Spatial variability of the nutrient distribution in Jerez vineyard soils (Spain).

La variabilité spatiale de la distribution des éléments nutritifs des sols des vignobles à Jerez (Espagne).

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Abstract

From a fertility standpoint, the vine has to extract from the soil mineral substances necessary for its existence. However, the amount of certain available nutrients does not always correspond to a proportional increase in quality. Such is the case with nitrogen and organic matter and is in contrast to that of P and K, whose presence has a positive relation to quality. Most of the vintage wines come from vineyards located on calcium-rich soils, which have a complex effect on their quality. It is therefore necessary to characterize the soil for fertilizer practices in an objective way. The production area of Jerez has a notable environmental variability due to the landscape morphology (hills and plains), soil characteristics and the climate conditions due to its oceanic proximity. To assess the fertility of the soils of different vineyards and detect potential imbalances that may impede the growth of the vine and affect its production, a study has been made of distribution parameters such as O.M., P, K, Ca and Fe available in three plots representing the area of Jerez (Cadiz, Spain).The results have shown that OM and Fe presented a greater homogeneity in their concentration for the entire sample area with variances ranging between 0.09 and 0.82, and between 36 and 90, respectively. For the other nutrients analyzed, the variation between different points within the controlled sample plots was very important, noting interval concentrations of 5900 to 12480 ppm for Ca, from 8 to 158 ppm for P and 342 to 1698 ppm for K. The differences observed in the surface horizon remained in the deeper layers.

Key words: soil fertility, spatial variability, vineyard, potassium content, phosphorus content

Introduction

To maintain its fertility, the vine has to extract the mineral substances from the soil that are necessary for its existence. In an area like that of Jerez (Cádiz), with approximately 10,200 Has of surface, in which there is a large amount of vineyards, it is of interest to establish the possible classification of soils in related groups, in order to predict their response to fertilization. The physicochemical characteristics of the soil should be known by the farmer since crop growth and development is in direct relation to the nutrients and the soil characteristics. Crop yields are affected by different factors, among which the availability in the soil of essential nutrients for the plant is an important need (Nissan and Wander, 2003).
As mentioned above, the vine has to extract vital minerals from the soil necessary for its survival. However, the amounts of some of the available nutrients do not always lead to a proportional increase in quality. This occurs with nitrogen and organic matter, in which, although their high levels give abundant harvests, these are poor in quality. Soil structure and nutrient content affect the vigour and growth of the vine.

The beginning of the 1990's saw the start of the development of technologies and principles for managing the spatial and temporal variability associated with some aspects of agricultural production, to improve yields and to preserve the quality of the environment (Pierce and Nowak, 1999).

Variability should be known and be of a sufficient magnitude for a management differentiated by sites to result in being beneficial compared to uniform management. Crop yield varies spatially (Ferguson et al., 1995), and determining when and where the variations in the soil properties cause variations in the yield is the challenge faced by precision agriculture (Mulla and Schepers, 1997).

The objective of this work, which is part of a more extensive study, was to establish the natural chemical conditions of the soil and to detect possible zonifications through a process of comparing the biophysical qualities of each natural unit identified, in order to establish management and fertility criteria in three areas of the district of Jerez (Cádiz).

Material and methods

The Production Area of the Designations of Origin Jerez, Manzanilla and Vinegar of Jerez (that commonly known as "Marco de Jerez") extends throughout eight municipalities of the province of Cádiz and one in the province of Seville (Figure 1). It is, thus, a location of a marked southern nature, in the extreme south of the Iberian Peninsula, which, therefore, has very well defined weather characteristics: a high insolation level (over 300 days per year of sunshine), very mild winters, and hot summers; important rainfall (over 620 litres per m^2 annually) and two dominant winds the warm "levante" and the gentle, humid "poniente" – which together ensure an acceptable ripening of the grape and act as a moderating factor in the high summer temperatures.

Figure 1 Localization of the area.

The soil is of a sedimentary origin and characteristic of the so-called "*albariza*" lands, with a high proportion of lime of an organic origin. These are organic, white, spongy loams with a great water-retention capacity and which, on drying up, form a very hard surface layer which prevents transpiration but permits the use of the water for the plants.

In a wine-growing area as important as that of Jerez, in which efforts are being made to improve quality and to adjust fertilization management in order to optimize yields, to do so, a possible zonification of the vineyards is being sought, and, for that purpose, 3 plots from the vineyards in Chiclana, Jerez and Sanlucar were allocated.

To identify the sampling areas, aspects like change in appearance and in production, alterations in their topography,different slope degrees, erosion, drainage, soil colour, and agricultural treatments in the last few years were taken into account. Small areas which greatly differed from the rest of the field were discarded.

At the beginning of the study, a soil sample was taken from the farm estates collaborating in the assay, which served to evaluate its physicochemical characteristics. As fertility indicators in this work, levels of the following elements were established: Organic Matter (OM), phosphorus (P), potassium (K), calcium (Ca) and Iron (Fe) available in these soils, Comparisons were also made between the mean levels of the different experimentation plots, between the levels present in each horizon within the same plo; and, inside the plots, the distribution of the levels of nutrients were studied to determine their uniformity and establish possible precision fertilization techniques.

With the information collected, and depending on the plot surface, a series of subplots will be established in it, with 5m x 4m rows of vines, on which controls will be made throughout the

development of the project. In the future, they will be correlated with yield characteristics, nutrient levels in leaves and the quality of the wines.
Depth refers to the thickness of the soil which can be explored by the plant's roots. It acquires great importance in areas in which high temperatures coincide with the resulting evaporation, and there are few precipitations at the moments when the vine is experiencing a high biological intensity. Like in most winegrowing areas in Spain, this occurs at the end of spring and summer. Under these conditions, the plant must seek deep down the moisture which is indispensable for its survival and the formation of its fruit. "Albariza" soils are fairly deep and the plant's roots are mainly located at a depth of 60 cms, which is where the plant is placed. In our case, and since these soils are tilled, samples from two depths were taken, the first at 0 to 20 cm, which is the area reached by the tilling implements, and the other at 20 to 40 cm, where it is estimated that the root system covers its largest volume.

Results and discussion

Table 1 shows the mean, maximum and minimum values and the coefficient of variation of the different study parameters. Significant differences can be seen in the levels of some elements between plots, even between horizons of one same plot (Table 2), in the cases of O.M., P. and Fe, and between the points of one same horizon inside the plots (Fig. 2).
It can be observed that for the elements used as indicators, all the plots show acceptable levels for a quality production. The content in OM of the Jerez plot was significantly lower with respect to the others, and it is inside the limits of what could be considered a low content of OM according to Hidalgo (2002). In the case of available P and K, the levels were found to be within the optimal range.
A comparison of means permitted us to establish the similarity between the conditions present in each plot, and the coefficient of variation provided information on the variability in the measurements inside the plots. Thus, it can be observed how P in Sanlucar presented the greatest variation inside the plot, and that K had a similar distribution in the 3 localities, although in the case of Chiclana the mean values were significantly higher than the others. The Ca levels were high, which is normal within the characteristics of the soil in the area, and its CV was similar in all the localities.
Phosphorus and potassium are elements which positively affect quality, proportionally to their presence. Calcium in its form of active lime exerts a notorious and complex influence on quality. Most of the great vintage wines come from vineyards planted on soils well endowed with this element.
In general, the greater variability in the concentration of the different parameters considered in the study was noted in the Sanlucar area, with the exception of Fe, whose coefficient of variation was similar in the three locations.

Site		**OM**		**P**		**K**		**Ca**		**Fe**	
		(%)		---------------------- ppm				------------------------			
Sanlucar	Mean	2.0	**a**	53	**a**	416	**b**	7704	**b**	31	**a**
	CV (%)	46		79		55		22		32	
	Minimum	0.7		8		174		5900		21	
	Maximum	3.5		158		900		12480		63	
Chiclana	Mean	1,9	**a**	31	**a**	611	**a**	7574	**b**	14	**b**
	CV (%)	36		32		48		8		43	
	Minimum	1.1		13		342		6264		5	
	Maximum	3.6		55		1698		8560		25	
Jerez	Mean	0.9	**b**	17	**b**	267	**b**	8602	**a**	56	**a**
	CV (%)	36		47		44		13		34	
	Minimum	0.1		8		162		6840		28	
	Maximum	1.5		41		612		12040		87	

Table 1 Exploratory analysis of the data.

With the means data of the nutrient availability in the plots, a classification could be established *a priori*, in which the Sanlucar and Chiclana plots can be considered as being “statistically” equal with respect to OM, P and Ca levels; with respect to K management, the Sanlucar and Jerez plots can be placed in one same group; and as for the Fe management, Chiclana and Jerez are considered to be equal.

Site	Depth (cm)	OM (%)		P		K	Ca		Fe	
				ppm						
Sanlucar	0-20	1.5	**b**	31	**b**	340	8924	**a**	33	
	20-40	2.5	**a**	74	**a**	491	6484	**b**	30	
Chiclana	0-20	1.8		27		660	7638		18	**a**
	20-40	2		34		561	7509		10	**b**
Jerez	0-20	1.1		20		362	9768		46	**a**
	20-40	1.2		20		447	9666		21	**b**

Table 2 Levels of means and comparison between each plot’s soil horizon.

In Table 2, showing inside each plot, it is of interest to note the differences in the P levels in Sanlucar plot (Figure 2), with significant differences of more than 35 ppm and 2000 ppm in the case of Ca, for the different depths examined.

Another factor clearly influencing the development of the vine was the iron content of the soils where it is planted. An excess of iron may originate wines with a tendency to oxidate as iron acts as a catalyser, but a shortage of this mineral, or its final blockage in highly limed lands, causes ferric chlorosis with a loss of the chlorophyllic synthesis function of the leaves. In the case of Fe content in Jerez, differences reaching 50% in the contents were seen between soil horizons (Fig. 3).

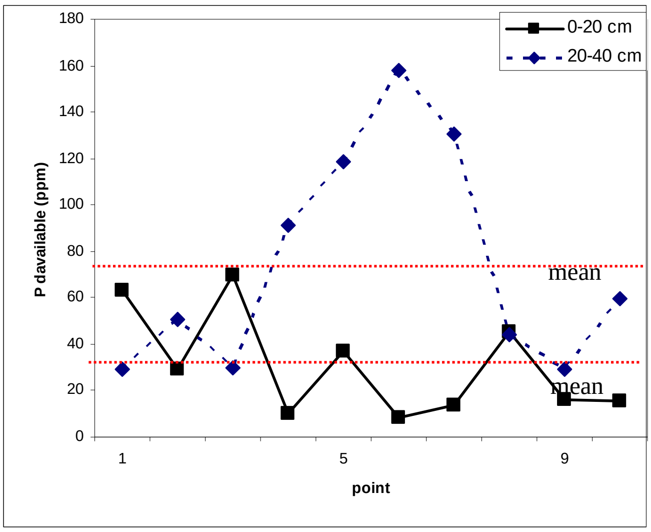

Figure 2 Available P distribution and mean in Sanlucar location.

Figures 2 and 3 show the distribution of the P and Fe levels in the two horizons, and their mean values, and they demonstrate the variability in the sampling per point and depth.

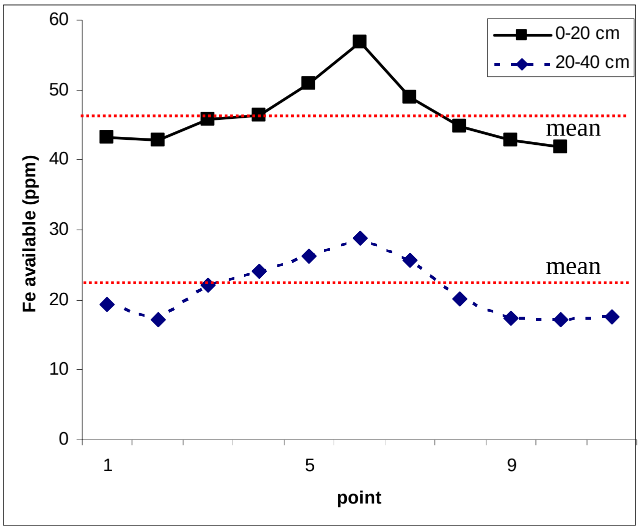

Figure 3 Fe distribution and mean in Jerez location.

With respect to the differences appearing in the plots, the differences in the Chiclana location were significant for the organic matter levels. Through ordinary kriging and the interpolation of non sampled points, an image of the spatial distribution of OM was obtained in this plot.Although the distribution of the OM content, and the difference in its levels can be noted, in no case can these levels negatively affect the yield.

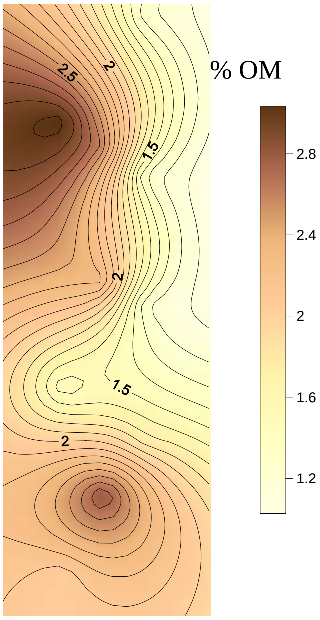

Figure 4 Spatial distribution of the mean levels of OM (%) in the Chiclana plot.

Conclusions

The variability present in the soil in the Jerez district allows to justify the differences observed in its production and to seek adjustments in fertilization management in accordance with plant needs and nutrient availability in the soil.

Calcium was the element most uniformly distributed in the plots due to the origin of these soils.

Phosphorus and potassium were the nutrients with the greatest irregularity in their spatial distribution, with values of between 8 and 158 ppm in Sanlucar for P, and of between 342 and 1698 for K content in the soil of Chiclana.

Bibliography

FERGUSON, R. B., C.A.GOTWAY, G.W. HERGERT and, T.A.PETERSON. 1996. *Precision Agriculture. ASA*, CSSA, SSSA. p.13-22.

HIDALGO, L. 2002. Tratado de viticultura general.3ª edición. Mundiprensa.

MULLA, D. J. and J. S. SCHEPERS.1997. The State of Site Specific management for Agriculture. ASA, CSSA, SSSA. p.1-18.

NISSAN, TM and WANDER, MM., 2.003. Management and soil quality effects on fertilizer-use efficiency and leaching. *Soil Sci. Am.*, **67**: 1524-1532.

PIERCE F. J., and P. NOWAK. 1999. Advance in Agronomy. 67.Academic Press. p 1- 85

SPARKS, DL., 1996. Methods of soil analysis. Part Chemical methods. 3ªed. SSSA book series nº5. *Soil Sci. Soc. Am.*