbon: nitrogen ratio) and there is no relationship with the distance to the tree.

Components 4th and 5th are small and tend to vary very little. There is no clear interpretation of their meaning.

b) *Floristical data.*

5 eigenvectors were computed tentatively from the correlation matrix of frecuencies of plant species. The results are shown in table 5.

The percentage of variation accounted by the 5 eigenvectors together is only about 66 % indicating that the information represented by the species frecuencies (floristical table) is very complex and difficult to summarize in a few independent factors. Nevertheless, the main objective of the study is the detection of those variations correlated with the presence of the *Quercus* tree and as we will see later, the first component obtained is the one showing this kind of relationship.—In addition, this component is the most important quantitatively and there is a substantial drop between it and the following, in terms of % of variation explained.

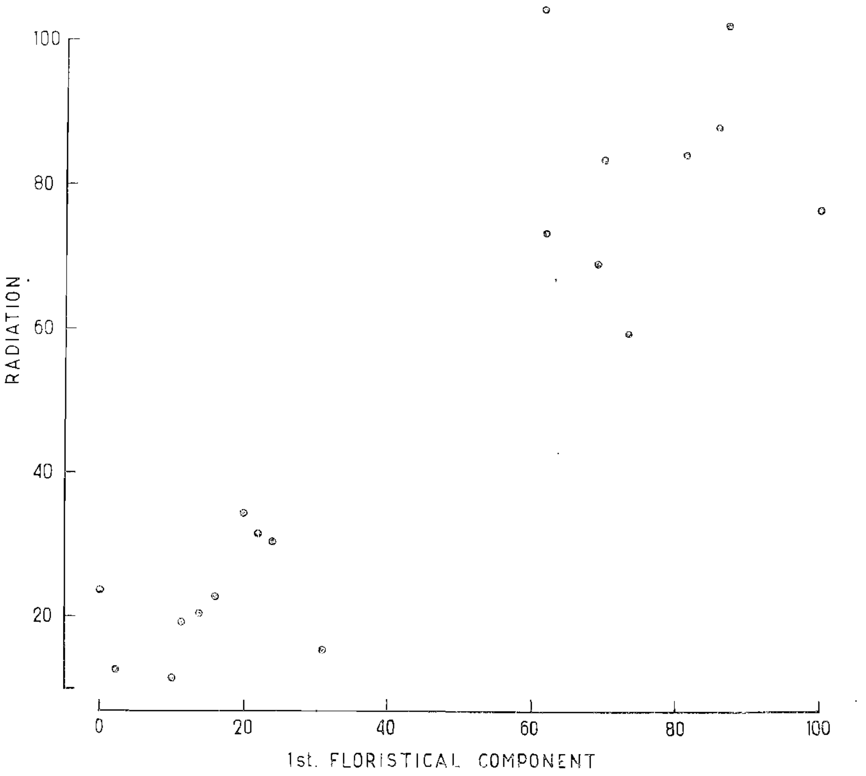

Fig. 3.—Relationship between maximum estimated radiation (from march 31 to june 1, cal/cm^2 × 10^3) and the first component from the floristical matrix.

The loadings for the different components of the plant species are shown in table 6. Species having high loadings for the same component tend to vary together, showing a similar response to a complex of environmental factors.— Each component represent a simple direction of variation, for which and interpretation may be tried by comparison with the physico-chemical factors (not included in the analysis).

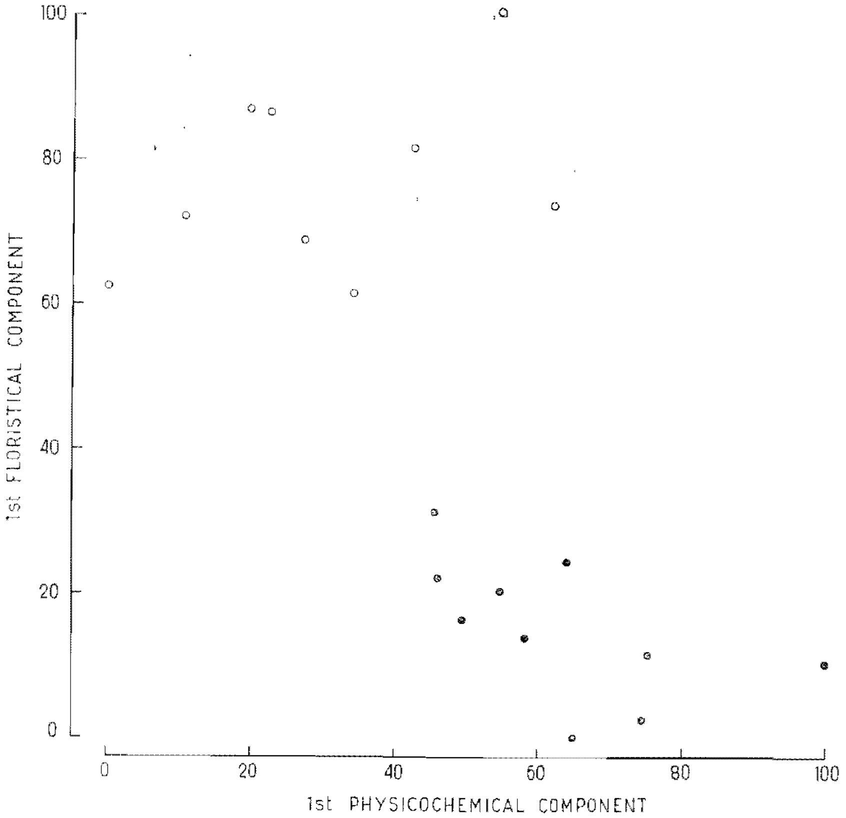

Fig. 4.—Relationship between the first component from the correlation matrix or 13 physico-chemical factors and the first component from the correlation matrix of the 54 plant species.

Figure 2 shows the relationship between the 1st component and the distance from the tree trunk. Some strinking features are apparent in this figure. First of all, the relationship has a sigmoid shape indicating two "saturation" effects both for the short distances to the tree as for the more remoted quadrats. Maximal variation of the values (quadrat coordinates) for the 1st floristical component occur for the intermediate distances from the trunk. The saturation effect for the more distant quadrats is naturely due to the scarce influence of the tree. On the other hand, when the quadrats are too close no additional increase of tree influences are observed.

It is also apparent that the relation is markedly distinct for the quadrats located on the North and West transects (black dots), and for the quadrats

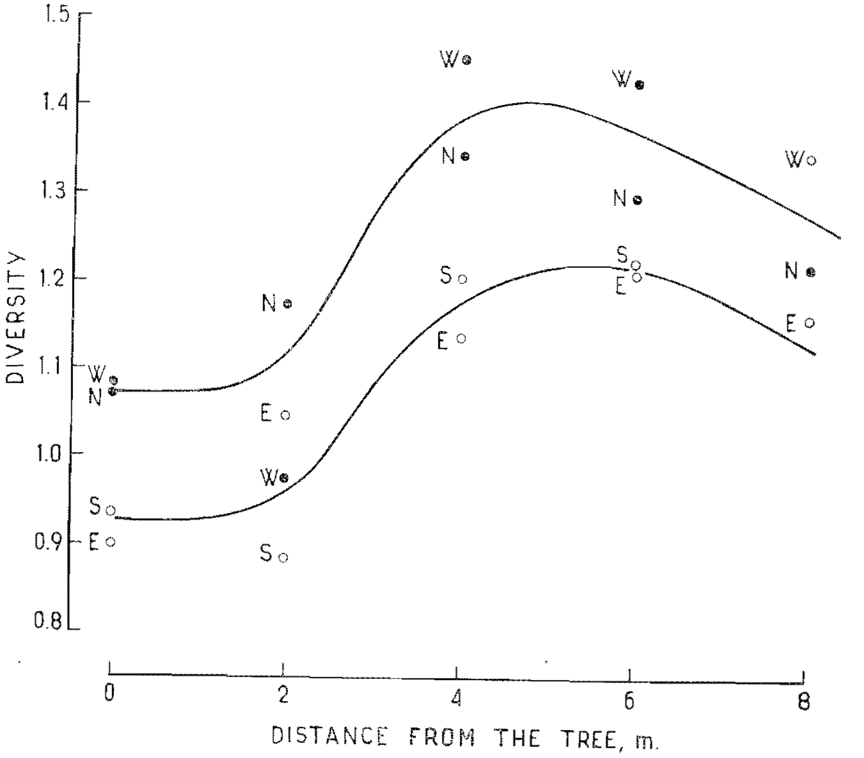

Fig. 5.—Relationship between diversity and distance to the tree trunk. Black dots: North and West transects. Open circles: South and East transects.

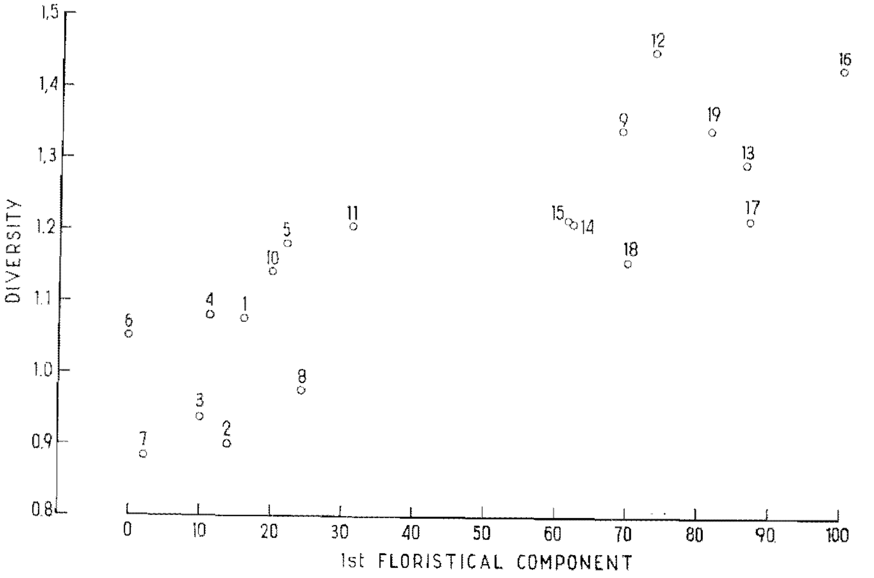

Fig. 6.—Relationship between diversity and the first floristical component.

placed on the South and East transects (open circles). As the prevailing winds in the area are North West-South East, deformation of litter projection on the ground may be an explanation for this effect. On the other hand, the discrepancy of the North, West and South East quadrats for the same distance is maximal for the intermediate values. This indicates again a "saturation" effect for the quadrats both very close and very far from the tree.

The first floristical component may be interpreted as a negative scale of "tolerance" of the tree's influence or conversely: as the values for the quadrats on the abcissa of Figure 2 increase, the abundance of Quercus-avoiding plants in these quadrats increases.

Therefore, this axis may be considered as a measure of the tree avoidance character of the herbaceous vegetation.

In table 1 the first floristical component appears to be correlated positively with tree distance and radiation and negatively with K^+, Mg^{++}, S, N, pH and organic matter.

Figure 3 shows the relationship between the estimated maximal radiation during the growing period and the first floristical component. It is apparent that both values show a marked discontinuity (there is a gap for the abcissa —floristical component— between 31 % and 62 %).—Thus, the quadrats are divided in two populations caracterized by very different floristical and radiations values. This was the reason for the computation of two separate environmental matrices in table 1 and table 2.

In figure 4 the relationship of the principal component obtained in the analysis of the physico-chemical data and first floristical component is presented. There is a large variation of floristical composition for the intermediate values of the physico-chemical component and a striking floristical invariance for the exterme values of this component.

Taking into account the correlations presented in table 1, the floristical direction of variation represented by the first component appears to be related to a complex of factors (radiation, S, etc.) that are also dependent on the tree distance. The plants having very large positive loadings for the first floristical factor like *Trifolium suffocatum*, *Helianthemum guttatum*, *Vulpia ciliata*, *Cerastium semidecandrum*, *Aphanes microcarpa*, etc. are conspicously tree avoidants in this case, and either photophilous or poor competitors for nutrients.

Plants species with large negative loadings for this component like: *Geranium molle*, *Stellaria media*, *Bromus matritensis*, etc. are more "exigent" in mineral nutrition and they appear as strongly tree dependent in the present instance.

Due to the strong interdependence between radiation, moisture and nutritional effects, etc. it is not easy to detect the responsible factors.

The second component from the floristical matrix is about 50 % the importance of the first, and could not be related to the tree position. The plant species *Hypochaeris glabra*, *Andryala* sp. and *Polycarpon tetraphyllum* have large loadings for this component, indicating that they tend to occur together, and that their distribution is independent of that of the species mentioned for the first component.

The component is negatively correlated with C/N ratio (a factor that appears also to be independent from the distance). This direction of variation of the

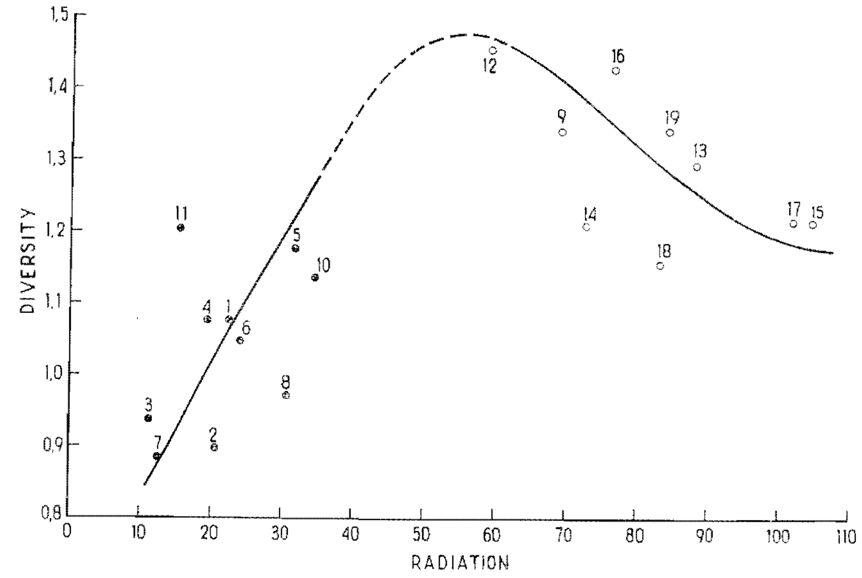

Fig. 7.—Relationship between radiation (estimated during March, April, May and June) and diversity.

floristical composition may be regarded as the result of unknown local influences, not related to the presence of the tree.

The third floristical component is also uncorrelated with distance from the trunk. *Bromus tectorum* has the largest positive loading for this component

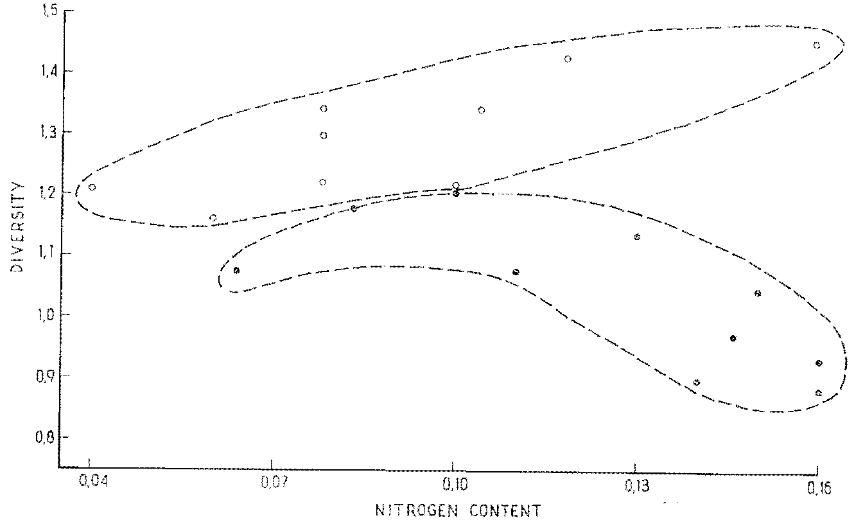

Fig. 8.—Relationship between soil N content and diversity. Black dots "shaded" population of quadrats. Open circles: "sunny" population of quadrats.

and *Urtica urens* the largest negative one. *Urtica urens* occur only in two quadrats, which were characterized by a peculiar type of "nitrophilous" vegetation. *Bromus tectorum* is a species of very comon occurrence in all transects but does occur or have a very low density in the patches where *U. urens* dominates. Areas dominated by *U. urens* presented visible signs of light diturbance of the soil surface and they are believed to depend on vertebrate activities. Although these areas would be correlated with tree vicinity in a larger scale, they appear to be independent of trunk distance when only the tree souroundings are considered.

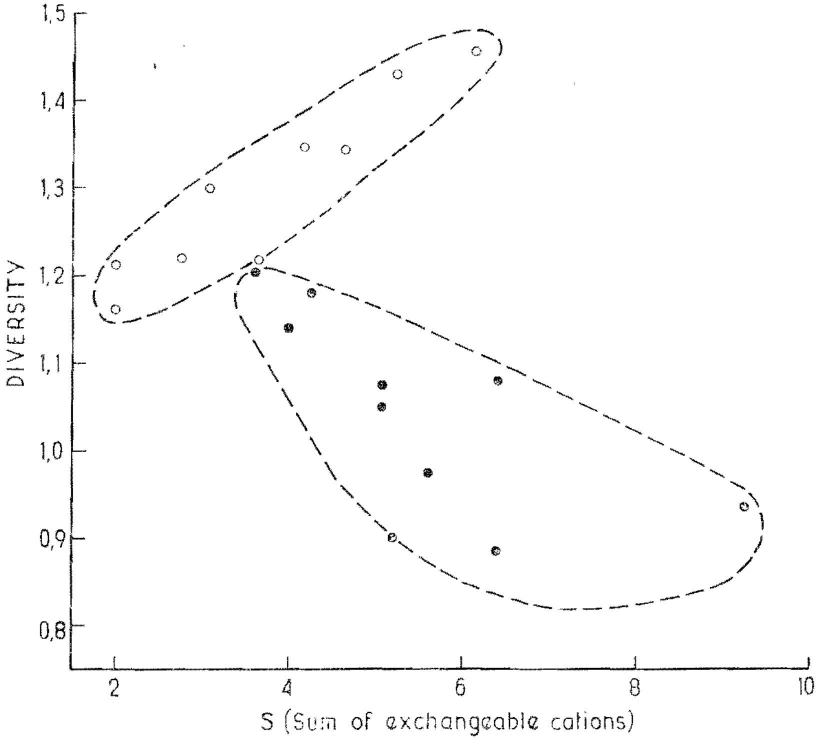

Fig. 9.—Relationship between S (sum of exchangeable cations) and diversity. Same symbols as in Figure 8.

The forth and fifth components characterized by *Corynephorus fasciculatus* and *Tolpis barbata* respectively are very small and do not show correlation with any of the measured factors.

c) *Species diversity.*

The favourableness of the physico-chemical environment for plant growth in the area examined may be taken as dependent on two main kinds of opposed stresses. The areas located very far from the tree influence may be considered

as having a less favourable microclimate (more exagerate temperature effect, earlier drought incidence, lower cation imput, poorer humification etc.). Conversely, in the deeply shaded areas light intensity may be deficient at least during some periods. It may be admitted that the most favorable growth conditions will be exist somewhere midway in the gradients of environmental conditions due to the presence of the tree.—Under steady state conditions (when species composition is in equilibrium with the prevailing condition) species diversity appear to be related to the favourableness of the habitat (Odum, 1965) so we may expect diversity increasing with distance to the tree and decreasing again from a certain distance onwards.

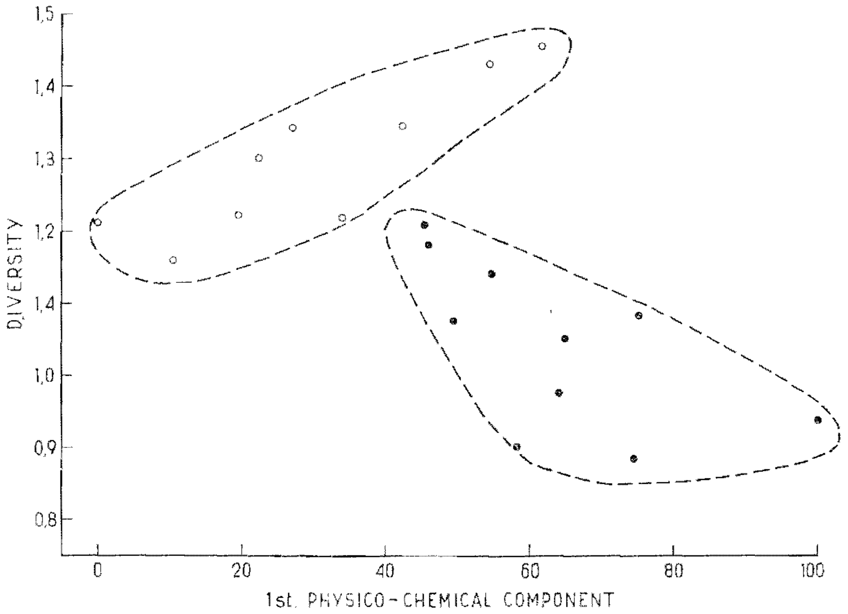

Fig. 10.—Relationship between the first physico-chemical component and diversity. Same symbols as in Figure 8.

On the other hand, floristical composition has been shown to exhibit a marked discontinuity for the species related to the first floristical component. This discontinuity is related to a gap in the radiation values (fig. 3). Diversity may be expected to increase in the contact zone of the two floristicaly more homogeneous areas (Margalef, 1957). This assumption may also lead to the expectation of a maximum of diversity midway in the range of distance to the tree.

Figure 5 shows the relationship between diversity and distance to the tree trunk. It is apparent that the quadrats located on the West and North transects are more diverse than the quadrats on the South and East transects for the same distance. We find again the effect of N W-S E dissimetry already mentioned (fig. 2). As a whole, the relationship shows a maximum of diversity for about the same distance for which maximal divergence between NW-SE quadrats has been found (fig. 2).

Figure 6 shows the relationship of the first floristical component and diversity. The quadrats having large values for the first floristical component have a much larger diversity. The relationship between diversity and radiation (fig. 7) shows the hypothetized dependence on two contraposed stresses. Diversity seems to increase with radiation to decrease again from a certain value onwards. When the "sunny" and "shaded" populations of quadrats are examined separarely in relation to the physicochemical factors, the trend of every relationship has a different sign for each of the two populations (figs. 8, 9 and 10; tables 2 and 3).

Figure 8 shows that diversity increases with N content in the soil for the "sunny" population, but decreases with N content for the "shaded" one; a similar situation exists for the S (sum of exchangeable cations) values (fig. 9) and for the first "physico-chemical component" (from the matrix of the physico-chemical factors) (fig. 10).

CONCLUSIONS.

The use of correlation techniques and the subsequent assesment in terms of significance is only meaningful when the results are intended to reject (or not to reject) hypothesis. From the 124 correlations taken as "significant" in tables 1, 2 and 3, approximately 4 are expected to be the result of chance alone. On the other hand, the cause-effect relationships are difficult to stablish without a more experimental approach.

Nevertheless some consistent relations arising from the interdependence patterns and the hypothetized influences of the tree, may be disclosed. These relations are better studied by examining the variation trends, discovered by the multivariate analysis of the data.

Although the influences of the tree, both on vegetation as on physico-chemical factors, appear to be extremely complex (fig. 11), some facts may be extrapolated to the similar situations (scattered *Quercus ilex* trees on sandy, light acidic soils under mediterranean conditions) which prevail in the "dehesa" woodlands.

1.—Judging from the correlations between the species frecuency and considering an area with a radius of about 4 times the radius of the crown, the variation in herbaceous vegetation related to the influence of the tree is about 27 %. Other directions of the variation in vegetation composition are "tree-independent" at the scale considered and seem to be conditioned by local surface disturbance, local nitrogen income, etc.—The influence of the tree on ground vegetation is appreciable until a distance more than 4 times the radius of the crown.

2.—The influence of the tree on ground vegetation may be represented by a sigmoid curve when related to the distance from the tree trunk. Maximum rate of change of the tree influence with distance coincides approximately with the projection of the crowris edge, but is much stronger in the South and East sides than in the North and West ones. The vegetational differences of the NW and SE diminish both when going closer as when going farther away from the tree trunk. These disymmetries appear to be related to the prevailing NW winds.

3.—*Geranium molle, Stellaria media* and *Bromus matritensis* appear to be most tree-dependent species, while *Tuberaria guttata, Trifolium suffocatum* and *Vulpia ciliata* are markedly tree-avoidant. *Hypochoeris glabra, Andryala* sp. and *Polycarpon tetraphyllum* tend to be distributed together. These species are probably associated with changes in the C/N ratio of the soil organic matter, that in the present instance are independent of the tree position at the scale considered. *Bromus tectorum* and *Urtica urens* tend to exclude one another showing no relation either with the forementioned species or with the tree position at this scale.

4.—The nitrogen content, pH and total exchangeable cations of the soil are clearly influenced by the presence of the tree, increasing towards the tree trunk. These factors are correlated, and the associated vector is negatively correlated with the distance from the tree. N content, pH and the sum of exchangeable cations vary respectively from about 0.08, 6.1 and 3.1 m. e. por 100 gr. in the less influencied area to about 0.12, 6.6 and 6.5 m. e. per 100 gr. near the tree trunk. These tree influences tend to reduce the oligotrophy of the soil. In the case of the pH and cations, the observed increase may be attribued mainly to the *Quercus* roots taking cation from the deeper soil zones and adding them to the supperficial zones with the litter. The origin of the N increase may be of diverse nature. A part of the N may come from non tree-influenced parts of the woodland ecosystem and concentrate around the tree by resting animals.

5.—The phytosociological gradient represented by the first floristical vector is markedly discontinuous and two distinct types of vegetation bay be differentiated. This discontinuity corresponds to the gap in the radiation values. Both types of vegetation show opposite relationships when species diversity is compared with physico-chemical factors. Diversity increases with soil nitrogen and exchangeable cations, and diminishes with radiation in the case of the "sunny" or tree remoted vegetation, the reverse being true for the "shaded" or three close type of vegetation. Favourableness of the intermediate habitats and (or) heterogeneity effect in the contact area may be invoked to interpret this effect.

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RESUMEN.

Influencias de *Quercus ilex rotundifolia* en el estrato herbáceo en el Monte de El Pardo (Madrid).

Se ha estudiado la vegetación herbácea influida por un ejemplar de *Q. ilex rotundifolia* en el Monte de El Pardo por medio de cuatro transecciones dirigidas hacia los cuatro puntos cardinales a partir del tronco.

La variación de la composición florística se puede reducir a una serie de componentes ortogonales, de los cuales el más importante muestra relación con la distancia del árbol. La relación del vector que representa esta dirección de variación con la distancia del árbol es de tipo sigmoidal con dos asintotas, interpretables como dos efectos de "saturación", tanto en la vecindad próxima al árbol como a partir de una cierta distancia de éste. La máxima tasa de cambio en la vegetación se encuentra para valores intermedios de la distancia al árbol. La asimetría de efectos en las transecciones, N-O y E-S, es muy clara.

El vector que presenta la variación florística divide las muestras de vegetación en dos tipos, caracterizados por tener valores de diversidad ($= - \Sigma p_i \log p_i$) claramente distintos.

El tipo de vegetación menos influida por el árbol tiene el valor más alto de diversidad. Los dos tipos de vegetación se caracterizan también por recibir cantidades claramente distintas de radiación solar.

Las relaciones entre la diversidad y los factores ambientales tienen distintas tendencias en la población "soleada" y en la población "sombreada".

El contenido de nitrógeno, el pH y la suma de cationes de cambio del suelo están claramente influidos por el árbol, variando desde 0,08; 6,1; y 3,1 m. e. por 100 g. en la zona menos influida hasta 0,12, 6,6 y 6,5 m. e. por 100 g. en la zona más influida por la encina.

Se discuten las relaciones existentes entre los factores de tipo florístico y físico-químico en relación con la presencia de la encina.

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