Listy Biometryczne - Biometrical Letters
Vol. 41 (2004), No. 1, 1-13

Comparison, through multiple factor analysis, of treatments for cork oak sudden death

Manuela M. Oliveira[1], Luis Ramos[2] and João T. Mexia[2]

[1]Departamento de Matemática, Universidade de Évora, Colégio Luis António Verney, Rua Romão Ramalho 59, 7000 Évora, Portugal;
[2]Departamento de Matemática, Faculdade de Ciençias e Tecnologia, Universidade Nova de Lisboa, Quinta da Torre, 2825 Monte da Caparica, Portugal

SUMMARY

Multiple Factor Analysis (MFA) uses a set of simultaneonly observed qualitative variables to analyse complex situations. The main features of MFA are presented. The part played by modalities, that is, dummy variables associated to the original qualitative variables, and of the corresponding principal components, is presented. The relationship between these principal components and the initial qualitative variables is discussed. Treatments for cork oak plantations suffering of a serious disease called sudden death are compared through the use of MFA. This technique enables a global treatment of the information available and gives a clear ranking of the treatments according to their effectiveness.

KEY WORDS: cork oak, multiple factor analysis, sudden death.

1. Introduction

The Cork oak (*Quercus Suber L.*) is the most representative Mediterranean tree in Portugal. It covers a large extension of the central and coastal regions in the south of the country. There are about 660000 ha of Cork oak, which is approximately 23% of the Portuguese forest area. Cork is one of the main Portuguese products with 120000 tons exported in the year 2000.

Nowadays a serious sanitary situation arose with many cork oaks quickly dying. *Phytophthora cinnamomi* is a fungus, which is responsible for this disease. The situation is complex and only a global study of the forest ecosystem may provide information useful in controlling this disease.

The aim of the paper is to provide a contribution to such a global approach using Multiple Factorial Analysis (MFA), see Caillez and Pagès (1976), Escoufier (1979) and Thurstone (1988), for the comparison of treatments for cork oak sudden death. After a brief introduction to this statistical technique in Section 2, in Section 3 we present the data we are going to analyse and in Section 4 the results we obtained.

2. Multiple Factor Analysis

We consider qualitative variables that only take a finite number m of values. Such variables classify the objects (or cases) on which they are observed into classes according to the values they take. For each of these classes we can consider a modality, that is, a dummy variable which takes the value 1 if the object belongs to the corresponding class and otherwise the value 0. The values of the modalities can be placed in an incidence matrix $\mathbf{X}$, with a row for each object and a column for each modality [class]. All the row totals will be 1, and the column totals $n_1, ..., n_m$ will be the numbers of objects in the different classes. These totals will be diagonal elements of a diagonal matrix $\mathrm{D}(\mathbf{X})$. Before going forward we point out that a quantitative variable may be condensed into a qualitative variable, for instance when we use *ph* values to classify soils into two classes as we do in this study.

In MFA we work with $p>1$ qualitative variables which distribute n objects into $m_1, ..., m_p$ classes. Let $\mathbf{X}_1, ..., \mathbf{X}_p$ be the incidence matrices for these variables and a given set of n objects. The matrix $\mathbf{X} = [\mathbf{X}_1 ... \mathbf{X}_m]$ will contain all the information on the n objects given by the qualitative variables. Matrix $\mathbf{X}$ will be of type $n \times m$, with $m = \sum_{j=1}^{p} m_j$, the total number of modalities. The row totals for $\mathbf{X}$ will all be equal to p and, see Saporta (1990, p. 223), we will have $rank(\mathbf{X}^t\mathbf{X}) = rank(\mathbf{X}) = m - p + 1$ whenever $n \times m$. The reason for this result is that the sum of the column vectors of each of the p incidence matrices is $\mathbf{1}^n$. Moreover, $\mathbf{X}^t\mathbf{X}$ will have eigenvector $\frac{1}{\sqrt{n}}\mathbf{1}^n$, the corresponding eigenvalue being p, and, since for every vector v we have $v^t X^t X v = \|Xv\|^2 \geq 0$, $\mathbf{X}^t\mathbf{X}$ will be positive semi definite, so the remaining $m - p$ non null eigenvalues will be positive. Moreover, $\mathbf{X}_i^t\mathbf{X}_l$ will be a $m_i \times m_l$ matrix whose rows correspond to the values of the i-th qualitative variable and whose columns correspond to the values of the l-th qualitative variable. Since the elements of $\mathbf{X}_i^t\mathbf{X}_l$ are the numbers of objects in the set in which the two qualitative variables take this pair of values, $\mathbf{X}_i^t\mathbf{X}_l$ can be seen as a contingency table and the Burt matrix

$$\mathbf{X}^t\mathbf{X} = \begin{bmatrix} \mathbf{X}_1^t\mathbf{X}_1 & \cdots & \mathbf{X}_1^t\mathbf{X}_p \\ \vdots & \cdots & \vdots \\ \mathbf{X}_p^t\mathbf{X}_1 & \cdots & \mathbf{X}_p^t\mathbf{X}_p \end{bmatrix}$$

as a multiple contingency table.

MFA gives geometrical representations of the distribution of the objects in the classes defined by the qualitative variables and of the objects themselves. In what follows we will consider only the first of these representations.

Let $\theta_1, \cdots, \theta_m$ be the eigenvalues and $\gamma_1, \cdots, \gamma_m$ the eigenvectors of matrix $\mathbf{W} = \frac{1}{p}\mathbf{D}^{-1}\mathbf{X}'\mathbf{X}$, with the block-diagonal matrix $\mathbf{D} = Diag(D(\mathbf{X}_1), \cdots, D(\mathbf{X}_p))$. The eigenvectors will be the vectors of coefficients for linear combinations of the modalities. We may consider these linear combinations as principal components. Since the initial variables and the principal components mutually determine each other, the two sets of variables carry the same amount of information. Moreover, it is well known that the variance-covariance matrices for both sets of variables have the same trace. Since the variance-covariance matrix for principal components is diagonal, we can accept that the information carried by each principal component is proportional to its variance. Then the relative amount of information carried by the principal components may be measured by the ratios

$$c_j = \frac{\theta_j}{\sum\limits_{i=1}^{m} \theta_i}, j = 1, \cdots, m.$$

We may represent the l-th class, or the corresponding modality, by the point in R^m whose coordinates are the l-th components of the eigenvectors, to obtain global images of the modalities. Often, projections of the corresponding points on the planes defined by the first pairs of eigenvectors are given. As we shall see, an alternative presentation is more informative. Moreover, the values of the principal components for the n objects will be the components of the vectors

$$\mathbf{Z}_j = \mathbf{X}\gamma_j, \quad j = 1, \cdots, m.$$

We can treat these values as the values of quantitative variables.

To measure the association between qualitative and quantitative variables we can use their empirical correlation coefficients; see Saporta (1990, p. 148). This coefficient is the quotient of the part of the variation of the quantitative variable that may be explained by the qualitative variable by the total variation of the quantitative variable. Let Z_i and $n_i, i = 1, \cdots m$, be the mean value of the quantitative variable and the number of objects in the i-th class defined by the qualitative variable. With $n = \sum_{i=1}^{m} n_i$, the general mean value of the quantitative variable will be

$$Z_. = \frac{1}{n}\sum_{i=1}^{m} n_i Z_i$$

while the part of the variation attributed to the qualitative variable will be

$$\sum_{i=1}^{m} n_i(Z_i - Z_.)^2.$$

Moreover, if $\mathbf{Z}$ is the vector of values for the quantitative variable, its total variation will be $s = \|\mathbf{Z}\|^2 - nZ_.^2$, thus the sample correlation coefficient is given by

$$r = \frac{\sum_{i=1}^{m} n_i(Z_i - Z_.)^2}{s}.$$

It is easy to see that this definition rests on an ANOVA-like partition of sums of squares. This partition is more clearly displayed in Saporta (1990, p. 148). We point out that r is scale free.

When MFA is used, for each qualitative variable we may obtain a correlation profile in which the empirical correlation coefficients of that variable with the first principal components are presented. Eigenvalues can be used as weights to obtain a weighted mean for empirical correlation coefficients.

For each qualitative variables and each principal component we may obtain the corresponding range breadth (rb), which will be the difference between the maximum and the minimum of the coordinates of the modalities defined by the qualitative variable in the axis associated with the principal components. As we shall see there tends to be a linear relation between sample correlation coefficients and rb values. Thus, the weighted average of rb for a qualitative variable may be used to express it's information content. As before, the eigenvalues will be used as weights. We found range breadths to be easier to interpret than the orthogonal projections mentioned above.

If r quantitative variables are observed simultaneously with the p qualitative variables, for each qualitative variable we may take the weighted average of its empirical correlation coefficients as a measure of global association of that qualitative variable with the quantitative variables. When the quantitative variables are principal components the weights should be proportional to the corresponding eigenvalues.

3. Data design

We used data colleted during a study carried out by Rhõne-Poulenc Agro to assess the results obtained with an experimental product. The treatments used were different applications of the tested drug and are described in Table 1.

The study was carried out in 14 cork oak plantations. In each of these plantations 7 rectangular plots, one per treatment, were chosen. Care was taken in plot location

Table 1. Modalities and codes of the qualitative variables

Variables and modalities	Codes
Treatments – sprays of tested drug	
2 air sprays of 5 kg/ha	Air 2-5
3 air sprays of 5 kg/ha	Air 3-5
2 ground sprays of 5 kg/ha	Ground 2-5
3 ground sprays of 5 kg/ha	Ground 3-5
2 ground sprays of 7.5 kg/ha	Ground 3-7.5
24 ground sprays of 5 kg/ha	Ground 4-5
Control	Control
Type of the soil	
Podzol	Podz
Cambisoil	Cambi
Luvissoil	Luvi
Ph of the soil	
$ph \leq 6.0$	$ph \leq 6.0$
$ph > 6.0$	$ph > 6.0$
Rainfall	
Rainfall 20-39mm	20-39mm
Rainfall 40-59mm	40-59mm
Rainfall 60-79mm	60-79mm
Rainfall 80-99mm	80-99mm
Rainfall 100-119mm	100-119mm
Final Sanitary Status	
Healthy	Healthy
Light defoliation	Light
Intermediate defoliation	Intermediate
Heavy defoliation	Heavy
Dead	Dead

to avoid contamination between treatments. In each plot three groups of 10 trees were chosen having light, intermediate and heavy defoliation. The study began in June 1995 and finished in February 2002. At the end, the trees under observation were classified according to their final sanitary status as *healthy*; with *light defoliation*; with *intermediate defoliation*; with *heavy defoliation* and *dead.*

In what follows we will apply MFA separately to the trees initially classified as having light, intermediate and heavy defoliations.

The objects were individual trees. For each degree of defoliation there were $14 \times 7 \times 10 = 980$ trees. We considered the qualitative variables:

- treatment applied, with 7 modalities,
- type of soils, with 3 modalities,
- ph of soil, with 2 modalities,
- rainfall, with 5 modalities,

– final sanitary status, with 5 modalities.

These variables were chosen, assuming that *Phytophthora cinnamoni* played a central role, thus expressing factors relevant for the disease evolution. Our main objective was to asses the significance of these factors.

The modalities for the qualitative variables and corresponding codes are presented in Table 1.

Thus we have $p = 5$, as well as $m_1 = 7$; $m_2 = 3$; $m_3 = 2$; $m_4 = 5$ and $m_5 = 5$. The third and fourth qualitative variables were obtained through a condensation of quantitative variables based on previous studies of the disease.

4. Results and discussion

As stated above, the starting point when applying MFA is obtaining the eigenvalues and eigenvectors of the matrix

$$\mathbf{W} = \frac{1}{p}\mathbf{D}^{-1}\mathbf{X}'\mathbf{X}$$

and assessing the relative amounts of information carried by the principal components. We carried out our study separately for each of the three degrees of defoliation. The eigenvalues and relative amounts of information are presented in Table 2.

Table 2. Eigenvalues and relative amounts of information

Initial degrees of defoliation					
Light		Intermediate		Heavy	
Eigenvalues	Relative amount of information	Eigenvalues	Relative amount of information	Eigenvalues	Relative amount of information
0.39	14.81	0.34	12.10	0.35	12.40
0.24	9.28	0.24	8.41	0.24	8.66
0.22	8.52	0.23	8.04	0.22	7.99
0.21	7.99	0.22	7.72	0.22	7.81
0.20	7.77	0.21	7.55	0.21	7.65
0.20	7.71	0.21	7.51	0.21	7.32
0.20	7.69	0.20	7.14	0.20	7.14
0.20	7.67	0.20	7.13	0.20	7.13
0.19	7.37	0.19	6.80	0.19	6.79
0.17	6.66	0.19	6.70	0.18	6.53
0.17	6.41	0.18	6.45	0.18	6.45
0.13	4.80	0.17	6.13	0.16	5.84
0.09	3.31	0.13	4.78	0.14	4.95

Table 3. Empirical correlation coefficients

	Qualitative variables	Principal components 1	2	3	4	5	Weighted mean
Light initial defoliation	Treatments	0.05	0.33	0.63	0.78	0.31	0.37
	Final sanitary status	0.11	0.58	0.39	0.05	0.61	0.32
	Type of the soil	0.67	0.28	0.06	0.12	0.09	0.30
	ph of the soil	0.67	0.00	0.01	0.02	0.00	0.21
	Rainfall	0.44	0.01	0.01	0.07	0.00	0.15
Intermediate initial defoliation	Treatments	0.00	0.52	0.07	0.57	0.54	0.31
	Final sanitary status	0.06	0.62	0.05	0.48	0.47	0.31
	Type of the soil	0.60	0.00	0.74	0.02	0.04	0.31
	ph of the soil	0.64	0.01	0.06	0.01	0.01	0.19
	Rainfall	0.40	0.03	0.21	0.00	0.00	0.15
Heavy initial defoliation	Treatments	0.00	0.55	0.17	0.50	0.51	0.31
	Final sanitary status	0.07	0.61	0.24	0.55	0.37	0.34
	Type of the soil	0.61	0.01	0.57	0.04	0.15	0.31
	ph of the soil	0.63	0.04	0.03	0.00	0.00	0.19
	Rainfall	0.43	0.01	0.11	0.00	0.03	0.15

The first five principal components appear to contain a sufficient amount of information to be considered separately. In Table 3 we present the weighted means of the correlation coefficient between the first five principal components and the qualitative variables.

Thus the first three qualitative variables are those with higher global association with the principal components. For each qualitative variable and each initial sanitary status we can draw a correlation profile. In these profiles the empirical correlation coefficients for the first five principal components are simultaneously presented.

To facilite the comparison we jointly present the correlation profiles for the same qualitative variable corresponding to the three degrees of initial defoliation (Figure 1).

We can draw the following conclusions.

– For the first three qualitative variables the profiles for intermediate and heavy initial defoliation are quite similar and differ from the one for light initial defoliation.

– For the first two qualitative variables the correlations are high for 2^{nd}, 4^{th} and 5^{th} principal components and low for the 1^{th} and 3^{rd} (with an exception for light defoliation). For the third qualitative variable we have the symmetrical situation.

– For the last two qualitative variables the three profiles are quite similar: with high empirical correlation for the first principal components and negligible empirical correlations for the remaining.

In Table 4 we present the coordinates for the first principal components F_1, F_2, F_3 , F_4 and F_5. The table has three groups of five columns, each group corresponding to a degree of initial defoliation. For each qualitative variable we will have a row for

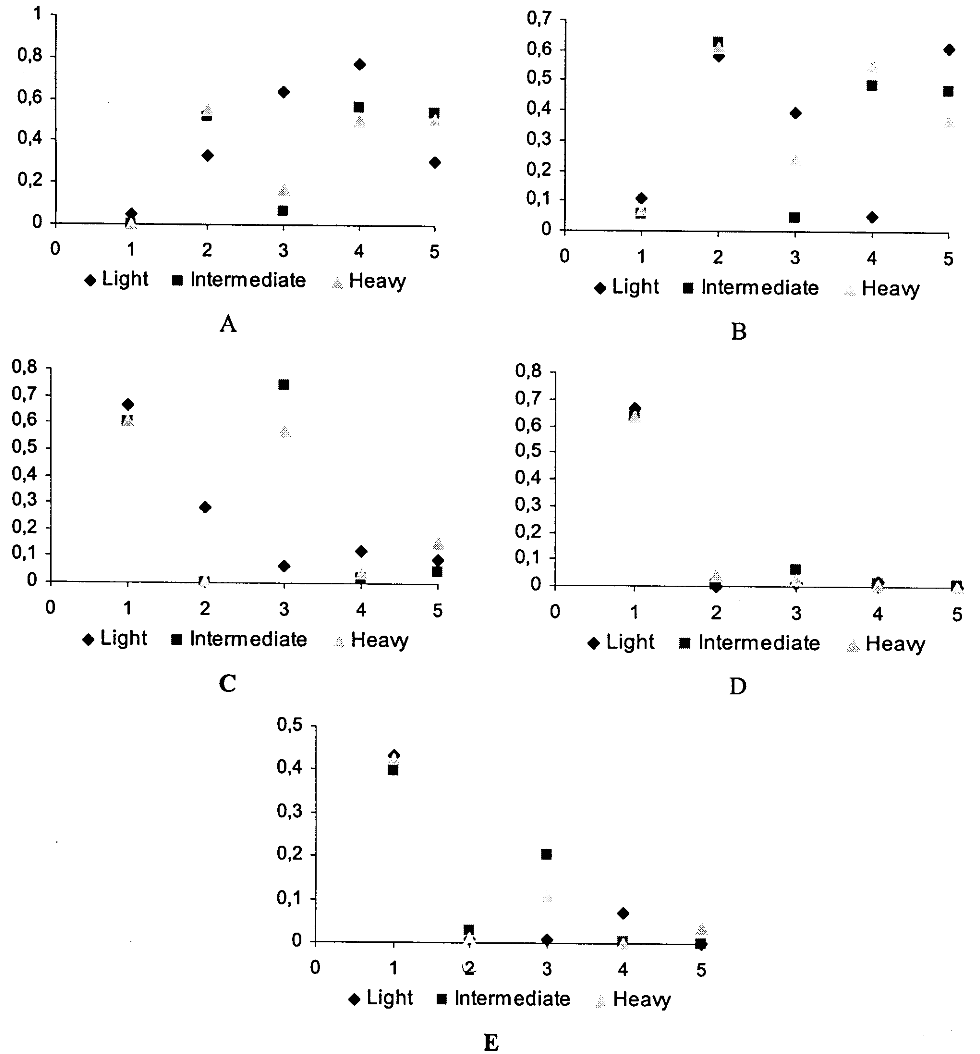

Fig. 1. Correlation profiles for: (A) Treatments, (B) Defoliation state, (C) Type of soil, (D) ph of the soil and (E) rainfall

Table 4. Modalities coordinates and range breadths

Modalities for qualitative variables	Ligth					Intermediate					Heavy				
	F_1	F_2	F_3	F_4	F_5	F_1	F_2	F_3	F_4	F_5	F_1	F_2	F_3	F_4	F_5
Air 2-5	0.09	-0.18	-1.06	-1.47	-0.24	-0.06	1.09	-0.58	-1.16	-0.25	0.05	0.20	0.19	1.47	-0.42
Air 3-5	0.28	0.55	1.73	-0.83	0.11	0.08	0.05	0.17	0.63	1.40	0.06	-0.98	0.58	0.44	0.05
Ground 2-5	0.21	-1.00	0.17	-0.33	-0.05	0.04	0.57	0.11	0.24	-0.38	-0.01	-0.07	-0.11	-0.71	0.94
Ground 3-5	-0.04	-0.27	-0.33	0.74	-1.03	-0.02	-0.39	-0.09	0.89	-1.20	-0.02	0.17	-0.61	-0.57	-1.35
Ground 3-7.5	0.13	-0.36	0.29	1.56	0.47	-0.01	-0.22	-0.02	0.29	0.32	-0.01	-0.27	0.45	-0.31	0.61
Ground 4-5	-0.10	0.31	0.26	-0.02	-0.11	0.07	0.27	0.16	0.18	0.13	0.03	-0.60	-0.48	-0.40	-0.28
Control	-0.39	0.78	-0.71	0.06	0.77	-0.11	-1.37	0.26	-1.13	0.01	-0.10	1.52	-0.08	-0.03	0.48
rb	0.67	1.78	2.79	3.03	1.80	0.19	2.46	0.84	2.05	2.60	0.16	2.50	1.19	2.18	2.29
Podz	0.84	0.26	-0.08	0.18	-0.17	-0.88	0.04	0.14	0.05	0.00	0.87	0.03	-0.10	0.02	0.08
Cambi	-0.46	-0.54	-0.10	-0.36	0.31	0.53	-0.03	-0.75	0.06	0.16	-0.56	0.04	0.66	-0.17	-0.36
Luvi	-1.50	1.05	0.70	0.68	-0.53	1.03	-0.03	1.86	-0.32	-0.49	-1.02	-0.20	-1.64	0.44	0.83
rb	2.34	1.59	0.80	1.04	0.84	1.91	0.07	2.61	0.38	0.65	1.89	0.24	2.30	0.61	1.19
$ph \leq 6.0$	0.74	0.04	-0.10	-0.13	0.01	-0.92	-0.11	-0.28	0.11	0.09	0.94	0.22	0.20	-0.07	-0.05
$ph > 6.0$	-0.90	-0.05	0.11	0.15	-0.01	0.69	0.08	0.21	-0.08	-0.07	-0.67	-0.16	-0.14	0.05	0.04
rb	1.64	0.09	0.21	0.28	0.02	1.64	0.09	0.21	0.28	0.02	1.61	0.38	0.34	0.12	0.09
20-39mm	-0.69	0.09	0.09	-0.28	0.02	0.63	-0.17	-0.46	-0.05	0.00	-0.66	0.11	0.34	0.01	-0.19
40-59mm	0.63	-0.08	-0.09	0.25	-0.02	-0.63	0.17	0.45	0.05	0.00	0.64	-0.11	-0.33	-0.01	0.18
60-79mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-99mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100-119mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
rb	1.32	0.17	0.18	0.53	0.04	1.26	0.34	0.91	0.10	0.00	1.30	0.22	0.67	0.02	0.37
Healthy	-0.71	-1.19	-0.76	0.37	-0.55	-0.46	2.64	-0.28	-1.00	-1.45	-1.99	-2.15	-9.95	-3.12	-7.74
Light	0.22	-0.22	0.46	-0.02	0.42	0.26	0.36	0.01	0.95	-0.20	0.58	-0.39	-0.09	-0.91	-1.28
Intermediate	-0.02	0.93	-0.33	-0.23	-0.80	-0.04	-0.09	0.07	-0.46	0.45	0.07	-0.57	0.09	0.39	0.13
Heavy	-0.58	2.42	-3.03	0.99	4.11	-0.26	-1.61	-0.17	0.27	-1.02	-0.25	0.81	0.00	-0.46	0.25
Dead	0.00	0.00	0.00	0.00	0.00	-2.38	-1.99	-3.48	-3.97	-6.84	0.68	3.96	-1.40	5.30	-2.44
rb	0.93	3.61	3.49	1.22	4.91	2.64	4.63	3.55	4.92	7.29	2.67	6.11	10.04	8.42	7.99

each modality, in which the corresponding coordinates are displayed. After these in the last row of the group the rb values are given.

The graphs shown in Fig. 2 jointly represent the range breadth and empirical correlations for all qualitative variables and initial sanitary status.

From these graphs we may conclude that range breadths and empirical correlation coefficients (except for final sanitary status when intermediate and heavy defoliation are considered) are linearly associated.

In Table 5 we present, for all initial degrees of defoliation and all qualitative variables, the corresponding weighted mean range breadths.

Table 5. Weighted mean range breadths for all initial degrees of defoliation

Qualitative variables	Initial degrees of defoliation		
	light	intermediate	heavy
Treatments	2.30	1.83	1.90
Final sanitary status	3.25	5.39	8.21
Type of the soil	1.85	1.47	1.62
ph of the soil	0.76	0.78	0.77
Rainfall	0.71	0.73	0.74

We thus see that the qualitative variable with higher weighted mean rb is, for all degrees of initial defoliation, the final sanitary status. This qualitative variable is of central importance for assessing the results of treatments. Moreover, the values of rb increase from light to intermediate and from intermediate to heavy initial defoliations. This increase is in good agreement with the data in Table 6. In this table we give the percentages of trees in the different final sanitary status for each initial degrees of defoliation. There will be a row for each initial degrees of defoliation and a column for each final sanitary status.

Table 6. Percentages of trees in the final sanitary status according to initial degrees of defoliation

Initial degrees of defoliation	Final sanitary status				
	Healthy	Light	Intermediate	Heavy	Dead
Light	14.94%	55.75%	27.51%	1.72%	0.00%
Intermediate	4.23%	29.70%	55.50%	10.25%	0.32%
Heavy	0.21%	9.14%	52.60%	36.98%	1.06%

As a result of the treatment applied, the degree of defoliation of a tree may improve, stabilize or worsen. Thus a tree with intermediate initial degree of defoliation has improved if its final sanitary status is either healthy or with light degrees of defoliation.

It may be of interest to compare under this heading the three initial degree of defoliation. The results are given in Table 7.

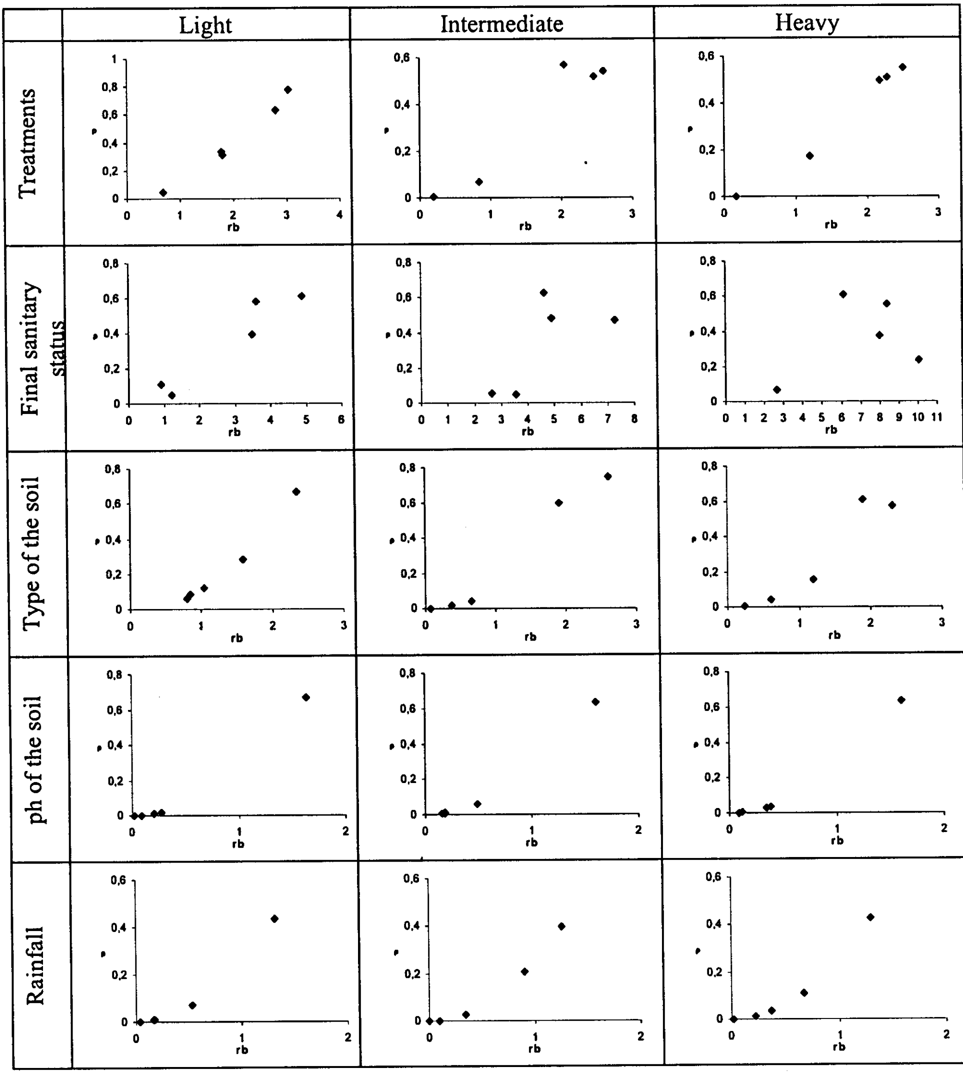

Fig. 2. Range breadths and empirical correlation coefficients

Table 7. Percentages of trees whose sanitary status is improved, stationary and worsened

Initial degrees of defoliation	Evolution of sanitary status		
	Improved	Stationary	Worsened
Light	14.94%	55.75%	29.31%
Intermediate	33.93%	55.50%	10.57%
Heavy	61.95%	36.98%	1.06%

These results point towards higher effectiveness of treatments when the initial defoliation was higher. We may now compare the treatments for each initial degrees of defoliation we obtain for the different treatments the corresponding weighted mean components for the first five principal components. The weights will be the eigenvalues and the individual coordinates were already presented in Table 4. In Table 8 we give these weighted means as well as their ranks.

Table 8. Weighted mean coordinates for treatments and ranks

Treatments	Initial degree of defoliation					
	Light		Intermediate		Heavy	
	weighted mean	rank	weighted mean	rank	weighted mean	rank
Air 2-5	0.35	6	0.35	6	0.36	6
Air 3-5	0.02	4	0.02	4	0.02	4
Ground 2-5	−0.04	3	−0.04	3	−0.04	3
Ground 3-5	−0.44	1	−0.46	1	−0.46	1
Ground 3-7.5	0.06	5	0.07	5	0.07	5
Ground 4-5	−0.37	2	−0.37	2	−0.38	2
Control	0.38	7	0.38	7	0.39	7

There is a perfect agreement between the orderings of the treatments. Since for all columns the control has the highest rank we may order the treatments according to their rank sum. We thus get Table 9 were the treatments are thus ordered and

Table 9. Treatments ranks and description

Treatments	Average rank	Total dosage	Mode of application	Number of applications
Ground 3-5	1	15	Ground application	3
Ground 4-5	2	20	Ground application	4
Ground 2-5	3	10	Ground application	2
Air 3-5	4	15	Air application	5
Ground 3-7.5	5	15	Ground application	7
Air 2-5	6	10	Air application	2
Control	7	–	–	–

in which the total dosage of the product applied as well as the mode and number of applications are presented.

5. Conclusions

The main points to be stressed are:

- treatment effectiveness appears to increase with the initial degree of defoliation,
- for all initial degrees of defoliation the treatments with ground application of 5 kg/ha carried out 3 or 4 times gave best results.

The way is thus opened for treatment of cork oak plantations even with high degree of defoliation.

References

Caillez F., Pagès J.P. (1976). *Introduction à l'Analyse des Données.* SMASH.

Escoufier B. (1979). Une Représentation des Variables dans L'Analyse des Correspondences Multiples. *Rev. Stat. Appl.* **27**, 37-47.

Saporta G. (1990). *Probabilités Analyse des données et Statistique.* Editions Technip, Paris.

Siegel S., Castellan N.J. (1988). *Nonparametric Statistics for the Behavioral Sciences.* Second Edition. McGraw-Hill, New York.

Thurstone L.L. (1988). *Multiple-Factor Analysis.* Univ. of Chicago Press. Chicago.

Received 15 December 2003; revised 12 October 2004

Porównanie sposobów traktowania "nagłej śmierci" dębu korkowego poprzez wielokrotną analizę czynnikową

Streszczenie

Wielokrotna analiza czynnikowa (MFA) wykorzystuje zbiór obserwowanych jednocześnie zmiennych jakościowych dla analizy złożonych sytuacji. W pracy prezentowane są główne cechy MFA. Omówiona jest rola modalności, to jest sztucznych zmiennych związanych z oryginalnymi zmiennymi dyskretnymi, oraz składowych głównych. Przedstawiony jest związek pomiędzy składowymi głównymi i zmiennymi dyskretnymi. Zaprezentowane jest zastosowanie MFA do porównania różnych sposobów traktowania choroby dębu korkowego zwanej "nagła śmierć". Przeprowadzona analiza danych pozwoliła na uszeregowanie traktowań pod względem ich efektywności.

Słowa kluczowe: dąb korkowy, wielokrotna anliza czynnikowa, nagła śmierć.