2

TRABAJOS CIENTÍFICOS

Revista PASTOS: XXIV (1). 33-46. 1994

DETECTION OF ASYNCHRONIES BETWEEN CLIMATIC FACTORS AND UNDERGROUND PHYTOMASS PRODUCTION IN SEMIARID PASTURES

GÓMEZ GUTIÉRREZ, J. M.[1], BARRERA MELLADO, I.[2], GALINDO VILLARDÓN, P.[2] and PÉREZ FERNÁNDEZ, M. A.[1]

(1) *Department of Ecology. University of Salamanca. C/ del Espejo s/n. 37008 Salamanca, SPAIN.Phone: 34 23 294464. Fax : 34 23 294513*
(2) *Department of Biostatistic. University of Salamanca. C/ del Espejo s/n. 37008 Salamanca, SPAIN.*

ABSTRACT

The influences of the climatic variables on the fluctuations of biomass production in the underground organs of the herbaceous plants of semi-arid pastures are investigated. The study of the most influencing variables was carried out by factor analysis.

The factor with the highest explicative power is a combination of the mean temperature 15 cm down in the soil, taken 30 days before collecting the samples and the maximun temperature taken 30, 20 and 25 days before sampling. The second factor is a combination of precipitations 30, 20, 25, 15 and 5 days before sampling. The third factor is the hours of sunshine 10,15 and 20 days before sampling.

Key Words: Root, biomass, climate, pasture.

INTRODUCTION

Herbaceous communities forming pastures in semi-arid regions are exposed to strong humidity and temperature variations (Luis and Montserrat, 1978). It is well established that slight variations in humidity and temperature can result in periodic modifications of both the botanical composition and biomass production (Selignan and Van Keuten, 1989; de Leeuw *et al.*, 1990; Stephenson, 1990). There is a close relationship between aboveground and underground biomass production in these communities (Barrera and Gómez, 1986). However, these studies have not included the effects of climatic factors on the underground biomass production and accumulation.

Barrera, Galindo and Gómez (1984) studied monthly variations in root biomass on semi-arid pastures. These considerable variations were called "monthly effect". Some of these variations are inherent to plants (Behaegue, 1978). However, in longer studies (three years) including various phenological cycles, it was possible to observe that underground biomass production was not similar in the same months of the different years studied. Obviously it was not the month as such that was responsible for these diffferences but the climatic variations. This was also observed by Troughton (1951) and Garwood (1967) who studying underground organs of herbaceous species found differences in the same month of successive years. They looked for an explanation of these differences in climatic variations and their effect on soil parameters.

Though it had been assumed that small variations in humidity and temperature could influence plant growth rate, it is only recently that this topic has been actually studied (Singh *et al.*, 1989; Blackshaw, 1990; Rychnovska, 1990). Blaisdell (1985) found that plant growth and development in herbaceous species was closely related to temperature during the first growth stages, whereas afterwards it was strongly affected by water availability. Pearson (1979) showed the great importance of soil temperature at the depth of 15 cm during anthesis for grain production. He also pointed out that higher soil temperatures during the vegetative-growth period retarded anthesis by about four days for each degree above 10°C.

Thus we may deduce that climatic and soil parameters, (and possibly others, like hours of sunshine, the number of days after minimum 10 mm rainfall, etc.), can affect underground plant biomass production and accumulation in semi-arid pastures. Kummerow et al. (1978) found that a certain increase in the monthly root biomass production in August were due to rainfall during the last three weeks of this month.

Rooyen et al. (1990) and Pandey & Sing (1992) had already detected asynchronies between the rain and biomass production. Nevertheless, only the aereal production was studied and the asynchronies were never studied specifically. The main aim of our study was to investigate the effect of rainfall, temperature, daily sunshine hours, and number of days following the last rainfall of at least 10 mm, on the root biomass of herbaceous plants on semi-arid pastures in CW Spain. These factors are closely interrelated, and their combined effect can be anticipated. Thus, it was interesting to investigate which of the factor combinations was most important in the studied process.

MATERIAL AND METHODS

The sudy was carried out in a "dehesa" ecosystem (a savannah type ecosystem of the semi-arid part of CW Spain). The study area is situated in a strip of terciary sediments at 5° 45' 30" W and 40° 54' 0" N, and at 830 m a. s. l. The soils in the area are alluvial, sandy-clay, permeable, of good structure, moderately fertile. The main plant-productivity limiting factor is water availability. The climate is cool semi-arid, in the biogeographical region of *Quercus rotundifola*, with 400-500 mm annual rainfall and 12-13°C mean temperature.

The pasture is dominated by the following herbaceous species:

Dactylis glomerata L.	*Festuca rubra* L.
Holcus lanatus L.	*Vulpia bromoides* L.
Cichorium intybus L.	*Agrostis castellana* Boiss.
Hypochæris radicata L.	*Bellis perennis* L.
Trifolium fragiferum L.	*Stellaria media* Vill.
Anchusa undulata L.	*Festuca arundinacea* Schreber.
Trifollium subterraneum L.	*Muscari racemosum* Mill.
Saxifraga granulata L.	*Rumex acetosella* L.
Alopecurus geniculatus L.	*Hieracium pilosella* L.
Taraxacum Dens-leonis Desf.	*Galium verum* L.
Medicago lupulina L.	

Nomenclature follows Tutin (1968).

It is a semi-natural pasture grazed by cattle in the extensive system.

Root-biomass sampling was carried out from September through to June of the years 1981, 1982 and 1983, i.e. during the months in which soil was humid enough as to allow the use of a sampling apparatus as well as plant growth and development. Especially designed steel cylinders, 30 cm long and of 9 cm internal diameter and 1 cm wall thickness, were used in the apparatus. A portable pneumatic hammer was employed to introduce these cylinders into the soil. The sampling method was described in detail by Barrera and Gómez (1985 a).

Samples were thoroughly washed to obtain clean root biomass, free of any soil particles, according to the method by Barrera and Gómez (1985 b). In order to facilitate the washing, the sampled soil cylinders were finely cut and rotated for 24 hours in hermetic bottles. Then the mixture was decanted and filtered to separate the mineral matter fraction. The prepared root-phytomass samples, including live and dead material, were dried and weighed.

Climatic data were obtained from the Meteorological Centre at Valladolid responsible for the Climatological Station situated on the farm where the sampling was carried out. The following climatological data were used: total precipitation (mm), mean temperatures (maximum, average and minimum) (^{O}C), mean soil temperature at the depth of 15 cm (^{O}C), mean sunshine hours, and number of days following the last 10 mm rainfall.

Each climatic factor requires a certain time for any effect to be noticed. It was assumed that this time should be different for each of them. However, since such data were not available, time intervals of 30, 25, 20, 15, 10, and 5 days before sampling were selected.

Statistical Analysis

Samples were taken in five replicates during three consecutive years. Values whose standard deviation was higher than twice the mean value were rejected.

Since the degree of the relationship between the variable "Root-Biomass Weight" (RBW) (g/1.9dm^3) and each of the climatic factors was very low it was felt convenient to evaluate the relationship between RBW and the combined factors action. This was carried out with the use of the multiple correlation coefficient.

The study was carried out this way because of its extreme complexity. The degree of association between the explanatory variables was much higher than that between each of them and the dependent one (colinearity phenomenon) and was contrary to the requirements of any theoretical model. Hence it was intended to reduce this great number of the observed dependent characteristics to a smaller number of independent ones, i.e. to the actually influencing variables named factors. In order to do this the principal components analysis (Pearson, 1901; Jolliffe, 1986) was used.

The possible colinearity would exclude the use of multiple regression and would make the estimators of the regression coefficients unstable and imprecise with the use of the classical Gaus-Markov method. However this model is valid from the explanatory point of view for the calculation of the percentage of controlled variations. Though it is impossible to know the contribution of each variable. This contribution was not the object of this study, in which the focus was on the multiple correlation coefficient that can be interpreted. A multiple regression analysis of the principal components was possible, but was not used because the estimators calculated by regression with the principal components were biassed, and the information thus obtained was irrelevant.

RESULTS

The multiple sample correlation coefficient proves that more than 99% of the variations found in the RBW are explained as a function of the 37 states corresponding to the studied climatic factors. A step by step regression analysis allowed us to select 15 variables with the highest explanatory value. These variables and their values are shown in Table 1 together with sampling dates and refer to biomass found in each sample (RBW):

DATE D	RBW g/1,9 dm^3	RBW g/m^3	Rf 30 mm	Rf 25 mm	Rf 20 mm	Rf 15 mm	Rf 10 mm	Rf 5 mm	DfRf 10 Days
24 M. (81)	26.84	14126.31	24.3	23.6	9.8	4.6	2.3	1.9	27
29 Ap. (81)	24.24	12757.89	62.6	51.8	47.5	32.1	22.1	2.4	7
11 My. (81)	32.96	17347.36	54.6	45.8	35.8	16.1	13.7	13.7	1
15 Jn. (81)	26.56	13978.94	26.4	3.2	3.2	0.7	0.0	0.0	21
15 Sp. (81)	29.30	15421.05	7.5	7.5	0.0	0.0	0.0	0.0	19
13 Fb. (82)	30.82	16221.05	25.1	12.2	0.7	0.7	0.7	0.7	24
23 M. (82)	23.46	12347.36	5.0	0.0	0.0	0.0	0.0	0.0	62
24 Ap. (82)	25.81	13584.21	9.6	26.0	13.4	8.1	6.1	0.0	24
22 My. (82)	29.78	15289.47	3.6	3.6	3.6	3.6	3.6	0.0	51
11 Jn. (82)	29.05	15289.47	82.2	78.6	77.7	62.4	28.7	0.0	8
18 Fb. (83)	23.60	12421.05	2.6	2.6	2.6	2.6	2.6	0.0	67
17 Mr. (83)	28.51	15005.26	13.7	13.4	0.0	0.0	0.0	0.0	105
20 Ap. (83)	26.05	13710.52	28.3	28.3	28.3	23.8	21.8	21.8	1
22 My. (83)	24.26	12768.42	121.9	87.0	68.1	64.4	59.2	16.7	5
18 Jn. (83)	22.95	12078.94	8.2	3.6	3.6	2.0	0.0	0.0	37

DATE D	T.max 30°C	T.max 25 °C	T.max 20 °C	T.max 15 °C	S. 20 hours	S. 15 hours	S. 10 hours	Tmin.Ss °C
24 M. (81)	17.43	13.40	14.90	14.42	97.3	77.7	49.6	-0.45
29 Ap. (81)	13.23	13.42	12.53	11.53	115.1	87.2	60.3	0.07
11 My. (81)	13.31	12.90	12.60	13.63	144.1	120.0	82.7	0.39
15 Jn. (81)	23.90	25.04	26.97	28.43	215.0	165.9	118.1	4.28
15 Sp. (81)	28.77	28.84	28.70	28.39	179.4	137.2	81.7	13.82
13 Fb. (82)	9.49	9.75	10.10	10.10	103.1	64.0	45.4	-3.48
23 M. (82)	13.33	14.27	14.40	15.16	185.5	131.3	86.7	-1.97
24 Ap. (82)	14.89	15.68	16.82	16.76	152.4	120.2	86.4	-0.21
22 My. (82)	19.89	20.50	20.50	21.40	206.7	149.9	93.1	1.27
11 Jn. (82)	23.17	23.52	23.40	22.60	177.3	125.6	94.1	6.63
18 Fb. (83)	8.73	8.48	6.89	4.86	91.1	59.3	36.0	-6.98
17 Mr. (83)	16.62	14.76	15.13	15.83	117.2	108.5	69.0	-1.05
20 Ap. (83)	14.23	14.08	14.70	15.93	120.7	88.0	62.6	-1.13
22 My. (83)	12.20	12.08	13.23	12.43	118.7	94.7	76.7	2.02
18 Jn. (83)	21.86	23.92	25.35	27.50	202.0	169.4	122.4	3.83

Table 1.- The 15 variables xith the highest explanatory value and their values.

Tabla 1.- Relación de valores correspondientes a las 15 variables con un mayor valor explicatorio.

D - sampling date; RBW - Root-Biomass Weight; Rf30, rainfall determined during the 30 days before sampling; Rf25 during the 25 days before sampling; etc. Tmax30 - mean maximum temperature determined during the 30 days before sampling; Tmax25 - mean maximum temperature during the 25 days before sampling, etc.; S20 - mean total sunshine hours determined during the 20 days before sampling, etc.; TminSs - minimum subsoil temperature on the day of sampling; DfRf10 - the number of days passed from the last 10 mm rainfall to the sampling date.

A 68% of the variations in RBW were explained by the combined action of these variables. Further simplification was impossible because the percentage of explained variations decreased sharply to 6%.

The investigated variables were strongly intercorrelated, which made the study very difficult (Gabriel, 1978). Therefore the initial variables were transformed to new ones that were a linear combination of the former ones.These new variables (principal components) absorbed maximum variance, were not intercorrelated, each of them had a lower descriptive value than the former one, and were found by diagonalizing the correlation matrix. This matrix, and not the variance one, was used because the variables were expressed in different units; and standarization is highly advisable (Gittins, 1969). The corresponding eigen values were exactly the variances of the new variables.

The first four components absorb more than 90% of variance, whereas the first two absorb more than 80% (Tab. 2).

Loading factors (Tab. 3), which measure correlation between the initial variables and their respective components (new variables), indicated that the first of the components was strongly correlated with the variables 8, 9, 10, and 14; all of them were temperatures.

The highest correlation was found between the first component (axis 1, Tab. 3) and minimum soil temperature at the depth of 15 cm measured 30 days before sampling date. The other three well correlated variables were maximum temperature 30, 20, and 25 days before sampling (Tmax30, Tmax20, and Tmax25).

The second component (axis 2,Tab.3) was defined by rainfall variables. The highest correlation was found for rainfall 30 days before sampling (Rf30) followed by Rf20, Rf25, Rf5, and Rf15.

The third component was less defined and the highest correlation was found for rainfall and temperature.

The fourth component was clearly related to hours of sunshine (S) and the highest correlation was found for S10 followed by S15 and S20.

A summary of the obtained results are presented in Table 4.

The root-biomass weight (RBW) of the studied herbaceous communities was different in each of the months of the year. It was also different in the same month of succes-

	AXIS I	AXIS II	AXIS III	AXIS IV
BASIS VALUES	7,414	4,715	0,893	0,724
% OF INERTIA EXPLAINED BY THE AXIX	49,43	31,43	5,96	4,83
% OF INERTIA ACCUMULATED	49,43	80,86	86,82	91,65

Table 2.- Vairance and inertia absorbed by the main axis.

Tabla 2.- Varianza e inercia absorbidas por los ejes principales.

LOADING FACTORS

	VARIB.	AXIS I	AXIS II	AXIS III	AXIS IV
Rainfall 30 days before **(Rf 30)**	1	-0.051	0.789	0.569	-0.050
Rainfall 25 days before **(Rf 25)**	2	-0.047	0.701	0.689	-0.065
Rainfall 20 days before **(Rf 20)**	3	0.002	0.709	0.679	-0.065
Rainfall 15 days before **(Rf 15)**	4	-0.049	0.650	0.715	-0.068
Rainfall 10 days before **(Rf 10)**	5	-0.017	0.717	0.587	-0.237
Rainfall 5 days before **(Rf 5)**	6	0.118	0.521	0.171	-0.629
Maximum Temperature 15 days before **(T max 15)**	7	0.523	-0.413	0.410	0.443
Maximum Temperature 30 days before **(T max 30)**	8	0.760	-0.036	-0.084	0.597
MaximumTemperature 25 days before **(T max 25)**	9	0.734	-0.045	-0.100	0.640
Maximum Temperature 20 days before **(T max 20)**	10	0.736	-0.042	-0.106	0.641
Total sunshine hours 15 days before **(S 15)**	11	0.380	-0.024	-0.333	0.838
Total sunshine hours 10 days before **(S 10)**	12	0.325	0.142	-0.318	0.842
Total sunshine hours 20 days before **(S 20)**	13	0.426	0.010	-0.290	0.822
Mean Minumim Temperature at 15 cm of the soil **(Tmin)**	14	0.850	-0.027	0.245	0.390
Days after 10 mm of rainfall **(DfRf 10)**	15	-0.453	-0.654	-0.180	0.380

Tabla 3.- Correlation of the initial variables with the respective main components.

Tabla 3.- Correlación de las variables iniciales con los respectivos compenentes principales.

COMPONENTS

FIRST	SECOND	THIRD	FOURTH
T. mim Ss	Rf 30	Rf 15	S 10
T. max 30	Rf 20	Rf 25	S 15
T. max 20	Rf 25	Rf 20	S 20
T. max 25	Rf 15	Rf 10	
	Rf 5	Rf 30	

Table 4.- Correlated variables with each component expressed in decreasing order.

Tabla 4. - Variables correlacionadas con cada componente, expresado en orden decreciente.

MEAN MONTHLY EFFECT

YEAR	FEBRUARY	MARCH	APRIL	MAY	JUNE
1981		-	+	+	-
1982	+	+	-	-	-
1983	-	+	+	-	+
EXPECTED EFFECT	+	+	+	-	-

Table 5.- Effect of each month during each year.

Tabla 5.- Efecto de cada mes durante cada uno de los años considerados en el estudio.

sive years. These differences were evident on calculating the deviation of the mean RBW value for each month in relation to the global theoretical mean value. This calculation showed months in which biomass production tended to increase, and other months in which biomass production tended to decrease (Tab. 5). Table 5 also shows months in which this effect was positive in one year and negative in the following.

DISCUSSION

The results of this study showed that the quantitative variations in the underground plant biomass could be interpreted in relation to some environmental factors (air and soil temperature, rainfall, hours of sunshine) during the 30 days prior to sampling date. Mean minimum soil temperature (TminSs) showed the strongest negative effect followed by maximum air temperature 30, 20, and 25 days before sampling (T max 30, T max 20, T max 25). It is important to realize that this occured during the period of maximum physiological activity and water availability, i.e. in spring. The third negative factor was rainfall, but it must be emphasized that the strongest effect was produced by rainfall not immediately before but 30, 20, and 25 days prior to sampling. The fourth in importance factor was the hours of sunshine, but it is noteworthy that hours of sunshine 10 days before sampling had the strongest effect followed by those 15 and 20 days prior to sampling.

These results could be explained on the basis of plant physiology. Water and nutrient transport, the metabolism of photosynthetic products and their translocation are by no means instant processes. It seems logical, from the results of the initial approach to investigate the phenomenon, to assume that the underground-biomass results obtained in a given moment could be influenced by environmental conditions prevailing during the few days that preceded the measurement.

On the other hand, according to the plant life cycles (Trougthon, 1951; Beraegue, 1978), the existence of temporary variations in the underground biomass could be assumed. These theoretical variations during monthly periods prior to sampling were the present subject of study. Theoreticaly, the first stage (February-March), after the winter decrease in physiological activity, the time of resprouting and new-root formation should show an increase in the underground biomass. The next stage (April), the period of growth and development of new above-ground organs and the transport of photosynthates to the underground ones, should again show an increase in their biomass. Finally, in the period of anthesis (May-June), in which organic substances are translocated to above-ground organs, a decrease in the underground biomass could be expected. The results obtained in this study are sometimes in agreement with those theoretical predictions. When the agre-

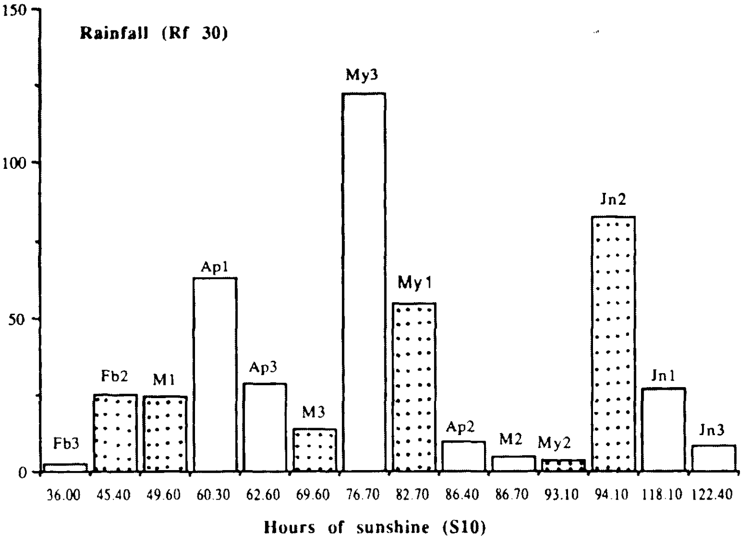

Figure 1.- Characterization of the different months related to the rainfall 30 and to the hours of sunshine 10.

Figura 1.- Caracterización de los diferentes meses en relación a la precipitación 30 días antes de la toma de muestras y a las horas de sol 10 días antes de la toma de muestras.

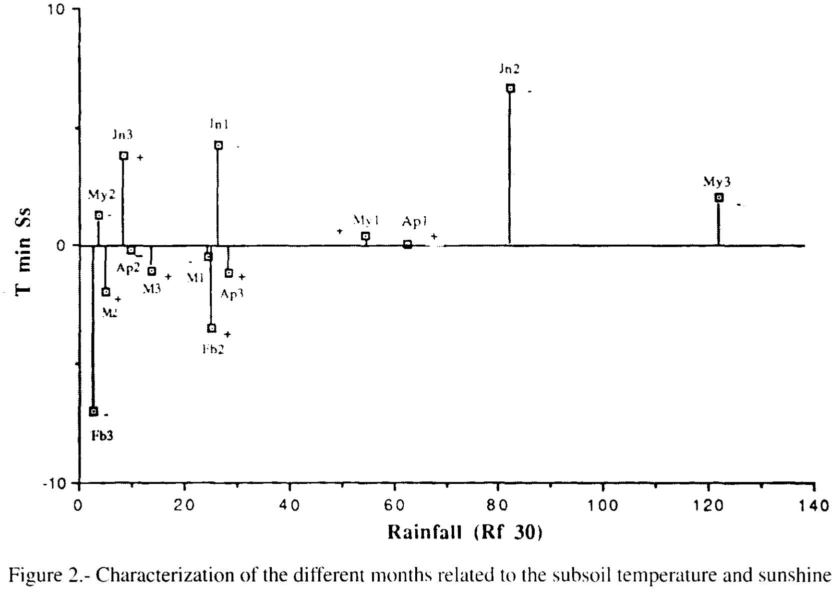

Figure 2.- Characterization of the different months related to the subsoil temperature and sunshine 30 days.

Figura 2.- Caracterización de los diferentes meses en relación a la temperatura del suelo y horas de sol, 30 días antes de la toma de muestras.

ement did not occur, the influence of unexpected climatic variations between the different periods should be considered.

As an example two climatic variables selected as the most responsible ones (Rf30, S10) for the underground-biomass variations, (Tab. 4) will be discussed.

Figure 1 sums up the characteristics of the five studied months (February, March, April, May and June) in the three years under investigation by means of the variables Rf30 (rainfall) and S10 (hours of sunshine) (see the second and fourth components, Tab. 4). Here, the intensity with which these variables modify the theoretical predictions, taking place only under controlled physiological condition, can be seen. In order to facilitate interpretation (dotted) the months in which there was an increase in biomass (RBW, g/1,9 dm^3), in relation with the global theoretical mean value have been marked.

On comparing the temporal evolution of the subterranean radical biomass during the three years of study (Fig. 3), with the rainfall 30 days prior to sampling and the hours of sunshine 10 days prior to the collection of the samples (Fig. 1), it is noted that March 1981 should have a biomass value lower than that of April. This value is, however, higher, hence in the graph the column corresponding to this month is dotted. May of this same year also shows a radical biomass production lower than that reached in April when that of April should have been higher.

Regarding 1982, February should show radical biomass values lower than March and April, but the results indicate the contrary, hence we have dotted the column corresponding to this value; similar results were observed for May and June.

Finally, in 1983 we see that the subterranean radical biomass values reached in March should be lower than those of April, although the graph shows us the contrary: biomass production in March is higher than in April (dotted column).

Each month was defined by the variations in these two parameters. Hence if one of them acts as a factor limiting growth and development it could modify the expected result. February in the third year of the study (Fb3, Fig.1) showed a negative effect. Hours of sunshine was not much different in the same month of the second year (Fb2), which had a positive effect, wheras rainfall was different and because of its scarceness could be the limiting factor.

April of the second year (Ap2) had a much higher number of hours of sunshine than in the other studied years (Ap1, Ap3). However, it showed a negative effect because rainfall in this month was very scarce.

The further variations could be explained by characterizing the months using other variables e.g. soil temperature and rainfall of the thirty days prior to sampling (Fig.2). A negative effect of the investigated variables on underground plant biomass was expected in the month of May. However, in the first year (My 1) there was an increase in this bio-

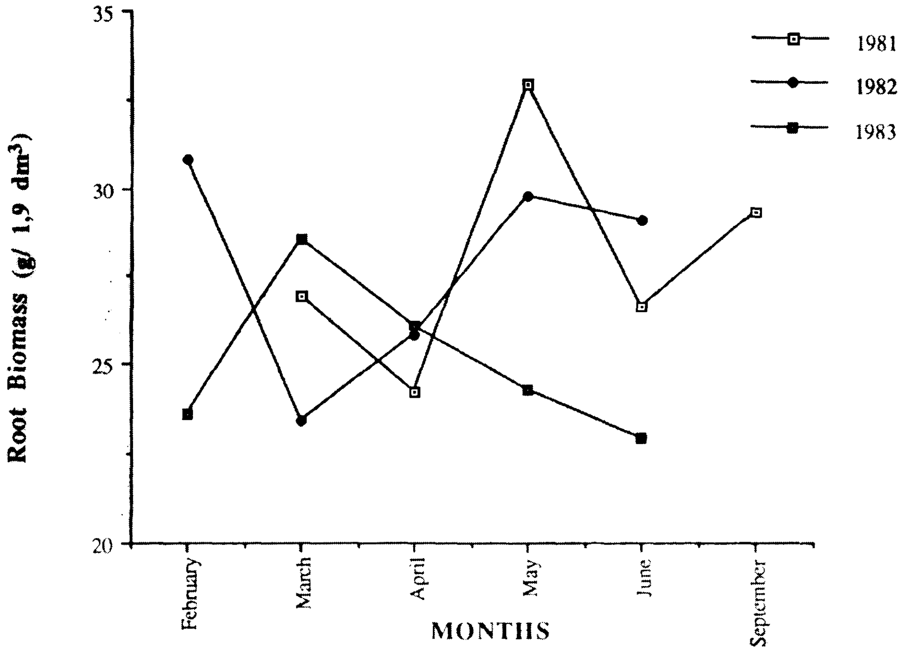

Figure 3.- Representation of the temporal evolution of the subterranean radical biomass during the three years of estudy.

Figura 3.- Representación de la evolución temporal de la biomasa radical subterránea durante los tres años de estudio (1981-1983)

mass (Table 5). Figure 1 shows that My1 was characterized by intermediate conditions between My2 and My3. But if we also consider soil temperature (Tmin Ss, Fig. 2), proved very important, it was lower and thus limiting the translocation of photosynthates; the velocity of the reaction being slow.

In view of the results, it is possible to find out the combined effect of the more significant factors in the thirty days prior to sampling, for each of the studied years. However, it does not have a better predictive value than the one that can be deduced from the "dominant tendencies", whether positive or negative. Under equivalent soil conditions, the process was controlled by climatic factors like a) minimum mean soil temperature during the thirty days before sampling; b) maximum mean atmosphere temperature of the 30, 20 and 25 days prior to sampling; c) rainfall of the 30, 20, 25, 5, and 15 days before sampling; d) hours of sunshine of the 10, 15, and 20 days before sampling.

BIBLIOGRAPHIC

BARRERA MELLADO, I.; GALINDO VILLARDON, P.; GOMEZ GUTIERREZ, J. M., 1984. Biomasa subterránea de productores pimarios de ecosistemas de pastizales adehesados en zonas semiáridas. *Stvdia Oecológica*, **3**, 169-184.

BARRERA MELLADO, I.; GOMEZ GUTIERREZ, J. M., 1985a. Biomasa vegetal subterránea en comunidades herbáceas. Toma de muestras. *An. Edafol. Agrobiol*, **42**, 1579-1587.

BARRERA MELLADO, I.; GOMEZ GUTIERREZ, J. M., 1985b. Aportación a la mejora de métodos de lavado de raíces. *An. Edafol. Agrobiol*, **44**, 257-280.

BARRERA MELLADO, I.; GOMEZ GUTIERREZ, J. M., 1986. Evolución de la relación biomasa subterranea y biomasa aérea en pastizales salmantinos. *Salamanca, Revista Provincial de Estudios*, **18-19**, 451-469.

BEHAEGUE, T. J., 1978. The seasonal discrepancies betwen potential and actual grass growth, an essay of explanation by eco-physiological contraints. *7th Gen. Meet. Eur. Grassland Federation*.

BLACKSHAW, R. W., 1990. Influence of soil temperature soil moisture, and seed burial depth on the emergence of round-leaved mallow (*Malva pusilla*). *Weed Sci.*, **38 (6)**, 518-521.

BLAISDELL, J. P., 1985. Seasonal development and yield of native plants on the upper Snake river plains and their relation to certain climatic factor. *U. S. Dep. Egr.Tech. Bull.*, **Nº 1190**.

GABRIEL, K. P., 1978. Least squares approximation of matrices by additive and multiplicative models. *J. R. Statics.Soc. B.*, **40**, 186-196.

GARWOOD, E. A., 1967. Seasonal variation in appearance and growth of grass roots. *Jour. British Grassland Soc.*, **22**, 12-130.

GITTINS, S., 1969. *The application of ordinations techniques*. British Ecol. Soc. Simp. 9. Blackwell Scientific Publications, Oxford (UK).

JOLLIFFE, I. T., 1986. Principal Component Analysis. Springer-Verlag. New York. Inc.

KUMMEROW, J.; KRAUSE, D.; WILLIAM, J., 1978. Seasonal changes of fine root density in the southern Californian chaparral. *Oecologia*, (Berl.) **37**, 201-212.

LEEUW, de J.; OLFF, H.; BAKKER, J. P., 1990. Year-to-year variation in peak above-ground biomass of six salt-marsh angiosperm communities as related to rainfall deficit and inundation frequency. *Aquat. Bot.*, **36 (2)**, 139-151.

LUIS CALABUIG, E.; MONTSERRAT RECODER, P., 1978. Mapa fitoclimático de la provincia de Salamanca. Estudio Integrado y Multidisciplinario de la Dehesa salmantina. I. *Estudio Geográfico Descriptivo*, **3er fasc.**,157-181. IRNA. Salamanca.

PANDEY, C. B.; SING, J. S. 1992. Influence of rainfall and grazing on belowground biomass dynamics in a dry tropical savana. *Can. J. Bot./Rev. Can. Bot.*, **70 (9)**, 1885-1890.

PEARSON, K., 1901. On lines and planes of closest fit to systems and points in space. *Phil. Mag. Ser.*, **6**, 559-572.

PEARSON, L. C., 1979. Effects of temperature and moisture on phenology and productivity of Indian Ricegrass. *Journal of Range Management*, vol. **32 nº 2**, 127-134.

ROOYEN, N. VAN.; BEZUIDENHOUT, D.; THERON, G. K.; DU, J.; and BOTHMA, P. 1990. Monitoring of the vegetation around artificial watering points (windnills) in the Kalahari Gerusbok National Park. *KOEDOE*, **33 (1)**, 63-88.

RYCHNOVSKA, M. 1990. Water relations of individuals, plant populations and communities in a grassland ecosystem. *Ekologia (CSSR/ Ecology (CSSR))*, **9 (2)**, 161-170.

SELINGNAN, N.G.; VAN KEUTEN, H. 1989. Herbage production of a mediterranean grassland in relation to soil depth, rainfall and nitrogen nutrition: A simulation study. *Ecol. Model*, **47 (3-4)**, 303-311.

SINGH, R. P.; GUPTA, M. K.; SINGHAL, R. M. 1989. Seasonal moisture variations under high altitude coniferous forest of Himachal pradesh. *J. Nat. Consrv.*, **1 (2),** 143-153.

STEPHENSON, N. L. 1990. Climatic control of vegetation distribution: the role of the water balance. *Am. Nat.*, **135**, 649-670.

TROUGTHON A., 1951. Studies on the roots and storage organs of herbage plants. *Journal of the British Grassland Society*, **6**, 197-206.

TUTIN, T. G., 1968. *Flora Europaea*, vol. **2.** Cambridge University Press.

DETECCIÓN DE ASINCRONÍAS ENTRE FACTORES CLIMÁTICOS Y LA PRODUCCIÓN DE FITOMASA EN PASTOS SEMIÁRIDOS.

RESUMEN

Se investiga la influencia de las variables climáticas sobre las fluctuaciones de la producción de biomasa en los órganos subterráneos de las herbáceas de pastizales semiáridos. La búsqueda de las variables que ejercen la mayor influencia se lleva a cabo mediante un análisis de componentes principales. El factor con mayor poder explicativo es la combinación de la Temperatura Media de las mínimas a 15 cm del suelo 30 días antes de la recogida de biomasa, y Temperatura Máxima 30, 20, 25, 15 y 5 días antes de la fecha de recogida. El segundo factor es una combinación de precipitaciones 30, 20, 25, 15 y 5 días antes de la toma de muestras

El tercer factor es las horas de sol 10, 15 y 20 días antes de la fecha de recogida.

Palabras clave: Raíces, biomasa vegetal, clima, pastos.