

SOIL AND CLIMATE FUNCTIONAL CHARACTERS FOR GRAPE RIPENING AND WINE QUALITY OF "VINO NOBILE DI MONTEPULCIANO"

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Abstract

The paper presents the results obtained from a methodological interdisciplinary study realised with the aim of setting the viticultural vocation of the "Vino Nobile di Montepulciano" territory and zoning the vineyards. The study provided for climate monitoring, soil biological, physical, chemical, hydrological characterisation, as well as soil survey and cartography. Moreover, a large set of winegrape characteristics was measured during the vegetation of vines and at the harvest. Finally, the wines obtained by the standard techniques for small-lot winemaking winery, have been sensory analysed.

The trial showed the importance of environmental characteristics to define the quantitative answer of the winegrapes, in particular it specified the fertility conditions of different lots and the relative oenological answer of the wines. So, the most fertile soils, those lacking permanent limitations to crop cultivation, owing to excessive productivity, provided the worst viticultural and oenological results. On the other hand, the best results could be obtained in quite fertile soils, but with some pedological limitations. The least fertile soils, those which have been more or less eroded, produced always less than the better preserved ones, but with very variable oenological results according to the influence of the year.

Key words: territory, climate, soil, grape and wine characteristics, zoning.

1. Introduction

In this last ten year period, there has been many integrated and interdisciplinary studies to determine the aptitude of different zones to viticulture (Lulli et al., 1989; Costantini, 1992; Fregoni et al., 1992). The researches examined the different impact of environment characteristics (soil, climate), ecology, vineyard management, vine genetic, winemaking and sensory analysis. The interaction of all of these factors produced the assessment about the environmental aptitude (Scienza et al., 1992). By means of this methodology, the "viticultural vocation" joined the word "zoning", that is the territory parting for its ecopedological and geographical characteristics in relation to adaptive answer of winegrape (Morlat, 1989).

2. Material and methods

The study was carried out during the four years 1989-1993 in the classic wine territory of *Vino Nobile di Montepulciano* (Siena, Italy) using the red variety "Prugnolo gentile", the most important winegrape of local production.

The soil survey was made in two times: at first 54 experimental, not irrigated vineyards homogeneous in soil, were selected (9 soils per 6 replications) to perform the viticultural trials; secondly a soil map of the Montepulciano hill on the scale of 1:25.000, was prepared, as a tool of controlling soil variability of the whole territory. The surveyed soils were evaluated physically, chemically, and hydrologically (Costantini). Microbial activities (soil respiration, soil microbial biomass and some ecophysiological indices) were also analysed in five selected soils (Anderson et al., 1986, Anderson et al., 1990, Jenkinson et al., 1981), moreover, soil temperature and humidity at two depths and every two month, during two years (Arcara and Cherubini) were measured. During this study, temperature and rainfall were monitored with 5 meteorological stations sited inside the study area and representative of all the vine-cultivation zones (Storchi and Pierucci).

Quantitative traits at vintage (yield per vine, cluster number, mean cluster weight) and the sugar accumulation rate in berries in relation to budding, flowering and véraison were recorded. Vineyards had a plant density of about 3000/ha and were trained following the normal agrotechniques of the area to limit grape productivity into 8000 Kg per hectare (*appellation of Vino Nobile di Montepulciano* limit). The grapes of each experimental plot were analysed at vintage for total soluble solids, titrable acidity, pH, malic and tartaric acidity, potassium. At ripeness 50-kg samples of grapes were collected and processed by the standard techniques for small-lot wine making used at the experimental winery of the Istituto Agrario at S. Michele all'Adige. Descriptor terms were defined after several taste sessions, and the relevant terminology underwent normalisation. All data were standardised by judges to avoid the difficulty of elaborating data obtained from the use different sales. The wines were submitted to a principal component analysis and a cluster analysis (Campostrini).

3. Results

Soils were different in terms of genesis and functional characters. Among the latter, available water capacity and air capacity distinguished soils different in degree of erosion, texture, and firmness of the subsurface horizon (tab. 1). The hydrological behaviour of the soils could be grouped as follow: soils without water and oxygen stress during the whole vegetative activity of the vines (fig. 1), soils with more or less pronounced summer water deficit (fig. 2), soils with summer water failure and spring oxygen deficit (fig. 3). Cation exchange capacity, extract conductivity, total and active lime of the studied soils were also different.

The estimates of some ecophysiological indices as microbial carbon to organic carbon ratio and specific biomass respiration outlined also different conditions of biological equilibrium between soils (fig. 4,5, and 6).

The climatic recorded data allowed to share the territory in three homogeneous areas owing the temperature, while the rainfalls did not show significative differences. The mean rainfalls amount of the studied years was lower than the long term (1926-1992: 670 vs. 728 mm). Also the year average temperature remained lower than the long term one (1928-1992: 12.9 vs. 13.9°C).

The Duncan's multiple range test on the productive data of the three areas (tab. 2) showed significant differences among some of them. At almost similar sugar levels at vintage, the Capezzine subarea needed 4 more days to reach the harvest sugar level. This area had the lowest maximum temperature in the 2 months before harvest (27.4 vs. 28.8°C).

The analysis of variance between the two subareas having the same soils is presented in table 3. The subarea factor is highly significant in determining the production per plant, while the soil factor is very important for some quantitative variables (cluster weight) and analytical variables (titratable acidity and pH of the must). Other statistical analysis (not reported in table) showed that the budding was strictly correlated with the maximum temperature of the previous month, while the flowering was influenced by the rain of April and May. The harvest time was strictly correlated with the flowering.

Soils control large differences on yield components (tab. 4). The average yield varied from 7.34 kg/vine for Valiano soils (V) to 2.70 and 2.61 kg/vine for Monte (CE) and Cusona (CU) soils. Yield differences were due to a combination of cluster number and cluster weight. In fact, the cluster number ranged from 18.2 for Valiano eroded soils (VE), to 12.0 for San Gimignano soils (G), while the cluster weight varied from 467.2 g for Valiano soils to 189.8 g for Poggio Golo soils (P). Differences in fruit ripening were lower than in yield components. Brix measurements differed, on average, only for 1.9°. The Valiano eroded soils showed the highest TSS value (21.9° Brix), while the Valiano ones the lowest (20.0° Brix). The titratable acidity ranged from 7.5 g/l for Quercia (C) soils to 8.7 g/l for San Gimignano soils.

Through the application of a statistical analysis, the wines were grouped in five groups (tab. 5). The wines obtained on the Valiano eroded, Cusona and Monte soils had a good structure, a good tipicity with high cherry and berry fruitiness. Unfortunately, the stability of wine sensorial profile during the years was low. A second soils group (Quercia, Poggio Golo and San Quirico) exhibited good structure, tipicity, with medium level of cherry and berry fruit and a good stability of wine sensorial profile. The wine obtained on the Strada soils showed medium structure, medium astringency, low cherry and berry fruitiness with a good stability of the sensorial profile. Finally, the wine of San Gimignano and Valiano soils had a low structure, low tipicity, high astringency with a good stability.

4. Discussion

This study demonstrated the importance of environmental characteristics to define the quantitative answer of the winegrapes, in particular of "Prugnolo gentile". The interdisciplinary approach allowed to identify the pedological and climatic functional characters that conditioned the physiological behaviour of the vines and the oenological quality of the wines, in particular it specified the fertility conditions of different lots.

Soils range in fertility conditions between very fertile soils, like the San Gimignano soils, providing the crop of water, oxygen and nutrients for the whole year, without causing any stress to the vines, to soils with severe permanent limitations to crop cultivation, like the Cusona ones, in which plants show the effect of restricted summer water supply. On the other hand, soils like those belonging to the San Quirico serie provide intermediate growing conditions, with some limitation due to an excess of water and an oxygen scarcity in early spring and a moderate water stress in summer, but with a fairly good microbial activity.

The winegrape production at vintage is strictly interactive with the different soils. In particular, the yield per vine, the mean cluster weight, the 100 berries' weight are deeply influenced. The number of shoots in the various soils is significantly different, because of the adaptation of pruning to the different water capacity of soils. Also the sugar accumulation rate in berries underlines the importance of the soil for a minimum sugar level of grape, necessary to winemaking as *Vino Nobile*. In fact, vineyards on Cusona soils do not reach the minimum sugar content every year, but only in the more rainy ones. On the other hand, grapes on San Gimignano and Poggio Golo soils reach the minimum sugar content only at late time.

Distinct soil groups show different wine organoleptic profiles. Good structure, typicality, high cherry and berry fruits' notes, are typical only of San Quirico, Poggio Golo, Quercia, Cusona, Monte and Valiano eroded soils, with a fairly harmony of the product. The last three soils, however, manifest high variability of oenological results between years. In any case, the natural resources knowledge of *Vino Nobile* di Montepulciano territory obtained from this research, beyond give indication for zoning, will permit to find a good vineyard's husbandry and to optimise the management practices for the best qualitative answer of *Vino Nobile* di Montepulciano.

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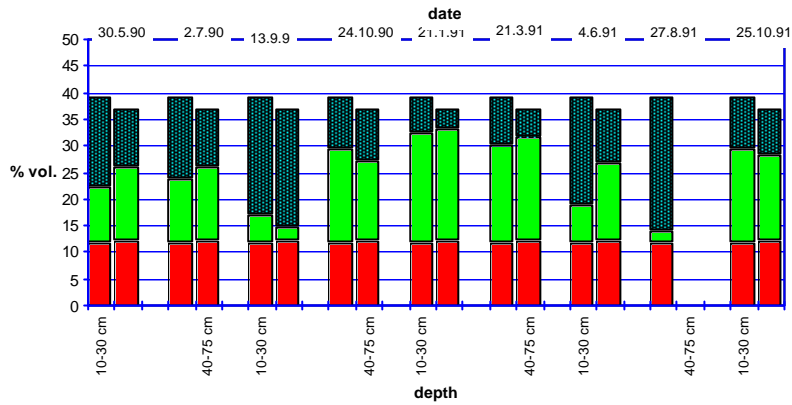


Figure 1 - Hydrological behavior of a San Gimignano soil: air (light gray), available (gray) and not available (dark gray) water at two depths during two years.

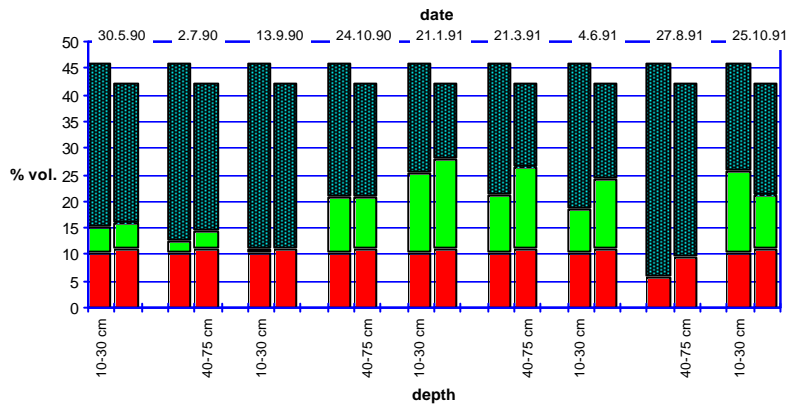


Figure 2 - Hydrological behavior of a Cusona soil: air (light gray), available (gray) and not available (dark gray) water at two depths during two years.

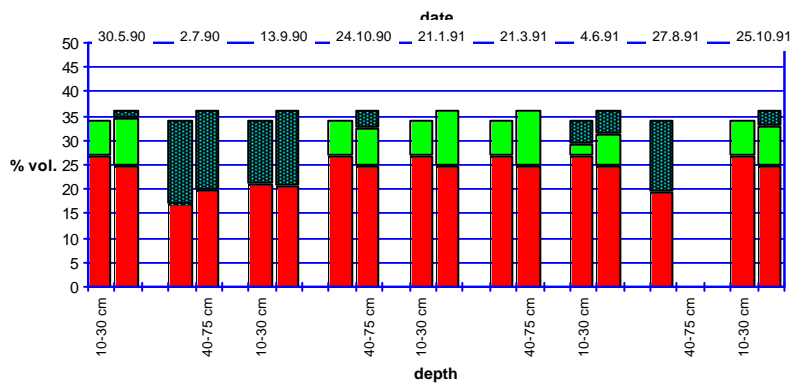


Figure 3 - Hydrological behavior of an eroded phase of a Quercia soil: air (light gray), available (gray) and not available (dark gray) water at two depths during two years.

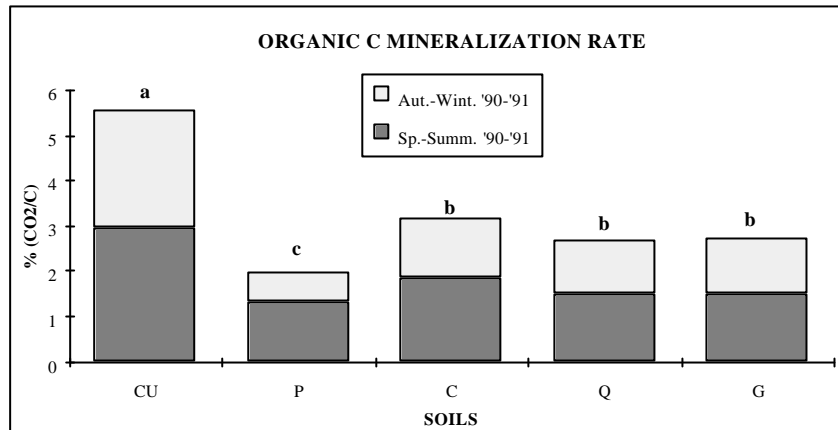


Fig. 4

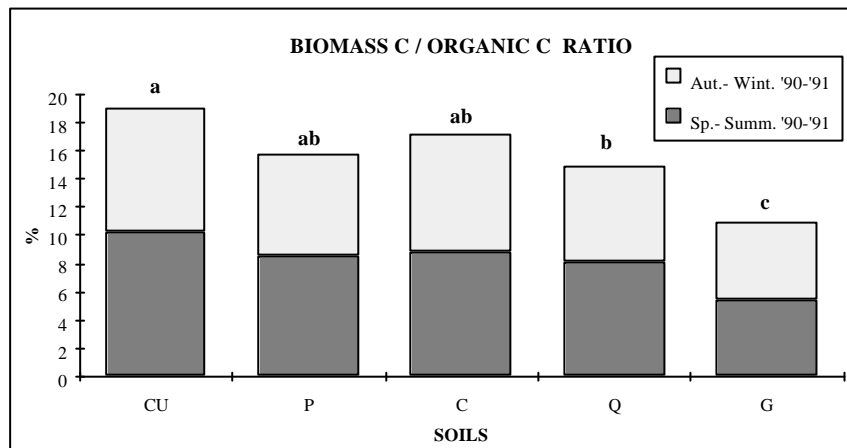


Fig. 5

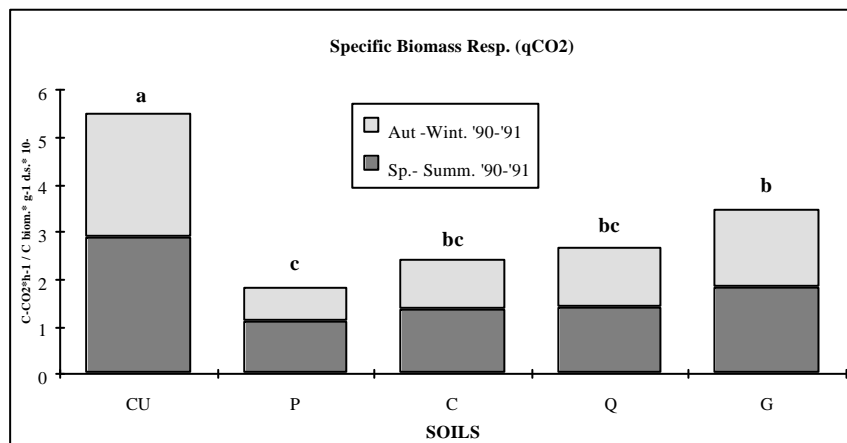


Fig. 6

Fig. 4, 5, 6 - Mean values of three ecophysiological indexes (carbon mineralization, fig.4; microbial and organic C ratio, fig.5; qCO₂, fig.6) at 10-30 cm depth in five examined soils (CU = Cusona, P = Poggio Golo, C = Quercia, Q = San Quirico, G = San Gimignano). Separated means are reported for the periods spring-summer and autumn-winter. Significant differences have been pointed out by different letters.

Table 1 - Main soil characteristics and classification. Values referred to the whole soil until the plantation plow layer; O.M. of the annual plow layer.

A.W.C. = Available Water Capacity; C.E.C. = Cation Exchange Capacity; O.M. = Organic Matter.

Soil serie	Classification (Soil Taxonomy, 1992)	Air capacity (%)	A. W. C. (mm)	C.E.C. (cmol+/1000g)	O.M. (%)	Total CaCO3 (%)	Active CaCO3 (%)	Electrical conductivity (dS/m)
Cusona	Typic Xeropsamment	16,2	83	17,5	1,5	10,9	1	100
Strada	Typic Xerochrept, coarse-loamy	10,9	157	9,5	1,1	10,7	1,1	117
San Gimignano	Typic Xerochrept, fine-loamy	10,6	195	10,5	0,8	16,9	2,2	133
San Quirico	Aquic Xerochrept, fine-silty	3,8	146	10,3	1,3	16,1	6,8	541
Quercia	Vertic Xerochrept, fine	3,0	165	11	1,4	20,8	7	453
Monte	Aquic Xerorthent, fine	1,4	75	21	1,4	18,9	9,7	941
Valiano	Typic Xerochrept, fine	9,7	169	21,1	1,8	10,4	3,1	172
Valiano eroded	Aquic Xerochrept, fine	5,5	142	16	1,4	9,7	2,9	287
Poggio Golo	Aquic Haploxeralf, fine	2,3	139	18	1,7	1,7	0,6	166

Table 2 - Effect of subareas on production (1989-1991). Means with the same letters are not significantly different (Duncan $p \leq 0.05$)

Variables	Abbadia	Capezzine	Montepulciano
harvest date	278.4 b	282.4 a	280.0 ab
sugar	20.4 a	20.7 a	21.0 a
titratable acidity	7.6 a	7.9 a	8.1 a
n. of shoots	14.0 b	20.2 a	13.3 b
n. of clusters	14.0 ab	17.9 a	11.9 b
production (kgs per plant)	4.6 b	6.3 a	3.5 b
average cluster weight	362.2 a	356.5 a	310.1 a
100 berries weight	192.6 a	194.1 a	180.9 a

Table 3 - Significance of variances for vegetative and productive variables in 2 sub-areas (Abbadia, Montepulciano) and 5 different soils (C; G; Q; S; CU) of Montepulciano territory (* $p \leq 0.05$; * * $p \leq 0.01$; n.s.=no significant difference)

Variables	Subarea	Soil	Interaction
harvest date	n.s.	n.s.	n.s.
sugar	n.s.	n.s.	n.s.
titratable acidity	n.s.	*	*
pH	n.s.	*	* *
n. of shoots	n.s.	* *	*
n. of clusters	n.s.	n.s.	*
production (kgs per plant)	n.s.	*	n.s.
average cluster weight	* *	* *	* *
100 berries weight	n.s.	* *	n.s.

Figure 7 - Evolution of sugar content in grapes of different soils during ripening (1989-1991) (CU = Cusona, P = Poggio Golo, C = Quercia, Q = San Quirico, G = San Gimignano)

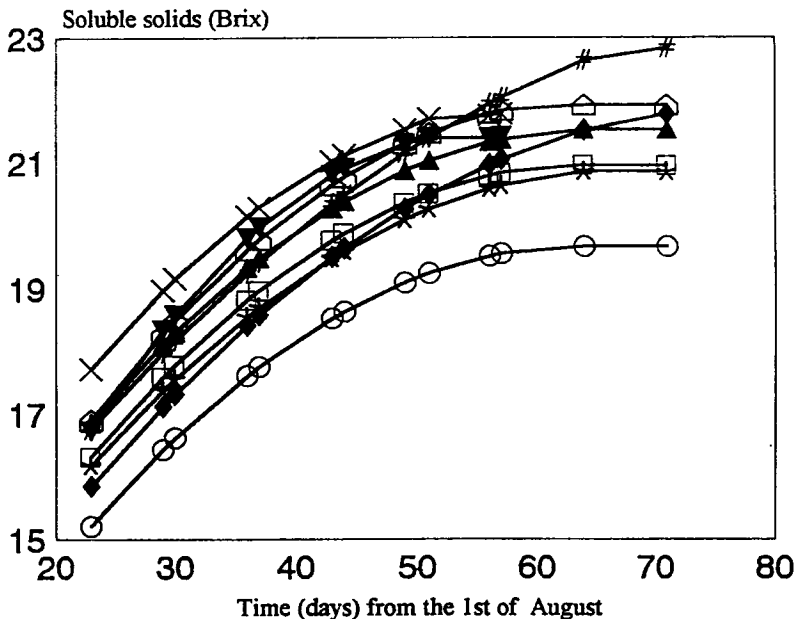
Table 4 - Effect of soils on some quanti-qualitative traits at vintage (mean 1989-1992). Means with the same letters are not significantly different (Duncan $p \leq 0.05$)

Soils	Cluster number	Yield/ plant (Kg)	100 berries weight (g)	cluster weight (g)	TSS (°Brix)
Quercia	12.1 b	3.95 bcd	180.8 c	336.1 bc	20.6 bcd
Monte	13.9 b	2.70 d	144.6 d	209.0 d	20.5 cd
San Gimignano	12.0 b	4.59 bc	223.1 a	405.8 ab	20.5 cd
Poggio Golo	15.1 ab	3.15 cd	187.7 bc	189.8 d	20.5 cd
San Quirico	12.3 b	3.96 bcd	174.3 c	340.8 bc	21.4 abc
Strada	13.3 b	4.33 bc	211.9 ab	336.6 bc	21.0 abcd
Cusona	12.2 b	2.61 d	186.5 bc	208.4 d	21.6 ab
Valiano	15.9 ab	7.34 a	214.9 bc	467.2 a	20.0 d
Valiano eroded	18.2 a	5.21 b	178.1 c	261.6 cd	21.9 a

Soils	pH	Titrateable acidity (g/l)	Malic acidity (g/l)	Tartaric acidity (g/l)	Potassium (g/l)
Quercia	3.21 abc	7.5 b	2.1 bc	7.5 ab	1.45 a
Monte	3.26 a	8.0 ab	2.4 bc	7.9 a	1.34 ab
San Gimignano	3.15 cd	8.7 a	3.2 a	7.1 ab	1.38 ab
Poggio Golo	3.13 d	7.7 b	2.0 c	7.2 ab	1.26 ab
San Quirico	3.16 cd	7.8 b	2.2 bc	7.1 ab	1.40 ab
Strada	3.12 d	7.6 b	2.2 bc	7.1 ab	1.25 b
Cusona	3.19 bcd	7.6 b	2.2 bc	6.8 b	1.39 ab
Valiano	3.24 ab	8.2 ab	2.9 ab	7.0 b	1.44 a
Valiano eroded	3.18 bcd	7.6 b	2.6 abc	7.2 ab	1.42 ab

Table 5 - Nobile di Montepulciano grape productivity and wine quality according to soils and relative constraint level

Soils	Constraint level	Grapes production	Harvest date	Wine structure	Wine typicity	Wine harmony	Year stability
San Quirico	moderate	***	****	**	**	**	**
Poggio Golo	moderate	**	**	**	**	**	**
Quercia	moderate	***	***	**	**	**	**
Monte and Cusona	severe	*	****	**	**	**	*
Valiano eroded	few	****	***	**	**	**	*
San Gimignano and Strad:	none	****	*	*	*	*	**
Valiano	none	*****	*	*	*	*	**



✱ CE ◆ C ▲ S ◻ CU ○ G ▼ Q ✱ P ◻ V # VE

Figure 7 - Evolution of sugar content in grapes of different soils during ripening (1989-1991) (CU = Cusona, P = Poggio Golo, C = Quercia, Q = San Quirico, G = San Geminiano).