SOIL FUNCTIONAL CHARACTERISTICS FOR QUALITATIVE SANGIOVESE WINE PRODUCTION IN TUSCANY (ITALY).

RECHERCHE DES CARACTERISTIQUES FONCTIONNELLES DU SOL IMPLIQUEES DANS LA PRODUCTION DE VIN DE QUALITÉ. EXEMPLE DU CEPAGE SANGIOVESE EN TOSCANE (ITALIE)

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Mots-clés: sol, caractéristiques fonctionnelles, Sangiovese, zonage, Italie.

ABSTRACT

The aim of this work is to summarize the results of several years of research work carried out in Central Italy, concerning soil functional characteristics for qualitative wine production. The reference variety was the Sangiovese vine. A set of 65 experimental plots were utilized during a time span varying from two to five years. Yield components, as well as phenological phases, were recorded. The main chemical characteristics of the grapes from each experimental plot were analyzed at vintage and grape samples were processed using the standard techniques for small-lot wine making. A relationship was established between enological and phenological results. An evaluation of the performance of each experimental vineyard, for every year of trial, was made, and a classification of the plots in terms of matching the optimal phenology was obtained. A matching table considering soil functional parameters and their interaction against site performance classes was finally built up, the final aim being the zoning of wine territories. A selection of all the soil qualities studied was made in order to take into account those which proved to be more important and, at the same time, which it was possible to routinely survey, i.e. available water capacity, aggregate stability, degree of structure, class of internal drainage, presence of a water table, electrical conductivity, vertic properties, rooting depth.

RESUME

Le but de ce travail est de faire une synthèse des résultats de plusieurs années de recherche en Italie centrale, sur les caractéristiques fonctionnelles du sol pour la production de vin de qualité. Le cépage de référence est le Sangiovese. Un dispositif de 65 parcelles expérimentales a été utilisé pendant une période de 2 à 5 ans. Les paramètres étudiés sont les stades phénologiques, le rendement par pied, le nombre de grappes, le poids moyen des grappes, le taux d'accumulation des sucres dans les baies, en relation avec le débourrement végétatif, la floraison et la véraison. Les résultats œnologiques ont été mis en relation avec les stades phénologiques pour obtenir une grille de valeurs de référence pour chacun des principaux paramètres agronomiques considérés.

La comparaison des valeurs récoltées sur les parcelles avec la grille permet d'évaluer les performances de chaque vignoble expérimental, pour chaque année d'essai ; il est possible ensuite d'établir une classification des parcelles expérimentales par rapport à l'état phénologique optimal.

Une table de correspondances entre les caractéristiques fonctionnelles du sol et les performances du site permet de prédire la qualité viticole d'un terroir. Le réservoir utilisable maximal, la stabilité structurale, la classe de drainage interne, la présence d'une nappe, la conductivité électrique et les propriétés vertiques, s'avèrent être les plus importantes caractéristiques du sol pour la production de vin de qualité. Ces caractéristiques pourraient faire l'objet d'un suivi de routine.

INTRODUCTION

In Europe there is a tendency to delegate most of the authority concerning agricultural matters to Regional and Provincial administrations. This is especially the case where land planning and expenditure policy are concerned. As regards vineyards for wine production, European regulation limits the diffusion of new plantations, obliging local policy makers therefore to plan the concession for new vineyards. A request which is often made to agronomists and soil scientists is to provide elements to assess the suitability of their competence territory in terms of wine quality, rather than quantity. As they are not interested in drawing conclusions for individual agricultural properties, but rather in assessing the probability of finding soils, within different areas, which are suitable for vine cultivation, the evaluation has to be made at the reconnaissance scale.

A possible solution is to define a set of soil characteristics and qualities, which can be routinely surveyed at the reconnaissance level and are particularly important in determining the crop phenology. In fact, research studies have established that the enological result of the plant corresponds to a specific plant growth and ripening model, which is determined by agricultural practices, climate and soil conditions. The rationale is based upon the observation that environmental factors influence the hormonal equilibrium of each variety, which in turn regulates the expression of the genotype (VAN LEEUWEN and SEGUIN, 1997; COSTANTINI, 1998). The Sangiovese vine, for instance, in the most fertile soils, i.e. those lacking permanent limitations, gives bad viticultural and enological results, due to excessive productivity. On the other hand, better results can be obtained in fairly fertile soils, but with some pedological limitations which induce moderate stress. The least fertile soils, e.g. those which have been severely eroded, always produce less than the better preserved ones, but they give very variable enological results, depending on the year. Therefore, in order to assess soil suitability, each site can be evaluated according to the differences between the actual soil conditions and the ones which correspond to those producing the phenologic model which coincides with the desired enological result.

The aim of this work is to draw up a set of soil functional characteristics for qualitative wine production, which can be routinely surveyed at the reconnaissance level. The study summarizes the results of several years of research work in Tuscany, which is located in Central Italy, and was conducted on some of the most renowned wines in the world, i.e. the "Brunello di Montalcino", the "Chianti" and the "Nobile di Montepulciano". The reference variety was the Sangiovese vine, the basic constituent of those wines.

MATERIAL AND METHODS

Several trials were conducted in the Province of Siena (Central Italy) and used for the vine zoning at different scales (LULLI et al., 1989; COSTANTINI et al., 1996; COSTANTINI and SULLI, 2000). To assess soil suitability for the Sangiovese vine, in particular, a set of 65 experimental plots, sited on 39 farms, were utilized during a time span varying from two to five years (1994-1998 and 1999-2000). For the selection of the vineyards, vegetation and plant homogeneity, as well as age and proximity to meteorological stations, were taken into account. Planting density was of about 3,000/ha; training systems, canopy, number of buds per plant followed the normal agrotechniques of the area to limit grape productivity to within 8,000 kg per hectare. Phenological phases, quantitative and qualitative traits at vintage (yield per vine, bunch number, mean bunch weight, berry weight) as well as sugar content and accumulation rate in berries were recorded. The grapes of each experimental plot were analyzed at vintage for total soluble solids, titrable acidity, pH, malic and tartaric acidity, potassium, and polyphenols. Every year, in about forty vineyards, at ripeness, 50-kg samples of grapes were collected and processed using the standard techniques for small-lot wine making. Descriptor terms were defined after several tasting sessions, and the relevant terminology underwent normalization.

The climate of the area was studied and compared to vineyard performance (COSTANTINI *et al.,* 1996; EGGER *et al,* 1993).

To individuate soil functional parameters for quality wine production, we first of all established the target enological result. The target wine was characterized by an alcohol content of about 12.5°, high color intensity and hue, harmony of bouquet, and harmony and persistence of taste. Enological results were put into relationship with phenological and productive parameters, in particular, date of flowering, veraison and harvest, weight of grape for plant, berry and bunch weight, sugar content, titrable acidity, pH, polyphenols (CAMPOSTRINI *et al*., 1997). A set of them were found to influence the achievement of the desired enological result. A matching table was then worked out, where the selected parameters were classified into three classes of decreasing performance (P1, P2 and P3). On the basis of the matching table, an evaluation of each experimental vineyard, for every year of trial, was made. Thus, the average plot suitability for the Sangiovese vine was summarized into three classes as follows:

- Class 1: high and yearly constant performance (most years with P1 performance)
- Class 2: medium average performance, often year dependent, with some problems of excessive or over reduced vegetation activity of the plants (most years with variable performance)
- Class 3: low and yearly constant performance (most years with P3 performance).

A reconnaissance soil survey was carried out for the whole vine-growing area. In the selected fields, soils were studied in detail and described, sampled, analyzed and classified following the Soil Taxonomy up to soil series level (Soil Survey Staff, 1999). Besides field assessment of their hydrological quality (internal drainage and runoff, permeability, presence of a water table) monthly measurements of the actual soil moisture were obtained using the gravimetric method.

In addition to routine laboratory analyses (particle size, pH, carbonates, electrical conductivity, organic matter, cation exchange capacity), a set of physical and hydrological characteristics were measured: bulk density (core method), moisture content at different matric tensions (sand box and Richards pressure plate extractor), aggregate stability (wet sieving) and coefficient of linear extensibility (COLE) (COSTANTINI *et al.,* in press).

The soils of the experimental vineyards were compared with the vine phenological and productive parameters. Firstly the soil as a whole (the soil series) was taken into account, then any soil characteristic. The purpose was to select a set of characteristics as "functional", that is, determining crop behavior. Of all the studied soil characteristics and parameters, we chose those which proved to influence the vine performance and, at the same time, could be surveyed routinely at the reconnaissance scale.

RESULTS AND DISCUSSION

Climate and soils of the study area.

The long-term mean annual air temperature of the vine growing area was about 14.5 °C, with little differences of standard variation between months. The long-term mean annual rainfall was around 700 mm. Summer months had a predictable behavior, but spring and autumn months, especially September, were rather variable.

As regards soil classification, three Soil Taxonomy orders (entisols, inceptisols, alfisols) were found. The most frequent soils were Typic, Aquic and Vertic Haploxerept (Soil Survey Staff, 1999). The average characteristics and properties of the 65 experimental soils were as follows: clay 29.8 %, sand 36.3 %, gravel 12.3 %, available water capacity 115 mm, aggregate stability (MWD) 0.9 mm, organic carbon content 1.13 %, cation exchange capacity 15.2 cmol(+)/Kg, pH 8.1, total calcium carbonate content 15.2 %.

Sangiovese phenology and productivity functional factors

From all the parameters studied, we chose those which were best correlated with the target enological result and, at the same time, easy to be surveyed (tab. 1). They were: sugar accumulation rate between veraison and harvest, grapes/sarment weight (Ravaz index), weight of 100 berries, grape weight per meter of row, sugar and polyphenol contents (Di Stefano method).

The berry weight, in particular, was chosen when polyphenol content was not available. It proved, in fact, to be well correlated with the polyphenol content (fig. 1)

The achievement of good equilibrium between vegetation and yield could be checked through the ratio between weights of grapes and sarments produced every year (Ravaz index). For the Sangiovese vine, good equilibrium corresponded to values ranging between 4 and 6, but it could be higher, when grape yield was very limited, less than 4 kg per meter of row.

The berry sugar content and the daily sugar accumulation rate from the time of veraison to harvest greatly influenced evaluation. The target wine could be obtained when the sugar content of must was at least 21.9 °Brix and when the accumulation rate was larger than 0.31 °Brix by day.

Lower values of daily sugar accumulation, in particular, indicated conditions of sever stress during berry ripening, such as a pronounced lack of water after the veraison or an excess of water in proximity to the harvest.

Regarding the results obtained using the matching table, the average suitability for the Sangiovese vine of the experimental vineyards was Class 1 for 13 plots, Class 2 for 33 and Class 3 for the remaining 19 plots.

<u>*Soil functional factors*</u>

The winegrape production at vintage was strictly interactive with the different soil series (fig. 2). In particular, the yield per vine and the sugar content (°Brix) were significantly influenced. Also the veraison and vintage dates, and sugar accumulation rate in berries, underlined the importance of soil for a minimum sugar level of the Sangiovese grape, necessary to winemaking. Although some of the soil characteristics considered resulted significantly correlated with plot suitability class (i.e. organic matter, available water capacity, degree of structure, aggregate stability) and many of them with specific vine and wine parameters (e.g. organic matter with sugar content, fig. 3), none of them alone could give a high determination coefficient.

We therefore elaborated a matching table, which was able to classify soil characteristics regulating vineyard performance classes (tab. 2). The criterion was to distinguish those conditions that were either too limiting, or too fertile for Sangiovese vine. In particular, high available water capacity, good aggregate stability and strong degree of structure were found related to excessive fertility conditions and were taken into account so as to penalize soils with better structural conditions and water regime. But if a limiting condition was present, namely vertic properties or rooting limitation, then the suitability class was increased. On the other hand, severe limiting conditions, such as a very low available water capacity, or an excessive or poor internal drainage, were also considered a hindrance to the achievement of the target vineyard performance.

We furthermore took into account permanent water table depth and electrical conductivity; in fact, of the 281 vineyards surveyed when choosing the experimental fields, none stood on soils with a water table higher than 1.50 m, only 7 % of soils had an electrical conductivity between 1 and 2 dS/m, none of them more than 2 dS/m.

The results obtained when the matching table was applied to the 65 experimental vineyards were the following: 12 plots fell into suitability class S1, 35 plots into suitability class S2, 18 into suitability class S3, none of them fell in suitability class N.

The soil suitability classes of the experimental vineyards were compared to the classes of vineyard performance, by means of the Spearman non parametric statistical test, which indicated a significant correlation between the two classifications ($P<0.0001$), with a rather high correlation coefficient ($R^2=0.71$).

CONCLUSION

As already found in previous experiences (LULLI et al., 1989; COSTANTINI et al., 1996), a good part of the total experimental variance of the considered enological and productive parameters was explained by different soil series, but none of the soil characteristics and parameters could satisfactorily explain the average vineyard performance, if they were taken alone.

The only way to manage the interactions between soil characteristics and factors of vine phenology and production was to work out a simplified expert system, that is a matching table, which penalized excessive fertility, as well as too limiting soil conditions.

As expected, the average soil suitability for Sangiovese vine of the experimental vineyards was in most cases class 2, that is corresponding to a medium vine performance (P2), often year dependent, with some problems of excessive or over reduced vegetation activity of the plants. This result underlines that in Central Tuscany the enological result can widely vary according to the interaction between the soil characteristics and the meteorology of the year, and that thorough vineyard husbandry is needed to regulate vine phenology in function of the desired optimal model.

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Tab.1 – Matching table used to evaluate the Sangiovese performance in each experimental vineyard every year.

	Performance class		
Parameters	P1	P2	P3
Mean weight of 100 berries (g)	< 150 or > 150 if polyphenols > 1600	150 – 190 or > 190 if polyphenols > 1300	> 190
Ravaz index	4-6 or > 6 if grape kg/m < 4	< 4, >6	< 4, > 6
Polyphenols (Di Stefano method, ppm of + catechins)	> 1600	1600 - 1300	< 1300
Sugar content at harvest (°Brix)	> 21,9	21,9 - 20	< 20
Daily rate of sugar accumulation (veraison-harvest) (°Brix)	> 0.31	0.31 - 0.28	< 0.28

Tab. 2 – Matching table for the evaluation of suitability classes of soil properties for Sangiovese wine

	Suitability class			
Soil property	S1	S2	S3	N
Permanent water table depth (m)	>1.5	>1.5	>1.5	<1.5
Electric conductivity dS/m (up to 0.8 m)	<1	1-2	>2-4	>4
Available water capacity (mm/0.8 m or to a root-restricting layer)	75-119 or 120 –140 if vertic properties	50-75 or 120-140 or >140 if vertic properties	20-49 or >140	<20
Internal drainage	Moderately well or somewhat poorly drained	Well or somewhat excessively drained	Excessively or poorly drained	Very poorly drained
Structural stability (MWD, mm)	<0.9 or >0.9 if vertic properties	0.9-1.8 or >1.8 if root-restricting depth ≤0.5 m	>1,8	
Degree of structure	not strong or strong if vertic properties	strong in at least one horizon in the first 0.8 m or root-restricting depth ≤0.5 m	strong in more horizons of the first 0.8 m	

Fig.1 – Relationship between polyphenols and average berry weight in Sangiovese vine

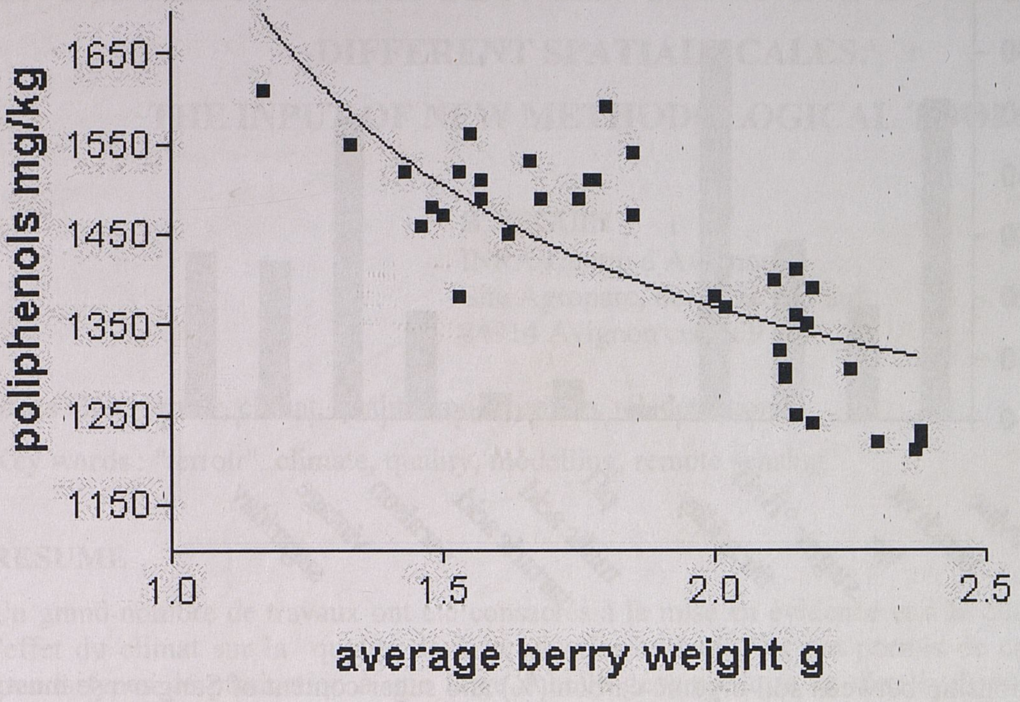

Fig. 2 – Percentage of the variance explained by the soil series effect on Sangiovese vine

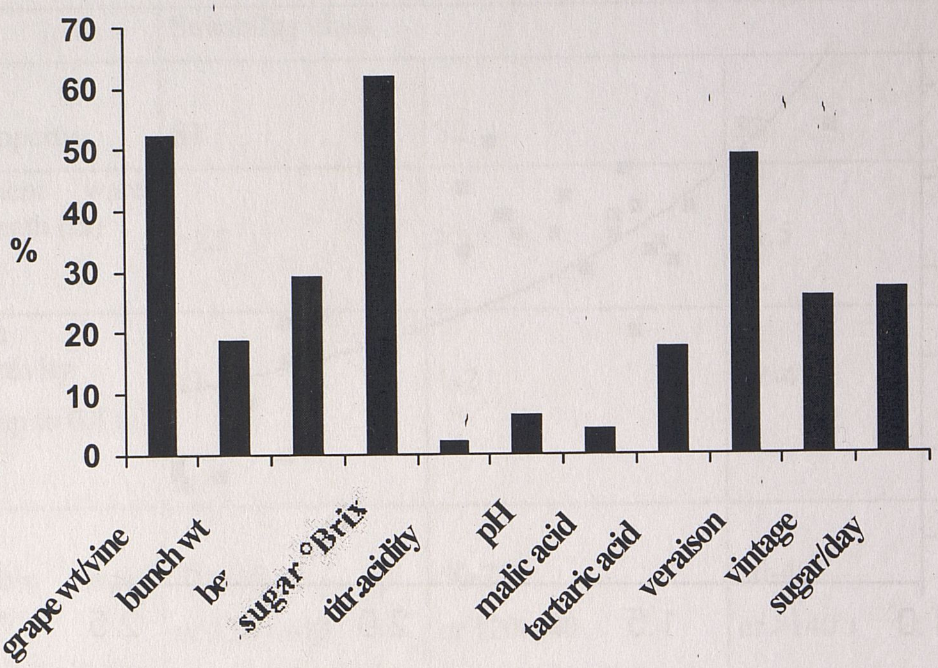

Fig. 3 – Relationship between soil organic carbon (%) and sugar content of Sangiovese must.