PEDOLOGICAL FACTOR INFLUENCE ON THE VITICULTURAL ZONING OF THE *ALJARAFE ALTO* (SEVILLE, SPAIN)

INFLUENCE DU FACTEUR PÉDOLOGIQUE SUR LE ZONAGE VITIVINICOLE DU *ALJARAFE ALTO* (SEVILLE, ESPAGNE)

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Mots clés : Aljarafe; Palomino Garrido Fino; zonage vitivinicole; môuts; vins.

ABSTRACT

The *Aljarafe Alto* is a small natural area in the province of Seville (Spain), where the autochthonous vine is the cultivar Palomino Garrido Fino. The authors study the influence of 3 types of soils (Mediterranean red soil (calcic Rhodoxeralf); calcareous brown soil (calcixerolic Xerochrept); white Rendsina (calcicxerollic Xerorthent)) in nine vineyard plots. The results reveal statistically significant differences in some characteristics of the agronomic fertility of the soils and, as a consequence, in the mineral nutrition stage of the plants and crop quality.

Musts proceeding from the vineyard plots chosen for this study were fermented in laboratory. The results from statistical treatment of oenological parameters of these wine samples reveal the pedological factor to be the most relevant for the viticultural zoning of the *Aljarafe Alto* zone.

RESUME

Aljarafe Alto est une petite zone naturelle dans le département de Séville (Espagne), où le cépage autochtone cultivé est le Palomino Garrido Fino. Les auteurs étudient l´influence de 3 types de sols (sol Rouge fersialitique, sol brun calcaire et Rendsine blanche) sur 9 vignobles de la variété “Palomino Garrido Fino” du “*Aljarafe Alto*” (Seville).

Les résultats expérimentaux montrent des différences statistiquement significatives pour quelques caractéristiques du potentiel agronomique des sols et leurs conséquences sur le niveau de nutrition minérale des vignobles et sur la qualité des récoltes.

Le traitement statistique des paramètres oenologiques des microvinifications des moûts issus des vignobles étudiés montre le facteur pédologique comme le critère les plus relevant dans le zonage vitivinicole de la région *Aljarafe Alto* (Seville).

INTRODUCTION

The *Aljarafe* is a small natural area in the province of Seville close to this Andalusian capital. Its wine production, although it is limited nowadays, has a large historical tradition. Its origin begins in the thirteenth century after the *Repartimiento* (HERRERA, 1980; BORRERO, 1995).

In the eighteenth century, vineyards in this region had a extension of up to 2,500 ha, and it was the predominant growing in the area of Espartinas, Umbrete and Villanueva del Ariscal, all of them located in the so-called *Aljarafe Alto* (altitude of 120 to 180 m above sea level) and at 15 Km from the capital city, Seville (11 m above sea level). This location allows the *Aljarafe Alto* to be opened to western Atlantic breezes (PANEQUE MACÍAS, 2000).

During the last century, the wines from the *Aljarafe*, made of Palomino Garrido fino grapes (GARCÍA DE LUJÁN *et al*., 1990), had its particular market in Jerez (Cadiz). This situation lasted until the creation of the Registered Apellations of Origin (AOC) of Jerez-Xérès-Sherry and Manzanilla-Sanlúcar de Barrameda and the Sherry Regulatory Board. From that moment on the wines from the *Aljarafe* were given the distinction of *Vinos de la Tierra* (*Local wines*).

The most interesting geological formation in the *Aljarafe Alto*, from a viticultural point of view, are the lime sandy loam and the calcarenites of the Superior Miocene. The *Aljarafe Alto* is bordered by the Guadalquivir River and Guadaira River and crossed by the Repudio stream. They all together have contributed to an important erosive moulding of the detritus block of the Betic Neogene which originated, therefore, an uneven landscape with gullies in the original platform and in the old fluvial terraces.

The viticultural soils of the Aljarafe Alto take up the central-north area of the region, over facies of the regresive saheliense Miocene. The chemical nutritional power of these soils is characterised by medium asimilable P contents (0,018 g Kg^{-1}), being critical those of the K^+ (0,2 $cmol_c$ Kg^{-1}). As for the chlorotic power index, CPI (JUSTE and POUGET, 1972), the predominant values are those higher than 30 (PANEQUE MACÍAS, 2000).

The superficial layer of the soils corresponds to anthropic horizons (Ap), more or less differentiated from the other layers of the profile. Subsuperficial layers are deep, corresponding to altered B horizons and argillic Bt, both of them with secondary calcic carbonate (Btk) and to the original geological lime material. All these horizons and layers form the *Aljarafe Alto soil cover* with white Rendsina, RBl, (calcicxerollic Xerorthent), calcareous Brown soil, SPk, (calcicxerolic Xerochrept), Mediterranean Red soil, SRk, (calcic Rhodoxeralf), and red-brownish calcareous soil, SPR, (CEBAC, 1962; MUDARRA, 1988; PANEQUE MACÍAS, 2000). These soils are distributed at three different altitude subzones of the detritus platform, in relatively flat areas with an erosive slope modelling.

The geological and climatic uniformity of the terrains in the *Aljarafe Alto* makes it possible its viticultural zoning according to the main types of soils, as long as it is confirmed a significant influence of the soils on the mineral nutrition of the grapevines that could have an effect on the quality of the resulting musts and wines. In this way, the aim of this work is an objective first approach to the previously mentioned purpose.

MATERIAL AND METHODS

PLOTS: nine plots of vineyard were chosen as representatives of the main three types of soils in the Aljarafe Alto (three plots for each one): Mediterranean red soil (calcic Rhodoxeralf, SRk); calcareous brown soil (calcixerolic Xerochrept, SPk) and white plough Rendsina (calcicxerollic Xerorthent, RBl) (PANEQUE MACÍAS, 2000).

VINES. Mineral nutrition of Palomino Garrido fino vines in the nine plots were monitored along three development stages (full-bloom, veraison and harvest) as described by CIITDF (1969). Na, K, Ca, Mg, Fe, Cu, Mn, Zn were determinated according to PINTA (1973); P_2O_5 to GUITIÁN and CARBALLAS (1976) and Kjeldahl N to DUCHAUFOUR (1975). Weight of 100 grapes were calculated, as well as kg of grapes per plant. Musts from the grapes were extracted to determine pH, titrable acidity (AMERINE y OUGH, 1974), Baumé degree and phenolic content (SINGLETON y ROSSI, 1965).

MICROVINIFICATIONS. Musts from four plots of vineyards with different type of soil (SRk, SPk, SPR y RBl) were fermented in laboratory. Conventional parameters were performed according to MAPA (1993); titrable acidity to AMERINE and OUGH (1974); organic acids by HPLC (PANEQUE MACÍAS, 2000); phenolic content as described by SINGLETON and ROSSI (1965) and mineral elements were determined using flame emission and atomic absorption by dissolving the ashes in acid solution (RIBEREAU-GAYON *et al.*, 1975).

STATISTICAL TREATMENT. Significant differences among values of mineral nutrition of the vines, musts and wines were assessed with a one-way analysis of variance (ANOVA) using a STATGRAPHICS Plus Version 2.0 program (Statiscal Graphics Corporation, 1996). Discriminant analysis and principal components analysis (PCA) were performed using the same statistics program.

RESULTS AND DISCUSSION

1. Leaf analysis

The tables 1 and 2 show the mean values obtained from the analysis in triplicate for macro and micronutrients in Palomino Garrido fino vine leaves during three development stages (full bloom, FB; veraison, V, and ripeness, R). The tables 3 and 4 contain mean values of different relations and indexes and nutritive balances calculated using the macro and micronutrients values above cited.

Analysis of variance: Table 5 shows the mean chemical values of all the variables according to the type of soil. As can be seen, significant differences were found depending on the type of soil of the plots: for Mg, Cu and Mn contents ($p < 0,001$), for K contents ($p < 0,01$) and for N and P_2O_5 contents ($p < 0,05$). Considering the relations between nutrients elements and other indexes calculated, there were differences for K/Ca, K/Mg and K/Ca+Mg ($p < 0,001$), for N+10P+K ($p < 0,01$) and for Fe index and Vegetative index ($p < 0,05$).

According to leaf analysis, grapevines from RBl plots had higher contents in Mg, Mn and Cu (as for the later, there was no significant difference with grapevines from SRk plots). The higher contents in K corresponded to vines from SPk and SRk plots, and grapevines from SRk plots had higher values in N than those in SPk and RBl plots.

Significant differences among vines from different plots were also found in the nutrients relations K/Ca, K/Mg and K/Ca+Mg ($p<0,001$) and for Fe and vegetative indexes ($p<0,05$). Vines from RBl soil plots had lower values of all these variables. There was also a significant difference for N+10P+K ($p<0,01$): lower values corresponded to vines from RBl and SPk soil plots, not existing any difference between them (5.02 y 5.92, respectively).

Discriminant analysis. Considering the three types of soil as a variation factor and those variables which showed significant differences in the ANOVA, the discriminant analysis grouped together the samples from the same type of soil (figure 1). Discriminant function 1 (87,53 %) separated the samples of the three type of soils according to their content in K, Cu and Mg: vines from RBl soil plots had lower content in K and higher contents in Mg and Cu. On the other hand, discriminant function 2 (12,47 %) allowed to discriminate samples from SRk soil plots by their higher content in N.

2. Crop level and musts quality.

Table 6 contains the results from musts analysis and some information about the production (weight of 100 grapes, and Kg of grape per plant). Some differences were obtained when applying one-way analysis of variance according to the type of soil. Significant differences were found for pH and Baumé degree of the musts ($p<0,05$), and for the weight of 100 grapes ($p<0,01$). Non significant differences were observed either for titrable acidity or phenolic content. Musts from SRk soil plots had lower pH (3,63) but higher weight of 100 grapes. There was no significant difference between Baume degree in musts of SRk and RBl plots (11,67 and 11,33, respectively), having higher values than musts from SPk plots (9,83).

By applying **discriminant analysis** to those significant different variables resulting from ANOVA analysis, and considering the type of soil, two discriminant functions were obtained. Plot of the discriminant functions showed a clear differentiation among the samples (figure 2). The first function explained the 79,10 % of the total variance. The samples were mainly separated according to the weight of 100 grapes: vines from SRk plots had a higher value for this variable. Discriminant function 2 explained the 20,90 % of the total variance and led to a clear separation of the samples according to Baume degree, being higher for musts fom SRk and RBl plots.

3. Microvinifications

Table 7 shows the mean chemical values of wines analyses. Wines were elaborated by fermenting musts from four vineyard plots with different types of soil (SPk, SRk, RBl and SPR, being the last one a brown-red calcareous soil). The analysis of variance of the data showed that many of them were significantly different among wines depending on the type of soil: for ethanol (%), residual sugars, phenolic content, K concentration, and acetic and malic acid contents ($p<0,001$); for pH, Mg, Na and malic acid ($p<0,01$); for relative density, volatile acidity, Dry extract/ashes relation, and Ca, Fe and Zn contents ($p<0,05$).

As for ethanol, wines from RBl plots showed significantly higher values (13,3 %) than wines from SRk and SPk plots (11,3 and 10,7 % respectively). Samples from SPR plot had higher residual sugars after fermentation (2,6 g L^{-1}) and pH value (4,0) than the rest of wines. There was also a significant difference for phenolic contents between wines from SRk soil plot and the wines from the remaining types of soil, which was higher in the former ones (223,9 mg L^{-1}). Wines from RBl and SRk plots showed significant lower volatile acidity than those from SPR and SPk plots, which had slightly high values (0,56 and 0,54 g L^{-1}, expressed as acetic acid). Finally, as for the mineral fraction, wines from RBl plot had lower concentrations of Ca, Na, K, Fe and Zn, but higher contents of Mg (25.0 g L^{-1}).

In short, the analysis of variance made it possible to find significant differences among the wines samples according to the type of soil of origin.

The analytical variables were gathered into two groups (conventional parameters and mineral fraction). Principal component analysis (PCA) was then performed on each one of the groups in order to find any wine samples grouping according to their origin. As for the first PCA (conventional parameters), the first two principal components (PC) accounted for 58,2 % and 22,19 % of the variance, respectively. As shown in figure 3, the first PC explained most of the differences among the wines according to the type of soil: PC1separated clearly wines from SPk and SPR plots, wines from RBl plot and wines from SRk plot. Phenolic content, relative density and lactic acid were loaded on the first PC: wines from SRk soils had higher phenolic contents, relative density and lactic acid. Second PC contrasted perfectly wines from RBl plot with those from the rest of the plots mainly for the ethanol (%) and malic acid, and the former wines were those with higher ethanol and lower malic acid.

When mineral compounds were analysed by PCA, a clear differentiation among plots was found (figure 4). The first two components accounted for 93,2 % of the total variance. Mg, Fe and Zn were loaded on the first PC, while Ca, Na and K were loaded in the second PC. The first PC explained the separation of SPk wines and RBl wines: wines from SPk plot had lower concentrations of Mg and higher of Fe and Zn, while wines from RBl plot showed higher concentrations of Mg. On the other hand, the second component separated wines of SRk plot from the rest of the samples according to their higher concentration of Ca.

CONCLUSION

Leaf analysis for Palomino Garrido fino cultivar grown in three types of soil in the *Aljarafe Alto* (1997 vintage) showed statistically significant differences ($p<0,001$): grapevines from RBl plots had higher contents in Mg and Mn. Grapevines from SPk and SRk plots had higher K contents and the highest N contents also resulted in SRk plot. Grapevines from RBl plots had lower values in the nutrients relations K/Ca, K/Mg and K/Ca+Mg ($p<0,001$), for N+10P+K ($p<0,01$), and in the Fe index and the Vegetative index ($p<0,05$). Discriminant Analysis differentiated the samples in three groups corresponding to three types of soils (SRk, SPk and RBL) according to K, Mg, Cu and N contents: vines from RBl plots had higher Mg and Cu contents and lower K contents, and higher values for N content corresponded to SRk plots.

Musts extracted from grapes from SRk and RBl plots had a higher Baumé degree; musts from SRk showed a lower pH and a higher weight of 100 grapes. Finally, the musts from RBl and SPk plots had higher pH (3,92 and 3,90), and those from SPk plot lower Baumé degree (9,8).

The samples of wines (1997 vintage) turned out to have significant differences ($p<0,001$), according to the type of soil, for ethanol percent (v/v), residual sugars, phenolic and K contents; for pH, Mg and Na ($p<0,01$), and for the Dry extract/Ashes relation, Ca, Fe and Zn contents ($p<0,05$). There were no statistically significant differences in the rest of the considered variables. Considering no mineral elements, PCA grouped the samples according to the pH and Dry Extract/Ashes relation. In the other hand, mineral variables grouped together the wines made of grapes from SPk plot due to their higher Fe content, and those from SPk and SRk for their content in K and Na; and the wines from SPR plot for their higher content in Ca,

According to the available information, we propose to differentiate three classes or three Terrain Units for Palomino Garrido fino grapevine within the *Aljarafe Alto* (townships of Espartinas, Villanueva del Ariscal and Umbrete), which have slight geomorphological differences among them, but with significant differences in relation to the associated soils. Eventually, the soil characteristics are reflected in those of the mineral nutrition of the vine and in the musts and wines quality; so, it is possible to propose a viticultural zoning of the *Aljarafe Alto* considering the pedological factor the most relevant one.

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Table 1. Mean values for N, P, K, Ca y Mg (g 100g[-1] dry matter, d.m.) in Palomino Garrido Fino leaves during three development stages[(1)], in 9 vineyard plots with three different type of soils (SPk, SRk y RBl)[(2)].

	N			P_2O_5			K			Ca			Mg		
	FB	V	R	FB	V	R	FB	V	R	FB	V	R	FB	V	R
SPk	2.14	1.61	1.28	0.37	0.43	0.29	0.37	0.78	0.76	1.62	3.55	3.46	0.14	0.25	0.31
SRk	2.47	1.80	1.53	0.48	0.40	0.36	0.35	0.79	0.81	1.90	3.86	3.53	0.09	0.23	.024
RBl	2.07	1.54	1.24	0.40	0.28	0.21	0.34	0.54	0.42	2.52	3.92	3.60	0.24	0.36	0.42

(1) FB: full bloom; V: veraison; R: ripeness. (2). SPk: calcareous brown soil; SRk: Mediterranean red soil; RBl: plough white Rendsina.

Table 2. Mean values for Fe, Cu, Mn y Zn (g Kg[-1] d.m.) in Palomino Garrido Fino leaves during three development stages[(1)], in 9 vineyard plots with three different type of soils (SPk, SRk y RBl)[(2)].

	Fe			Cu			Mn			Zn		
	FB	V	R	FB	V	R	FB	V	R	FB	V	R
SPk	0.07	0.11	0.26	0.05	0.03	0.03	0.03	0.02	0.04	0.13	0.02	0.02
SRk	0.12	0.17	0.21	0.12	0.26	0.22	0.04	0.02	0.05	0.15	0.02	0.03
RBl	0.24	0.19	0.13	0.24	0.24	0.21	0.09	0.03	0.08	0.19	0.03	0.02

(1) FB: full bloom; V: veraison; R: ripeness. (2) SPk: calcareous brown soil; SRk: Mediterranean red soil; RBl: plough white Rendsina.

Table 3. Nutrient relations and indexes in Palomino Garrido Fino leaves during three development stages[(1)], in 9 vineyard plots with three different type of soils (SPk, SRk y RBl)[(2)]

	K/Ca			K/Mg			K/Ca+Mg			N+10P+K			Fe index [(3)]			Vegetative index[(4)]		
	FB	V	R	FB	V	R	FB	V	R	FB	V	R	FB	V	R	FB	V	R
SPk	0.23	0.22	0.22	2.70	3.13	2.49	0.21	0.21	0.20	6.16	6.70	4.90	2.71	2.33	0.72	1.28	0.64	0.47
SRk	0.18	0.20	0.23	3.65	3.49	3.41	0.17	0.19	0.21	7.61	6.58	5.95	2.77	1.47	1.05	1.42	0.59	0.58
RBl	0.14	0.14	0.12	1.45	1.51	0.99	0.12	0.13	0.10	6.45	4.87	3.74	1.32	0.91	0.94	0.88	0.42	0.34

(1) FB: full bloom; V: veraison; R: ripeness. (2) SPk: calcareous brown soil; SRk: Mediterranean red soil; RBl: plough white Rendsina.

(3) Fe Index= $\frac{50(10P+K)}{Fe}$; (4) Vegetative index = $\frac{0,365(N+10P+K)}{Ca+Mg}$

Table 4. Nutritive balances in Palomino Garrido Fino leaves during three development stages[(1)], in 9 vineyard plots with three different type of soils (SPk, SRk y RBl)[(2)].

	N:10P:K			Ca:Mg:K		
	FB	V	R	FB	V	R
SPkP	35:59:6	24:64:12	26:58:16	76:6:17	78:5:17	76:7:17
SRk	33:63:5	27:61:12	26:61:13	81:4:15	79:5:16	77:5:18
RBl	32:63:5	32:57:11	33:56:11	81:8:11	81:7:11	81:10:9

(1) FB: full bloom; V: veraison; R: ripeness. (2) SPk: calcareous brown soil; SRk: Mediterranean red soil; RBl: plough white Rendsina.

Table 5. Mean values and analysis of variance for leaf analysis of Palomino Garrido fino vines in nine vineyard plots with three different type of soils[(2)].

	p	Significance [(1)]	SPk	SRk	RBl
N (g 100g[-1] d.m.)	0,0407	*	1,68±0,37	1,93±0,42	1,61±0,36
P_2O_5(g 100g[-1] d.m.)	0,0278	*	0,36±0,10	0,41±0,15	0,29±0,13
K (g 100g[-1] d.m.)	0,0020	**	0,64±0,21	0,65±0,12	0,43±0,10
Ca (g 100g[-1] d.m.)	0,2657	n.s.	2,89±0,96	3,09±0,90	3,35±0,67
Mg (g 100g[-1] d.m.)	0,0000	***	0,23±0,08	0,19±0,07	0,33±0,10
Fe (g Kg[-1] d.m.)	0,1530	n.s.	1,15±0,09	0,16±0,05	0,28±0,37
Cu (g Kg[-1] d.m.)	0,0000	***	0,37±0,00	0,20±0,00	0,23±0,00
Mn (g Kg[-1] d.m.)	0,0000	***	0,03±0,01	0,04±0,00	0,07±0,00
Zn (g Kg[-1] d.m.)	0,6730	n.s.	0,06±0,07	0,07±0,06	0,08±0,09
K/Ca	0,0000	***	0,22±0,03	0,21±0,04	0,13±0,02
K/Mg	0,0000	***	2,83±0,57	3,60±0,82	1,36±0,39
K/Ca+Mg	0,0000	***	0,21±0,03	0,19±0,03	0,12±0,02
N+10P+K	0,0030	**	5,9±1,1	6,71±1,54	5,02±1,51
Fe Index	0,0117	*	1,9±0,9	1,8±0,9	1,1±0,7
Vegetative Index	0,0403	*	0,8±0,4	0,9±0,5	0,5±0,3

(1) * $p< 0.05$, ** $p< 0.01$; *** $p< 0.001$. (2). SPk: calcareous brown soil; SRk: Mediterranean red soil; RBl: plough white Rendsina.

Table 6. Mean values for must analysis and crop results according to the type of soil [(4)].

	pH	Titrable acidity [(2)]	Baumé Degree	Sugars (g L[-1])	Etanol (%)	Phenolic content[(3)]	100 grapes weight (g)	Kg/plant
P	0,0215	0,1750	0,0407			0,7849	0,0027	0,2906
S[(1)]	*	n.s.	*	*	n.s.	n.s.	**	n.s.
SPk	3,9±0,1	3,3±0,3	9,8±0,8	166,0±	9,8±0,8	269,9±25,6	396,9±9,0	1,81±0,12
SRk	3,6±0,9	4,9±0,9	11,7±0,6	205,0±	12,1±0,6	284,3±84,3	493,4±20,5	2,77±1,23
RBl	3,9±0,1	3,8±1,3	11,3±0,8	201,7±	11,9±0,8	313,7±100,3	342,7±48,3	1,77±0,50

(1) S= Significance: * $p< 0.05$, ** $p< 0.01$; *** $p< 0.001$. (2) tartaric acid (g L[-1]). (3) gallic acid (mg L[-1]). (4) SPk: calcareous brown soil; SRk: Mediterranean red soil; RBl: plough white Rendsina.

Table 7. Mean values and analysis of variance for wine analysis of Palomino Garrido fino vines of vineyard plots with four different type of soils[4].

	p	S	RBl	SPR	SRk	SPk
Ethanol (% v/v)	0,0004	**	13,3	11,8	11,3	10,7
Relative density	0,0207	*	0,9956	0,9947	0,9994	0,9965
PH	0,0033	**	3,6 ab	4,0 c	3,6 a	3,9 bc
Titrable aci dity (g L^{-1}) [1]	0,0701	n.s.	5,1	4,8	7,1	4,5
Volatil acidity (g L^{-1}) [2]	0,0135	*	0,29 a	0,56 b	0,24 a	0,54 b
free SO_2 (mg L^{-1})	0,2622	n.s	1,60	2,35	3,90	2,35
Binded SO_2 (mg L^{-1})	0,9194	n.s.	1,80	11,8	12,6	11,8
total SO_2 (mg L^{-1})	0,2451	n.s.	13,40	14,20	16,53	14,2
Sugars (g L^{-1})	0,0000	***	0,77 a	2,62 b	0,90 a	0,71 a
Phenolic content (mg L^{-1}) [3]	0,0001	***	152,58 a	150,3 a	223,93 b	157,7 a
Ashes content (mg L^{-1})	0,1301	n.s.	2398,0	3038,0	2820,0	2800,0
Dry extract (g L^{-1})	0,0785	n.s.	33,3	26,45	37,23	27,9
Dry Extract/Ashes	0,0382	*	14,16 c	8,73 a	13,16 bc	9,97 ab
Ca (mg L^{-1})	0,0159	*	15,0 a	17,5 a	37,75 b	25,5 ab
Mg (mg L^{-1})	0,0018	**	25,0 d	22,0 c	17,0 b	16,5 a
Na (mg L^{-1})	0,0024	**	5,1 a	6,0 ab	5,1 a	7,7 b
K (mg L^{-1})	0,0000	***	382,7 a	476,2 b	422,4 a	611,1 c
Fe (mg L^{-1})	0,0115	*	0,9 a	1,3 ab	1,25 a	1,7 b
Cu (mg L^{-1})	0,1048	n.s.	0,4	0,5	0,5	0,3
Mn (mg L^{-1})	0,7560	n.s.	0,7	1,1	1,15	0,7
Zn(mg L^{-1})	0,0147	*	0,2 a	0,3 ab	0,45 c	0,40 bc
Acetic acid (g L^{-1})	0,0010	***	0,44 ab	0,84 b	0,29 a	0,91 b
Citric acid (g L^{-1})	0,3801	n.s.	0,27	0,34	0,28	0,26
Lactic acid (g L^{-1})	0,0004	**	0,21 a	0,35 ab	0,71 b	0,12 a
Malic acid (g L^{-1})	0,0066	**	0,65 a	1,06 ab	1,75 b	1,13 ab
Succinic acid (g L^{-1})	0,2037	n.s.	0,97	1,89	1,21	1,14
Tartaric acid (g L^{-1})	0,1338	n.s.	1,29	1,24	1,44	1,13

S (Significance): * $p < 0.05$, ** $p < 0.01$; *** $p < 0.001$; (1) tartaric acid g L^{-1}; (2) acetic acid g L^{-1}; (3) gallic acid mg L^{-1}; (4) RBl: plough white Rendsina; SPR: red-brownish calcareous soil; SRk: Mediterranean red soil; SPk: calcareous brown soil.

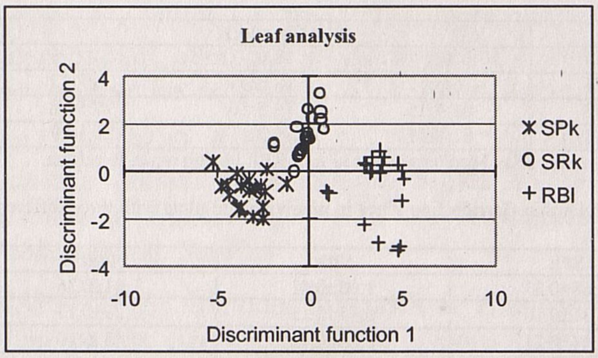

Figure 1. Plot of Discriminant Functions obtained considering the soil as variation factor and those significant different variables when ANOVA was applied to leaf analysis. Samples grouped together according to the type of soil.

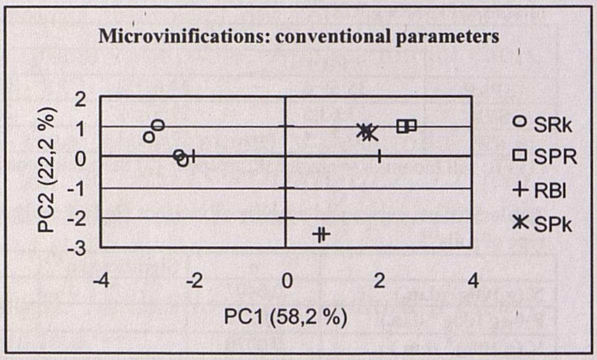

Figure 3. Two-dimensional plot of the two first principal components obtained when conventional parameters of the wines were used on the PCA, showing a separation among them according to the type of soil.

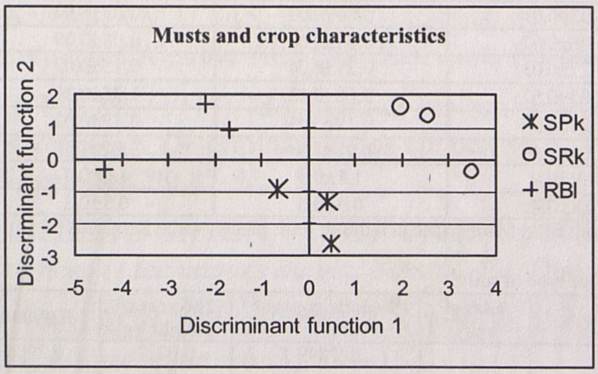

Figure 2. Plot of Discriminant Functions obtained considering the soil as variation factor and those significant different variables when ANOVA was applied to must analysis. Samples grouped according to the type of soil

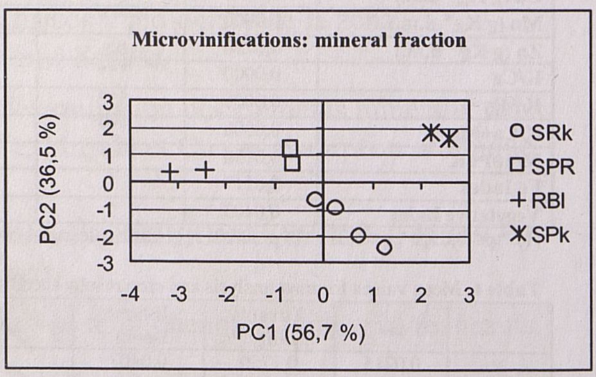

Figure 4. Two-dimensional plot of the two first principal components obtained when mineral fraction of the wines were used on the PCA, showing a separation among them according to the type of soil.