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Natural and genetic resources

The Climate

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Climate represents one of the most important variables in the cultivation of the vine, able to impact, at times dramatically, the quality and quantity of obtainable production. It is an essential component for determining the use of the environment, and therefore explains the need for an in-depth understanding of the relationship between the various climatic factors and production characteristics.

To obtain the necessary climatic data, the estate has three monitoring stations, located at Santa Costanza, Madonnino and Centro Frutta. The following parameters are measured daily: minimum and maximum air temperature, precipitation and evapotranspiration (evaporimeter class A pan), heliophany, and wind. the information thus obtained can be practically used to help determine the ideal types of vines for the different environments and help select the cultivation techniques (for example, management of emergency irrigation and protective treatments). The monitoring stations identify the three principal productive areas of the estate: Santa Costanza, the hilly zone where planting began (end of '70s-mid '80s); Madonnino, which comprises the vineyards planted on the plain during the following decade; Centro Frutta, where the most recently planted vineyards can be found. In general, the entire area is characterized by a high rate of sun exposure and wind, factors which, combined with the thermo-pluviometric trend, help determine an evapotranspiration of some 5-8 mm/2- 3 inches per day during May-August from the soil-crop system, for all three zones.

Analysis of historical climatic information over several years reveals that minimum temperatures fall below 5° C/41°F from November to April, though rarely less than 0°C/32°F, and range from 10°C/50°F to 15°C/60°F from June to August. High temperatures range between 10°C/50°F and 15°C/60°F between December and February, while, starting in June, they rise above 25°C/77°F, sometimes reaching 33°C/91°F in August. In the vegetative-productive period (April-September) the average temperature is 19.5°C/67°F, which characterizes the area as temperate-warm. The mean temperature variation (difference between daytime highs and nocturnal lows) which is such an important factor in the correct ripening of the grape and color of the musts, is 16.2°C /61.2°F in July, 16.7°C/62.1°F in August and 14.4°C/57.9°F in September. However, the values vary from year to year, and can reach peaks of 19-20°C/66-68°F (August 2000, 2001, and 2004).

The data on rainfall shows an overall mean value of little more than 500 mm/19.7 inches per year of rain, with great variations from year to year. Of the last fourteen years, 1992 was particularly rainy (705 mm/27.8 inches), as was 1996 (691 mm/27.2 inches), while 1993 stood out for the paucity of rain (311 mm/12.2 inches) and was one of the most arid years ever recorded. During the year, maximum rainfall is concentrated in the period from September to November, when it is possible to refill water basins for emergency irrigation. On the other hand, from January to June, average rainfall is around 30 mm/1.2 inches per month, excluding April, since at times (e.g., 1998 and 2001), there have been abundant rainfalls during this month. Although the three areas of the estate fall under the same Beta zone (see "in depth analysis"), upon careful scrutiny they reveal different characteristics, producing a wide range of agro-climatic conditions. This diversity creates the rich palette of colors and aromas of Banfi's grapes. The different climate trends in the areas can be attributed to the particular exposure and placement of each monitoring station. The slopes' exposure and incline, which influence the incident angle of the sun's rays, modify the quantity of radiation that hits the soil. Thus, considering the sun's motion, during the day the warmer slope is the one with the southern exposure, followed by the one exposed to the west and then to the east, while the coldest slope obviously faces north.

As mentioned before, the station of Santa Costanza is located in a higher zone and thus is positively affected by the hotter air rising; on the contrary, the areas in the plains (Madonnino and Centro Frutta) are influenced by the masses of cold air flowing down towards the valley. For this reason, in the winter periods (above all from December to February) the minimum temperatures recorded in Santa Costanza are slightly higher than those in the other two stations. In springtime this same condition has a considerable influence on the risk of frosts, which occur, in fact, less frequently in the area of the Santa Costanza station.

In summer, however, temperatures recorded in the plains are slightly higher than those in the hilly regions because of the angle of incidence of the sun's rays, which allows for a higher transfer of heat per unit of surface and thus a more intense warming during the day, but a more marked nocturnal radiation. The two main sources of water are the rivers Ombrone and Orcia, which mostly influence the climate data registered at the Centro Frutta station, as they reduce the thermal variation between day and night.

As previously, noted, thermal variation is an important factor for the bioclimatic indices of Fregoni and glad stones (1992) (see "in depth analysis"); in fact, these indices become higher for the station of Madonnino, which is farther from these water sources.

recent studies of the of the soils around the Centro Frutta found that average temperatures during the ripening phase are 2-3°C/4-7°C higher than the rest of the estate (due to factors mentioned above), and lower mean rainfall. this called for the study of micro-irrigation techniques in order to optimize the conditions during the ripening phase and thus avoid water stress to the plants (see chapter on Irrigation).

Finally, it should be stressed that there are areas not covered by the existing monitoring stations (Cerralto, Sorrena and perella) because of the distance from the monitoring stations and the particular conformation of the landscape. There were intentions to monitor the climatic parameters of these areas as well. An analysis of the data for single years and for each monitored area reveals a certain degree of variability, above all in the monthly distribution of rainfall. Restricting the analysis to the last few years makes it possible to observe the following.

The Banfi Case

Banfi also attempted to evaluate the terroir determining the values taken from the indices of Winkler, Hughlin, Fregoni and gladstone based on the collected climatic data in the three stations of the Azienda: Santa Costanza (SC), Madonnino (Md) and Centro Frutta (CF), located, respectively, in the hilly area (SC), on the plain along the river Ombrone (Md) and alongside the river Orcia (CF).

The results, reported in tab. 2, highlight the variability of the climatic characteristics, which distinguish the three stations from each other. An in-depth analysis of the course of hughlin index during the crop cycle reveals that until around June the area dominated by the S. Costanza station reports lower values, but eventually it surpasses the other two areas.

Finally, when classifying Banfi's various areas according to their total hours of sun light and of the effective day degrees, the differences between the three "historical" areas of the estate stand out, especially in terms of the obtainable product's potential characteristics.

Index	Winkler	huglin	Fregoni*	gladstone	SFI
Station					
Centro Frutta	1923.5	2745.3	485.0	36.5	12.7
Madonnino	1842.5	2633.3	506.0	69.0	13.5
Santa Costanza	1966.5	2724.8	449.0	58.5	11.2

Tab. 3. Mean values in the ripening month of some parameters or the various climate survey stations

parameter	Centro Frutta	Madonnino	Santa Costanza
Mean temperature (°C)	22.9	22.7	22.6
Maximum temperature (°C)	35.0	35.0	35.0 rainfall
(mm)	113.0	116.0	154.0
Afternoon relative humidity (%)	54.9	69.8	52.9

Rainfall and wine quality

Most high-quality wines are produced in areas where the annual rainfall is below 700-800 mm, and it is well-known that a high water input diminishes quality. With abundant rainfall, the grape berries are likely to burst and become susceptible to Botrytis or other fungi, necessitating, in some cases, an early harvest. Furthermore, excessive rainfalls can slow ripening, above all in the alpha zone, preventing grapes from achieving full ripeness before the date of harvest, and thereby diminishing quality.

In terms of natural rainfall, Banfi is characterized by a sub-arid climate, as 700mm per annum have historically been reached only in exceptionally rainy years.

Light Intensity

The amount of photosynthetically active radiation (pAr) which reaches the grape bunches is about 2500 e m^{-2} s^{-1} without clouds and approximately 300-1000 on cloudy days. A pAr of 700 is the optimum for photosynthesis, while the point of light compensation (below which the leaves consume as many carbohydrates as they produce) is from 15 to 30. Greater radiation, both in intensity and duration, increases production and the soluble solids, besides obviously determining higher temperatures.

Wind

Wind can break the shoots and diminish their growth, reducing the size of the leaves and the stomatic density. Besides, it can have a cooling effect, reducing the stomatic conductivity and the rate of transpiration, thus lowering both photo- synthetic activity and obtainable soluble solids. During the period of development and ripening of the grape bunch, the concomitance of high light intensity and hot winds make Banfi's environment particularly susceptible to water stress, even though it improves grape health. The following table (tab. 3) reports the principal average parameters of the period from July 15th to September 15th, and overall, these data offer interesting points to reflect on.

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Soils and landscapes of the Castello Banfi estate

F. Lizio Bruno

Environmental Context

The paleo geographic evolution of the area of Montalcino, and the Castello Banfi estate in particular, is directly correlated to that of Tuscany. The Iano- Montagnola Senese-Monticiano-Roccastrada-M. Leoni ridge (Mid-Tuscan ridge) was a paleo geographical element with an extensive longitudinal development that conditioned the sedimentary evolution of the neoautoctonous basins in the upper Miocene. This mountain ridge separated two areas, one to the west and one to the east, in which the Miocene sedimentary evolution developed independently.

With the Pliocene-era marine transgression (rising of the sea level) in the basins west of the Mid-Tuscan ridge (but also in those to the east) another phase of sedimentation began. In this period, because of the higher sea level, the Mid-Tuscan ridge was no longer a significant element of separation between the two areas, though still a morphologically elevated formation.

The lower Pleistocene was the period of the sea's greatest extension in Tuscany, south of the river Arno: in this period, one could find lowlands with strong sedimentation and less depressed zones, which in part remained emerged. The lithological distribution (clays, sands, conglomerates and organic lime debris) is linked to the position, more or less distant in relation to the zones that remained higher (or more emerged over sea level). With the end of the lower Pliocene, the entire area began to rise, reaching its maximum height along two strips. The first goes from the mountains of Castellina through the mountains of Castelnuovo Val di Cecina, le Cornate di Gerfalco, il poggio di Montieri, up to the area of Boccheggiano. The second more southerly one is also located to the east of the region around Mount Amiata, going towards the region of Bracciano. This uplifting affected the future paleo geographic configuration of this area, determining a progressive narrowing of the areas occupied by the sea. During this uplifting trend, there is a rapid evolution of the basin of Radicofani from being a ditch during the lower Pliocene, it quickly became a risen area in the middle Pliocene, with a consequent retreat of the sea from the area and from the entire Val d'Orcia.

During the upper Pliocene – lower Pleistocene, a general regression (lowering and withdrawal of the sea level) occurred, with the development both of sedimentary and erosive processes; the retreat of the sea towards the west created fluvial and lacustral environments in which sedimentation is of mixed origin (i.e. corresponding to the water flow of the torrents and rivers, there are sediments with mixed origin in which fine and coarse sediments prevail, characterized by fine sands, silts, crushed stones and pebbles of various sizes). During the Pleistocene, Banfi's territory, in the areas around Madonnino and Pascena, is correlated to the fluvial system of the river Ombrone and its confluence with the river Orcia, which generated three orders of terraces: the first situated between 75 m/246 ft and 100 m/328 ft above sea level, the second around 50 m/164 ft above sea level, and the third around 25 m/82 ft above sea level.

The results of the erosive and sedimentary processes that start from the confluence of the Orcia into the river Ombrone and make their way to Castello Banfi can be found in the areas of Piano della Ricciardella, Casaccia and Madonnino.

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The Landscapes at Castello Banfi

The landscape of the Castello Banfi estate is, from a morphological-geo-lithological point of view, highly complex. It is a succession of varied soil types. From the fluvial and alluvial area set at 80-100 m/262-328 ft above sea level, it passes through a variety of physiographic forms before reaching the hilly landscape, with its 330 m/1082 ft above sea level, in the area of Tavernelle, characterized by sandy and sandy-calcareous soils with loose conglomerates of the mid Pliocene. The geology of the area surveyed is complex and distinguished by a prevalence of sediments form the marine Pliocene and the continental Pleistocene that, with their lithologies, conditioned the distribution of the soils. An analysis of the geographical maps reveals that at higher altitudes there are marine sediments, made up of sands and calcareous sands with loose psc conglomerates with the sandy parts from loose to diagenized, above all in depth. These sediments are in direct contact with clay and clayey-sandy sediments of the pa Pliocene typical of deep-sea sedimentation conditions: they are heterotypical with the ps marine sands, often coarsely loose or diagenized with conglomerate levels that characterize the base of the formation. The coarse deposits gradually become fine sands with some alternating areas of sandy silt and silt (Pascena-La Pieve-I Leccini etc.) that can be found locally above the coarse sands.

The deposits of the Pliocene rest stratigraphically above and are in contact with the polygenic conglomerates of a sandy-clay Mcg matrix that have only sporadically affected the vineyards. These deposits are often in contact (through faults) with the marls and the blue-grey Ma clays with levels of saline, sand and loose elements of puddingstones. In the past, the latter formations were tettonized and used by man for the development of linear slopes where vineyards were grown; thus their thickness was reduced and the subsoil, often pebbly and saline, appeared. In the area corresponding to Castello Banfi, the substratum that appears is of clear marly lime, UL marl-schist, which at times is more prevalent than the lithoide part. The structures above are in direct and erosive contact with the Pleistocene sediments found in the morphologically lower areas of the estate and are characterized by conglomerates that are loose or weakly-fused by a sandy-clayey, reddish-brown matrix and by very fine terraced sands. These sediments are in contact with alluvial sediments of the Orcia and Ombrone rivers, characterized by sandy silts, and rounded pebbles of a sandy matrix. The change towards alluvial sediments takes place through bounding surfaces with abundant loose pebbles and sporadic fused areas (La Casaccia) and colluviums with a clayey-sandy matrix and varying structure, which are often terraced.

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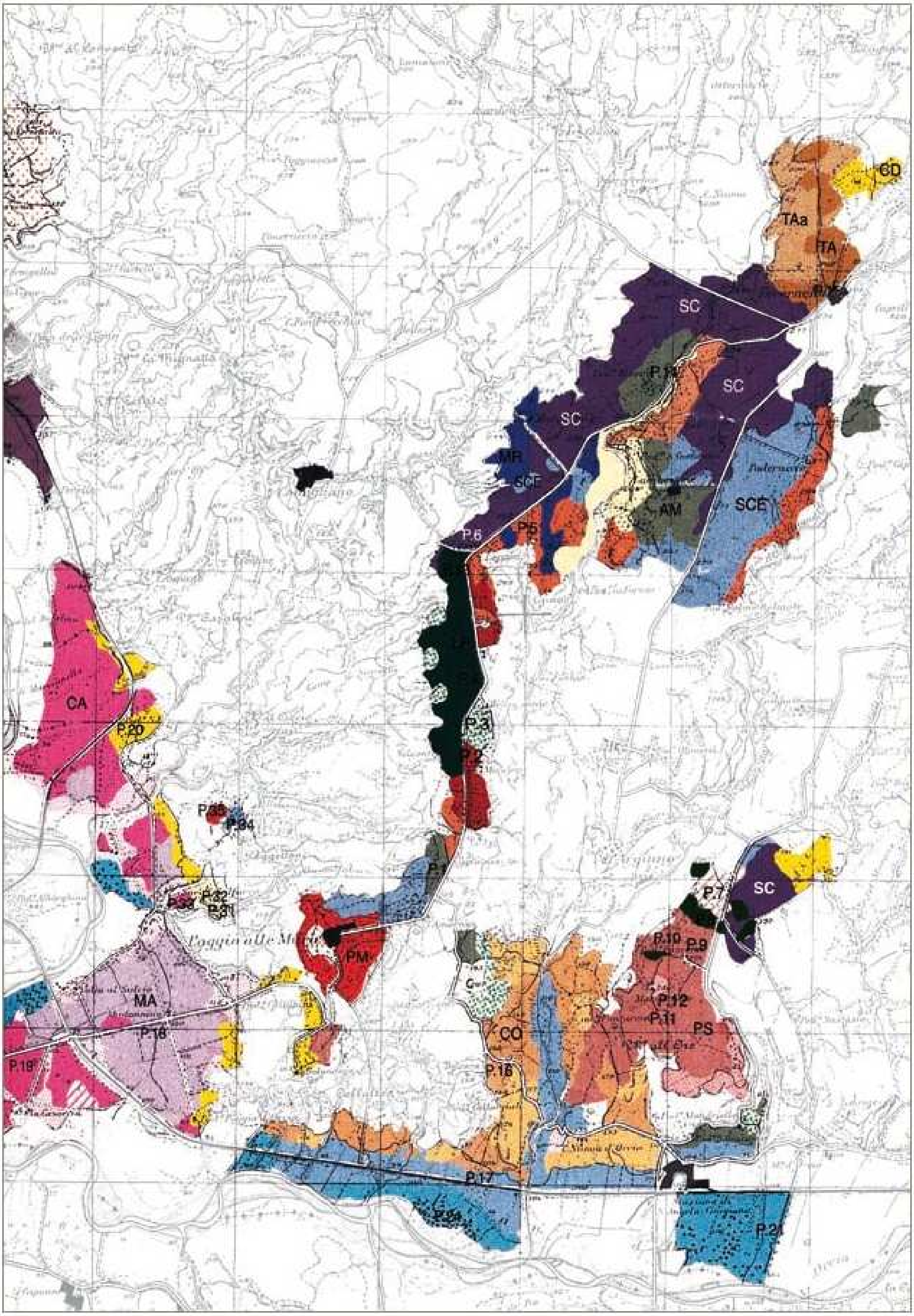

Geomorphological and soil-landscape notes

A geomorphological survey was conducted to represent the characteristic forms of the landscape and to describe the existing relationship between lithology, morphology and evolutionary tendencies of the soils that are modeled according to their lithological constitution and the climatic factors, distributed across the area under study. The geomorphological study of an area is a fundamental factor of pedogenesis. It is also a preliminary and essential applicative model necessary for the cartographic representation and understanding of the soil types present. The general morphology of the area surveyed at the Banfi estate is correlated not only to erosive morphological processes, but also to the anthropogenic impact in the remote past for specialized arboreal cultivations (vineyards). After an in-depth geomorphological analysis of the area, it was possible to divide the territory of Banfi into three macroscopic "environments":

Less hilly Areas

Characterized by formations of prevalently fluvial origin, with fluvial terraces, fan formation conoid, connecting surfaces between the terraces and the alluvial valley floor (Madonnino, Casaccia, Cardeta and the part of the terraces and the alluvial terraces of Pian delle Vigne) with small areas characterized by high terraces of the inland (Caciaio, Belcontento, Lavacchio). These soils are well preserved, pedogenetically developed with forms that often make them belong to the order of the Alfisols.

Prevalently hilly Areas

Surfaces with linear slopes and soft erosion, and slightly convex slopes (Tavernelle, S. Costanza, I Leccini, Mirabene, Pascena); more regular areas with appearances in levels of blue-grey sandy- clayey sub-soil, characterized by slopes and linear slopes (Marchigiana, Pod. Nuovo) and also by direct contact between clay and coarse sand lithologies, with variations both in internal and external drainage, and variable forms of erosion. These depend on the lithologies present and their differing degrees of cementation. Most of the soils are moderately developed belonging to the order of the Inceptisols, with sporadic clayey and sandy layers with very young soils that belong to the order of the entisols.

Hilly areas with prevailing forms due to human impact

Examples are: Collorgiali, Casanuova, Lambertone, Sorrena, Cerretalto, characterized by the appearance of the subsoil and regular slopes; and areas modified by human impact with the elimination of crests, the filling-in of adjacent valleys and formation of flat areas and terraces.

Pedoclimatic framework

Soil climate, or pedoclimate, is a factor to evaluate during a geopedological study because many pedogenetic processes are directly influenced by the pedoclimate. Analysis of the thermo-pluviometric data enabled calculation of the water and thermal regime of the soils of Banfi according to Soil Taxonomy: the classification of the climate was carried out adopting a specific program that works with existing data (newhall Simulation Model): the values of meteoric rainfall and temperature for a water reserve of 150 mm / 5.9 inches were analyzed, making it possible to determine the water balance of the soils and the pedoclimate of the area.

Characteristics of the climate

Regarding the thermo-pluviometric data, the rainfall and temperature readings used (historical data) from station number 051 of Montenero-Grosseto, Lat. 42.55.00 n, Long. 11.30.00 W. altitude 300 a.s.l., released by ARSIA- regional Agro meteorological Service. The pedoclimate of the area is XerIC. A Xeric soil moisture regime is generated when the section being controlled is dry everywhere for 45 or more consecutive days in the 4 months following the summer solstice.
The temperature regime was therMIC, that is, characterized by average ground temperatures, equal to or greater than 15°C but not less than 22°C. the data gathered made it possible to classify the soils of Banfi and put them at the level of a great group using the classification adopted by Soil Taxonomy.

Compilation of the pedological chart: methodology

Before compiling the pedological chart of the Castello Banfi estate, it was necessary to carry out a preliminary study of all the information and collect all the documents necessary for a better understanding of the territory. A historical reconstruction of the area analyzing the appearance of the estate before human impact for cultivation purposes was of particular use.
After the first phase of research, the photographic and written material was examined using photo-interpretation enabling a deeper understanding of the soils' evolution and their use in recent decades. Areas that were homogenous for the intensity of the mophogenetic processes were identified and called physiographic units. A preliminary worksheet and program of the countryside surveys were compiled. during the on-site survey of the territory, the lithologies present were confirmed. The primary information on the variability of the principal pedological characteristics of the soils taken as reference was also acquired, and the physiographic unity and the lithology were confirmed.
After correlating this information and the indications derived from the description of the landscape's characteristics (morphology, lithology, internal drainage, erosion, use of soil, etc.), the next step was to subdivide the territory into homogeneous areas by soil type: in this way, the pedological units were identified. At this point, the "profile campaign" proceeded, beginning with the description and classification of the soils present: to begin, some sites were chosen for open pedological profiles (some trenches opened with mechanical means) to gain in-depth knowledge of the soil types present in the areas, also describing their chemical and physical traits. For every profile, a soil sample was taken at each level (or representative horizon) and sent to the lab for chemical analysis.
the final goal was a better understanding of the quality of the sample soils and their soil-water relation, and to classify them according to the uSdA Soil Taxonomy. For this purpose, the data regarding the soil texture, color, presence of carbonates, ph, organic matter, the composition in mineral elements and the cationic exchange capacity (C.e.C), were analyzed. The number of profiles opened in every cartographic unit is noteworthy, because of the remarkable variety of the soils existing within the same cartographic unit. Finally, the soils were described, furnishing a classification, through cartografic symbols, for the principal chemical and physical characteristics, as well as the major demarcations. Along with the survey of the environment and of the Banfi vineyards, there is a geopedological map on a scale of 1:25.000 with a legend attached, with all the information concerning the areas, subsoils, landscape, and soil groups. The relative abbreviations make it possible to identify the most important pedological characteristics very quickly.

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Vineyard Zonation

A. Scienza, L. Brancadoro

Premise

The study of vineyard zonation, as we know it today, got its start in the early '80s. the countries with the most historic tradition of winemaking, Italy and France, desired to overcome a dualism that had long set two different methods of wine making against each other. One was typical of the wine producing countries of the old World, which identified the vineyard site as the key to product quality. The other, particularly attributed to those countries with an emerging viticulture (California, Chile, Australia, etc.), regarded the vine type as the main determinant of a wine's quality and fundamental characteristics. Vineyard zonation studies were a new interpretative key to better explain enological results, and went far beyond the methods previously used. By carefully studying the relationship between cultivated vine type, environmental characteristics and human intervention, vineyard zonation attempts to evaluate the production and quality potential of the various viticultural ecosystems. It uses innovative interpretive models and unites the two previously opposing key concepts in a single one, the interaction between the vine and its environment. The approach introduced by zonation represents a true "cultural revolution" helping us to understand that the vineyard is no longer a disjointed series of elements to be studied and managed separately, but a system of factors harmoniously integrated and combined to produce the final result: the wine (Falcetti, 1999).

Over the course of these decades, thanks to scientific and technological progress, research procedures have been perfected and enriched. This has enabled increasingly efficient definition and evaluation of the factors that make up the different viticultural models, which characterize the various vine-growing regions. These models, thus identified, represent the basic knowledge, which is needed to interpret the interaction between vine and environment, using an eco-physiological approach.

However, this evolution of research methods has not modified the criteria underlying the experimental protocol of zonation, which are:

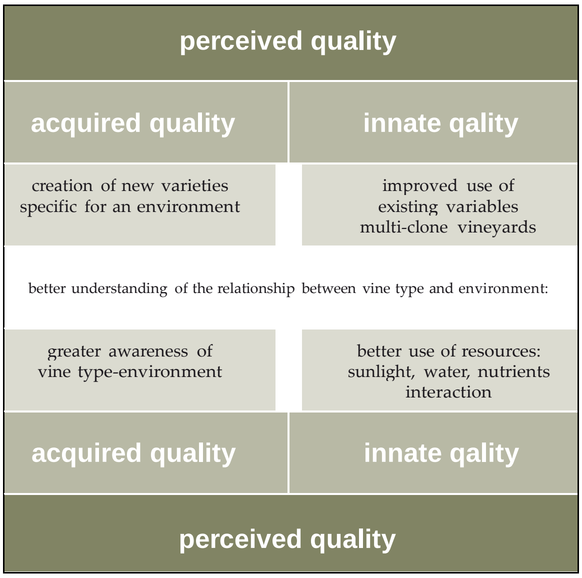
- Interdisciplinary research approach, integrating agronomic, soil, climate, oenological and informational proficiencies
- Study of the interaction between vine type and environment
- Sensory analyses of the wines produced in each environment.

It also has not changed the goal of this research, which is to: identify, within an area, units of territory, called Vocation units (V.u.), within whose confines the vegetative, productive and qualitative performance of a given vine type can be considered sufficiently homogeneous, in comparable conditions of agricultural management (rootstocks, training method, layout, pruning intensity etc.) (o. Failla et al., 1998). However, these vocation units were not identified to draw up a quality classification of the production obtained in the different areas, but rather to evaluate the adaptive responses of the vine types to the different soil climate conditions of each production zone. In other words, the product of a given vine type cannot be rigidly determined, but its expression falls within a range determined by the environment's influence. This wide range can be seen as a vine's reactionary capacity to its environment. In fact, one describes vine types as more or less responsive to the different pedoclimatic conditions, and a zone's vocation attitude, as well as the varietal choice decided for it, is closely tied to this reaction. (Scienza et al, 2003).

Understanding these adaptive responses is necessary for the development and choice of the appropriate agronomic and enological techniques suited to enhance production. This makes the typicity of the different terroirs appear evident (optimization of vine-environment interaction).

Wine quality

The scientific community has examined the problem of wine quality for some time now. Despite these efforts, it is not yet easy to determine the actual contribution of the climate, the physical environment, and the agricultural and enological techniques on quality of the wines produced (Jackson and Lombard, 1993). As is evident from the pertinent scientific literature, the hierarchy of factors, which determine product quality changes according to the conditions in which the study is carried out. This illustrates how the environment's influence on the quality of winemaking must be investigated as a sum of its components, and not as the single factors, which compose it, soil and climate. "Terroir," a concept which associates climate-soil-vine type, is the term best suited to describe this series of environmental factors and their interaction with the vine type. For a correct understanding of the concept of wine quality, it is thus necessary to distinguish between innate quality, attributable to the interaction between vine type and environment (typicity) and an acquired quality, which is the result of the modifications brought about by man using agronomic and enological techniques with the intention of reflecting the peculiar characteristics of the grapes in the wine (Scienza, 1992). The sum of these two qualities, plus other qualities which are actually tied to the product, creates the "perceived quality" which the consumer has for a given product. In the last 20 to 30 years, progress in enological and viticultural techniques has greatly improved the "acquired" quality of products. Considering this, it is necessary to focus attention on the "innate" component. Viticulture has, by now, a strategic goal of producing original, not ordinary wines, and to reach this goal, it is necessary to increase the "innate quality" of wines (which is tied to terroir). There are ways to reach this goal and they involve clone selection and mixing, the creation of new vine types, an improved use of site resources through suitable rootstocks, forms of training and soil operations. These are all methods whose main objective is to optimize the relationship between vine type and cultivation environment. (Fig. 1)



Zonation of the estate

As already mentioned, the scientific approach to this theme is relatively recent and has not been universally accepted yet, due to the numerous variables which must be studied and for the complex interdependent relationship which ties the vine's influence on the wine to its terroir. Moreover, in most cases it is possible to demonstrate a close tie between the Vocation unit and the typology of the wine, though this is a much more complex evaluation and therefore tends to have less of an impact on the final product. This occurs particularly when this kind of research is carried out in extremely large areas, such as across an entire appellation or even a whole province. Microzonations that evaluate the role of the variables in the viticultural model, and

therefore have direct influence on the vine type composition of the vineyards, have a more effective influence on product quality (Fig. 2, 3). The use of meso- and micro-environmental parameters is an appropriate method for evaluating the results of the interaction of the vine type and its environment and for suggesting action when that situation is undervalued for its effectiveness.
Farming operations are able to control the exchanges between the root system and the plant canopy and, for the latter, the balance between the vegetative phase and the productive phase of the plant. This is carried out by the choice of the rootstock, soil management, the choice of the training forms, etc. Before vinification, the results of these choices for the optimization of the vineyard-environment interaction can be objectively evaluated by observing the course of the grape ripening kinetics with respect to three groups of substances:

- accumulation substances: sugars, potassium, skin tannins, anthocyanins, terpene, aminoacids, norisoprenoids
- degradation substances: organic acids, poorly polymerized skin and grape seed tannins, me toxypyrazine, carotenoids
- reaction substances: from processes of glycolization, polymerization between tannins and anthocyanins, tannins and polysaccharides, tannins and proteins.

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Zonation of the Castello Banfi Estate

Tab. 1 - list of the pilot vineyards chosen for being representative of the different soil and climate conditions found on the Castello Banfi estate in Montalcino

Vine type	Farm name and code	Landscape unit	Altitude (meters above sea level)	Year planted	plant density (vines/ha)	rootstock
Cabernet Sauvignon	tavernelle 09-05	tA	375	1981	2777	So4
	Marrucheto 05-01	pS 2	315	1983	2777	779p
	Marchigiana 08-02	SC	300	1980	2777	1103p
	Sorrena 13-04	So	215	1985	2777	1103p
	Voltalsalcio 34-05	VS	170	1995	4166	1103p
	Fontaccia 06-02	Co	300	1986	2777	1447p
Merlot	poderuccio 11-12	SCe	280	1990	2777	1103p
	pascena 04-05	pS	315	1990	4166	420A
	pieve 15-02	Lp	300	1987	2777	1103p
	Belcontento 15-05	Lp	300	1993	4166	3309C
Sangiovese	Mirabene 16-04	MI	300	1993	4166	420A
	poggioni 02-03	Co	310	1987	2777	1103p
	Cardeta 24-02	CA	175	1997	4166	1103p

Research method

This project is the first example of farm zonation carried out on such a large scale in Italy. The Castello Banfi estate is a contiguous 2.800 hectares/7.100 acre plot in the township of Montalcino, and includes 850 hectares/2.000 acres of vineyards, mostly red varieties – mainly Sangiovese, Cabernet Sauvignon, and Merlot.

The zonation project specifically took these three varieties into consideration for both the acreage dedicated to them and the importance of the quality of the wines made with them. On the basis of the soil and climate studies carried out, results of which are published here, pilot vineyards were identified as representative of the different soil and climate conditions, as well as the agricultural conditions found on the estate (Tab. 1).

Enological and agronomic studies were carried out on these vineyards from 1998-2002 to analyze the interaction of between genotype and environment. These studies looked at:

- grape ripening kinetics, followed in the period between onset of grape ripening and harvest, with particular reference to the phenolic and anthocyanic composition of the grapes (tab. 2).

- characterization of the grapes at harvest from a vegetative, productive and quality standpoint (tab. 3).

- every year, for each pilot vineyard, vinification of about 1.5 tons of grapes, following a standard procedure (tab. 4).

- physical and chemical characterization of the wines using analyses to evaluate the characteristics of the wines produced, performed at racking and after about 8 months of storage before bottling (tab. 5).

- organoleptic characterization of the wines.
About six months after bottling, the wines underwent sensorial analysis with the help of a panel of expert wine-tasters.

- in Spring 2001, research was carried out in the pilot vineyards on the development of the root system with soil trenching.

- starting in 2000, in the most representative pilot vineyards, the tensiometric values were gathered to evaluate the water-soil-vine plant relationship.

- when all the data had been gathered, it was statistically elaborated.

Tab 2 - Methodology followed for determining parameters relative to grape ripening kinetics			
Starting from the onset of full grape ripening, a sampling of about 1.200-1.500 grams/2.6-3.3 pounds of grapes, gathering berries taken from the various portions of the bunch in a randomized way, was carried out every week in each vineyard. The following parameters were determined on these samples:			
parameter	Method	parameter	Method
Mean berry weight (g)	Weight of three samples of 100 berries	ph 1 extractable anthocyanins	glries and collaborators (Saint-Cricq de gaulejac *et.al*, 1998)
Sugars (°Babo)	densimeter	ph 3.2 extractable anthocyanins	glories and collaborators (Saint-Cricq de gaulejac *et.al*, 1998)
ph	potentiometric reading	total polyphenols	Spectrophotometric reading at 280 nm
titratable Acidity (g/l in tartaric acid)	For titration up to ph 8.2 with naoh 0.1 n	eA index	glories and collaborators (Saint-Cricq de gaulejac *et.al*, 1998)
Malic Acid (g/L)	enzymatic determination	tV index	glories and collaborators (Saint-Cricq de gaulejac *et.al*, 1998)

Tab. 3 - Methodology followed to determine vegetative, productive and quality parameters			
In each pilot vineyard, a parcel representative of the overall condition of the vineyard, and consisting of several dozen vines, was singled out. Within these parcels, on a representative sample of 6 plants, the following parameters were determined yearly:			
parameter	Method	parameter	Method
Buds per plant (g)	number of buds normally left with winter pruning	Anthocyanins per plant	total weight of grapes produced per plant (kg)
Blind buds %	100 x (blind buds/ total buds	Mean bunch weight	plant production/ number bunches per plant
Fertile buds per plant (#)	number of grape-producing sprouts per plant	Sugar (°Babo)	densimeter
Bunches per plant (#)	Bunches per plant (#)	ph	By potentiometric reading
real bud fertility	Mean number of bunches per bud	tittratable acidity (g/1 tartaric ac.)	By titration up to ph 8.2 with naoh 0.1n

Tab. 4 - Winemaking methodologies followed

A micro-winery for the production of experimental wines was set up in the estate's winery. These wines were vinified in temperature-controlled steel vats, which hold 20hl. Vinification was performed with maceration of the grapes for 10 days, inoculation of 200 mg/L of selected dry yeast, with a daily punching down and pumping over. Malolactic fermentation took place with the introduction of inoculate bacteria. At the end of secondary fermentation, the wines were stored for about six months in previously used and exhausted *barriques*. This method was chosen to test wine capacity to handle refinement in wood, without the wood influencing the wine's organoleptic aspects, as the release of aromatic substances is tied to the use of new barrels. The wines were filtered and bottled eight months after harvest.

Tab 5 - Methodologies employed to determine the physio-chemical profile of the wines

During vinification, all of the wines underwent analytical and organoleptic testing in order to do assure accurate controls. At the end of vinification the wine is analytically verified according to the present method.

parameter	Method	parameter	Method
Alcohol	Distillation	total polyphenols	Spectrophotometric reading
ph	potentiometric reading	non-anthocyanic flavonoids	Spectrophotometric
Titratable acidity	By titration up to ph 8.2 with NaOH 0.1N	Vanilla index	Spectrophotometric
Free anthocyanins	Spectrophotometric reading	Degree of anthocyanic polymerization	Spectrophotometric

Tasting the wines produced from the various pilot vineyards was a key step for vineyard zoning. The methods adopted were based on the use of non- structured parametric tasting notes and on a panel of trained win-tasters. The notes, prepared for each single vineyard (reproduced here to exemplify the one used for Sangiovese), were made by the same panel of tasters. During some tasting sessions, they chose the olfactive (fruited, spicy, phenolic, etc.) and taste (acid, astringent, etc.) descriptors which were best able to describe the product being examined. This method enabled the creation of a common vocabulary among the different members of the panel, which allowed the tasters, at the moment of making their sensory analysis with the non-structured parametric tasting notes, to have the same descriptive points of reference, and therefore to evaluate the wines more objectively.

Role of ripening kinetics in aiding environmental vocation assessment

The onset of the ripening process (veraison) and its course depend firstly on the variety but also on the plant's physiological conditions and on the environmental conditions.
One can generally state that vines with high productive yields, and those with big bunches, within the same range of plants, tend to start ripening later and to accumulate sugar more slowly. This occurs particularly if the environmental conditions favor berry development or, in general, an excessive vegetative-productive

vigor of the vine. On the contrary, slight water and nutritional stress tends to anticipate ripening. Besides the above mentioned factors, the efficiency, entity and duration of the leaf apparatus are decisive elements for determining the persistence and the intensity of sugar accumulation in the berries. Acid degradation is a consequence of the rate of accumulation but also of the temperature and water regime to which the vine is subjected during the ripening period. The build-up of substances is partly correlated to the build-up of sugars and its synthesis is stimulated by sunlight and by cool weather conditions.

The data reported in this section represent the mean values registered during the five-year study carried out on the Banfi estate. The data gathered during that time were reported on a standardized temporal scale where the first day of full grape- ripening was taken to be, for each of the five years, the day in which the pilot vineyards attained mean sugar values of 16° Babo (for further explanations on the method, see Failla et al., 2003). Grape ripening kinetics enables a better under-standing of the quality results obtained at harvest and furnishes extremely important insights as to how a vine furnishes a certain final result. Using this study, it is our intention to show how these kinetics occurred in the different Vocation units identified.

Cabernet Sauvignon

Right from the first samples, the three V.u.s differed in a statistically significant way during ripening, particularly for the parameters concerning mean berry weight and malic acid content. For these two parameters, V.u. CS3 had clearly lower concentrations, followed by high sugar concentrations, which classified this V.u. as an early ripening one. on the other hand, the data also demonstrate how the Cabernet Sauvignon grapes of the site had ph3.2 extractable anthocyanins values which were lower than the other two V.u.s, and this difference becomes increasingly statistically significant as the ripening process proceeds. This information, put in relation to this V. u.'s soil characteristics, the coarse texture of the soils, shallow depth, and reduced AWC, indicates how Cabernet Sauvignon suffers from reduced water availability, in this environment, from the beginning of the ripening process. This fact does not allow for a regular course of accumulation and degradation kinetics of the substances monitored during ripening. Thus at harvest, there is a sufficient technologic maturation and a reduced phenolic maturation.

The other two units have significant differences regarding the values of malic acid for the first two samplings, while there were no other statistically significant differences for the other parameters. In general, CS2 V.u., characterized by sandy-loam soils of medium depth and good AWC values, at the height of the ripening process had intermediate values for berry weight and for anthocyanins, low malic acid and sugar concentrations. This delay in sugar accumulation continued during maturation without, however, causing any important final differences,

While the anthocyanin values have a particularly intense kinetics, above all in the final phase. This causes the grapes of this V.u. To have the highest mean values at harvest time. In this V.u. the ripening of the grapes, during the five-year period, had a regular course enabling the attainment of a good phenolic maturation of the grapes together with their technologic maturation, which was not unlike that of the other V.u.s.

Finally, during the five-year period, the CS1 V.u. had the most regular ripening course. In this V.u., the course of the various parameters analyzed was optimal in all cases, ranging in the high-average values. The soil composition, with a finer texture compared to the preceding V.u.s, a good depth and AWC, ensured that the ripening of the Cabernet Sauvignon was not influenced by water scarcity, at least in the first part of the season, as can be deduced by the berry, which grows regularly in this period. At the same time, the high sugar content, right from the first samples, causes this V.u. to be classified as an early maturing one. With these data, both the technologic and phenolic maturation of the Cabernet Sauvignon grapes of this unit can be judged as optimal.

Merlot

The ripening kinetics of the Me1 V.u. were markedly different from those of the Me2 V.u. during the five-year period. In general, the Merlot of the first V.u. shows more regular accumulation and degradation courses compared to the second V.u. For example, there is a statistically significant difference in berry development (Fig. 1b) and in the mean upper values during all the ripening process, except for the first sampling. The sugar content (Fig. 2b) is always greater in the Me1 V.u. and this difference becomes statistically significant at harvest time. The malic acid values in the Me1 V. u. are much higher in the first phase, and then go through a regular and continuous degradation, until they reach the same values as those recorded for Me2 V.u. these had an anomalous acid degradation, as the grapes had extremely low values, starting right from the first samples, due to stress phenomena at the beginning of ripening. higher ph 3.2 extractable anthocyanin values were registered in Me1 V.u., where accumulation reaches a plateau around the 19th day after the full onset of grape ripening. on the other hand, the values of the second V.u. tend to continue increasing beyond that point.

The differences highlighted between the two V.u.s can be attributed to the soil water characteristics in relation to this vine type's particular sensibility to drought. The soils of Me1 V.u. are characterized by good AWC and soil depth, but they do not have a high saline content, while on the contrary, Me 2 V.u. has fairly shallow soils and insufficient AWC values coupled with a high electrical conductivity, which is a sign of elevated saline concentrations in the soil. The combination of these factors causes the Merlot of V.u. Me 2 to suffer from water scarcity right from the first phases of ripening, which does not allow the vine type to achieve a good phenologic or technologic maturation of the grapes, contrary to what happens in Me 1 V.u.

Sangiovese

As vine-growers know well and as the present study has already put forth, Sangiovese, due to its peculiarity, was particularly responsive to the soil- climate conditions of cultivation. This is especially evident when observing the kinetics of ripening, recorded for the 1998-2002 period, which we have reported. Statistically significant differences between the Vocation units for all the parameters reported are evident in the ripening period. The soils of Sg1 V.u. are fresh, deep, with a fine texture and an elevated AWC, and the course of ripening of Sangiovese in this unit was classified as late. In fact, in this case there were higher initial values of malic acid together with low sugar content. As the season continued, the content of this acid in the grapes tended to decrease rapidly causing the Sangiovese of this V.u. to have intermediate values at harvest compared to the other V.u.s. At the same time, sugar content increased to an extent that enabled the grapes of Sg1 to reach a good technologic maturation at harvest. Regarding the content of ph 3.2 extractable anthocyanins, the V.u. Sg1 had the lowest values during all the ripening process and was statistically inferior to Sg 4 V.u., which shows that the phenolic maturation of the grapes was not optimal. The soils of Sg 2 V.u. had a greater percentage of sand, compared to the preceding unit, but they are deep, fresh, with a good AWC. The Sangiovese produced there during the five-year period showed a slight delay in the technologic maturation of the first phase, due more to the high malic content than to a delayed accumulation of sugars. As the season progressed, this slight, albeit not statistically significant delay, remained; however, it did not have negative repercussions on the final technologic maturation of the grapes, which was good.

Meanwhile, the kinetics of anthocyanin accumulation show a positive trend with a rapid increase of coloring substances, which arrive at a plateau precociously (around the 18th day). This also leads to a positive

judgment of the phenolic maturation of the Sangiovese grapes within this V.u. The third Sangiovese V.u., with medium-depth, sandy-loam soils, has a more intense rate of sugar accumulation and malic acid degradation compared to the other units. For this reason, the unit is classified as medium-early and also in this case, the evaluation is tied particularly to the malic acid content, which is slightly lower than the other later units during the ripening process. On average, during the five-year period, the grapes had an excellent sugar: acid ratio, with an optimal technologic maturation. Over the years, the phenolic maturation of the grapes in the first phase was delayed, on average, compared to the other zones, and this can be evinced from the data on the accumulation of ph 3.2 extractable anthocyanins. The continuous and intense processes compensated for this delay at the time of harvest, and the Sangiovese of the Sg3 V.u. had values which were comparable to and not statistically different from the other, best V.u.
Finally, Sg4 V.u. had soils characterized by a high saline content that increased its osmotic potential, causing phenomena of marked water stress. This caused the results of the V.u. to differ greatly from the results of the other V.u.s. the effects of water stress are easy to note when looking at the berry weight data and in the case of V.u. Sg 4, the mean value for berry weight is clearly inferior and statistically different from the other units during the entire ripening process. These data illustrate that there is marked water stress in these soils from the very first moment, and its effect on the course of grape ripening is a strong acceleration of all the processes that occur in this phase, causing the V.u. to be classified as an earliness-inducing one. In fact, both the significantly higher sugar contents and the significantly lower malic acid values, compared to the other V.u.s, are proof that the course of the ripening process of the Sangiovese in this unit is particularly fast. Further confirmation of this can be found by observing the analysis of the kinetics of anthocyan accumulation. For this parameter, V.u. Sg 4 has the highest values among those registered for the five-year period, but a careful analysis of the data reveals how the curve, though it reaches extremely high values, tends not to flex, as would a trend that corresponded to the physiology of the plant.
This leads to the conclusion that the Sangiovese grapes cultivated in this unit have undergone, on average in the five-year period, phenomena of over-ripening the data reported in this section demonstrate how the cropping environment significantly affects the grape ripening processes and how the study of these courses can explain the differences that occur in the final results at harvest time. Moreover, it is important to underline the relationship, which was found between the chemical characteristics of the grapes, berry development and soil water characteristics, within these areas of cultivation and for all the vines studied.

Water-soil relationships and their influence on grape quality

In the pilot vineyards selected for Sangiovese and Cabernet Sauvignon, starting in Spring 2000 the soil water condition was monitored using electric resistance sensors placed along the soil profile, at a depth of 30 to 70 cm/12 to 27 inches. The data were gathered on a weekly basis. In general, monitoring the water potential of the soils from 2000-2002 made it possible to study the average trend of soil water availability for all four Sangiovese V.u. and for the two most representative, in terms of size, of Cabernet Sauvignon. For the sake of brevity, only the data regarding Sangiovese will be reported. These data illustrate how water availability, independently of the soil type, decreases from fruit set to the onset of grape ripening. At that point, water levels are at a minimum, after which they tend to increase as ripening proceeds until harvest, when water levels are the same as those registered at fruit set. These data are in agreement with the climate conditions normally found in the Montalcino area, where the period between July and August, when the onset of Sangiovese's ripening occurs, is the hottest and driest (see the chapter on climate of this publication). A more in-depth analysis of the data underscores substantial differences among the four Sangiovese Vocation units, which are even more pronounced for the values collected below 70cm/27 inches in depth. The results show that the Sg1 V.u. has the greatest soil water availability during grape ripening, particularly in the period that goes from the onset of grape ripening to harvest. At this time, the water potential values drop below –100kpa, a threshold measure for readily available plant soil water, only for a brief period compared to the trend registered for all the other V.u.s. In fact, during the three-year period, the other V.u.s registered mean values inferior to –100kpa for the entire period that goes from the onset of ripening to harvest, with peaks of –150kpa in particular for V.u. Sg4. This information leads one to conclude that in the last three units, Sangiovese ripens in conditions of water stress ranging from moderate, meaning levels below –100kpa, to severe, levels below –150kpa. The difference in water availability had a determining influence on Sangiovese quality. In particular, a statistically significant and negative relationship has been identified between soil water potential, and sugar and ph3.2 extractable anthocyanins contents. These data confirm, also for Sangiovese, what numerous other studies have demonstrated (poni, 2000). A moderate condition of water stress favors, in general, the grape ripening and in particular, in the present case, grape phenolic maturation derives greater benefits from conditions of water stress. Further analysis of the data illustrates how these relationships were not found for Cabernet S. , once again demonstrating that the interaction between genotype and cropping environment is a determining factor for vegetative-production responses and quality of the vine. It also demonstrates how Cabernet Sauvignon has genetic traits, which make it particularly stable in the most diverse cropping conditions. In conclusion, it is necessary to underline the fundamental role of soil characteristics in balancing the climate conditions, in general, and the effects of rainfall on the water nutrition of the vine in particular. Proper water nutrition of the vine, above all when considering the possibility of emergency irrigation, is a determining factor in attaining high enological goals. This must be determined according to the different soils and vine type characteristics.

Soil-root system relationship

Because of the objective difficulties in carrying out studies on the root systems of the vine, this kind of analysis is not very widespread. However, the relationship between the above ground and below ground parts of plants in general, and of the vine in particular, is well-known, especially since the latter is a cultivated plant that is the result of grafting a vine type with a rootstock. Regarding the zoning study, the research on the root system can furnish important details about the adaptability of the vine to the different soil conditions present. The literature regarding this subject indicates how the depth of root penetration is closely tied to soil characteristics (Van huyssteen, 1988), particularly to its density, and how moderate water stress increases root growth (Van zyl, 1988). On the other hand, it is a well-known fact that poor root system development causes inadequate vine vegetative-productive responses. Only a study that identifies these causes can be the starting-point for operations to remove these limiting factors. Thus, this study also examined the existence of differences between the root system of the vines in the different sites of the four Sangiovese V.u.s. the data gathered are plotted in a graph and expressed as a mean value of root counts in relation to the depth and to the distance of the vine plant towards the inter-row. In general, in the various V.u.s, differences occur in the roots with a greater diameter at the greater depths (80-100cm/31.5-39 inches), in the section closest to the vine plant. For the section taken at 60cm/24 inches from the vine plant, the differences occur at a minor depth (40-60 cm/16-24 inches). This difference based on the distance from the vine plant does not apply to the fine roots (Ø< 2mm/ Ø<1/8 inch). In this case, the differences among the various units generally occur along the entire profile starting from the depth of 60 cm/24 inches. In particular, in the soils of the Sg3 V.u., denser root systems were found, with more roots, both structural and fine, compared to those found in the Sg2 and Sg4 V.u.s. Moreover, when examining Sg3 V.u., it is important to highlight the root system's different structure compared to the other Vus. In fact, in this case, the distribution of both the bigger and the finer roots has the typical double-layer conformation; there is a first peak at the 40-60cm/16-24 inches depth, which is also found in the other V.u.s, where the roots find the best conditions for carrying out their nutrient uptake function. There is a second peak in the layer of depth, between 80 and 100cm/32 and 39 inches, where the roots absorb water the best, particularly in dry periods when the surface is dehydrated in absence of water supply. This did not happen in the other V.u.s.

The polyphenolic profile of wines produced under zonation

When considering wine quality in general, and particularly that of red wines, the evaluation of their polyphenolic profile is a key point. Current analytical methods enable in-depth study on the contents and characteristics of the different phenolic compounds found in wine, to evaluate their quality and determine the implications that these substances have on the organoleptic aspects. Part of the research carried out at the Castello Banfi estate examined this aspect of the wines produced with the grapes of the various vineyards being studied. The objective was to determine the relationship between the characteristics of the various Vocation units and the polyphenolic profiles of the wines produced there.

Anthocyanins

The color of red wines is due to the quantity and quality of the anthocyanins present. These molecules are part of a larger family of phenolic compounds and their analytical definition enables an objective judgment about the color characteristics of a given wine. The wine produced during the five years of the project were analyzed (see methodology on page 98) to determine content, quality and stability over time of the colorant substances present. The analysis of the total and free anthocyanin content underscores, first of all, how the three varieties being studied have essentially different mean values. The Cabernet S had the highest average values of both free and total anthocyanins, while Sangiovese had the lowest average values for the parameter under consideration. This confirmed, once again, the essential differences, which exist in the genetic backgrounds of the three vine types. When studying the anthocyanin content of the wines in relation to the V.u., a determining factor, which emerges, is the interaction between the "terroir" and the vine type. Data regarding this demonstrate how, for the total anthocyanian values, the Cabernet and Sangiovese vines react more to the environment than does the Merlot. In fact, substantial differences can be found between the CS3 V.u., and the others of the same vine, and between the Sg4 V.u. and the rest of the V.u.s of the Sangiovese, while there are no substantial differences for this parameter between the two Merlot V.u.s. Furthermore, for the Sangiovese, these data confirm the results obtained about the anthocyanic content of the grapes during maturation where Sg4 V.u. was the one with the highest values of extractable anthocyanins. Regarding the parameter of free anthocyanins, the results are similar to those described above for the total anthocyanins, with the addition that the V.u. also had an effect on Merlot.
to illustrate the qualitative aspect of the colorant materials, the results of the five-year study are reported in Figure 2 and expressed as average percentage values of the three fractions of copolymerization between anthocyanins and tannins, and in Figure 3, the values of intensity and tonality of the wines are reported. The formation of copolymers between anthocyanins and tannins is fundamental for the long-term stability of color in wines, as the polymerized forms (dtAt) are more stable than both the single molecules (dA1) and the transition forms (dAt) that have intermediate stability. The analysis of these data reveals how, among the

wines of the different V.u., in each vine type, differences of copolymerization of the anthocyanins exist, which allow the wines of different origins to undergo fairly long periods of refinement with no color decline. For an overall judgment of the "quality" of the coloring substance, the tonality parameter must also be evaluated. This scale assigns the highest values to the wines with yellow-orange hues and the lowest values to those with red hues. Thus the best combinations regarding color are those with low tonality values and high values of copolymerization. The analyses of the combinations of these different parameters enable the expression of an exhaustive judgment of the quality of wine color; Sangiovese, for example, produces the best results in the Sg3 and Sg4 V.u.s which have a dtAt % superior to that found in Sg2 and an inferior tonality compared to Sg1. this is a combination that allows the two wines of these two Vu to undergo long periods of aging with no color decline. Many conclusions can be drawn from this study, but in the specific case of this zonation project it is worth stressing that even for these parameters, drawn to evaluate the different aspects of a wine's color, the interaction between the vine type and environment is the key to interpreting these results.

Other phenolic compounds

The other phenolic compounds present in wine are mostly involved in determining other quality aspects of this product, in particular, those relating to taste. Their quantity and quality can be viewed in relation to the sensations of structure, astringency and bitterness. While one can establish a direct relationship between the contribution of phenolic substances and the color aspects of wine, it is not yet possible to apply a given analytic value to a particular organoleptic sensation. This is due to the extreme complexity which unites the molecules in giving the sensation perceived by the taster. On the other hand, the analytical figures for phenols make it possible to draw fundamental indications about the organoleptic characteristics of wines, and more. Figure 4 reports the average five-year values of the main parameters for the quantity-and-quality evaluation of the phenol compounds found in the wines. The value of the total polyphenols is the most approximate data that quantifies the general content of these compounds. Furthermore, both the value of the procyanidine and the non-anthocyanic flavonoids enable quantification of tannin content without, however, expressing a quality judgment related to the degree of polymerization of these compounds. The oligomeric tannins, commonly called green tannins, are responsible for the astringent, sometimes bitter, tannic sensation, found in wines, while the polymer tannins or sweet tannins, help to heighten the sensation of wine structure. Using the vanilla index, with which the degree of polymerization of the tannins is determined (a high value of this index corresponds to a low degree of polymerization), it is possible to express a judgment of their quality. The analysis of the data reveals differences among the various units of each vine type both for the quantity and the quality of the substances being examined. These differences make it possible, as is the case for Sangiovese, to highlight V.u.s like Sg4 that furnish wine with clearly superior quantities of tannin in respects to V.u.s, like Sg3. As previously stated, this furnishes "indications" about wines and should be evaluated in relation to other characteristics, mainly organoleptic, in order to address wines of different V.u.s and direct winemaking solutions that permit the individual character of each single wine to stand out.

Identification of the vocation units and analysis of the viticultural model for verification of their performance

The vocation units of the Castello Banfi Estate

Within an area under vine, units of territory, called Vocation Units (VU), demarcate an area within which the production, quality and vegetative performance of a given vine type can be considered sufficiently homogenous, under comparable agricultural conditions (rootstocks, training method, layout, pruning intensity, etc.) (Failla et al., 1998). The identification of the key variables, which are most suited to describing the territory being examined, is essential for the delimitation of the homogenous territories under study. These variables are chosen on the basis of their physiological, agronomic and enological significance and because of their ability to reflect the typicity of that particular unit. In the present study, among the various parameters gathered during the five-year period, the guiding variables chosen were malic acid and sugar content of the musts, which were excellent indices both for the kinetics of ripening and for grape quality. Also chosen were the values of pH 3.2 and at pH 1 extractable anthocyanins, as well as the tannins of the grape seeds, which were selected for their enological value and for the importance of their impact on the quality of the wines produced in the area. Finally, the mean berry weight value was used both as an indication of the physiological phenomena of the water-soil-plant system and as a production crosscheck.
The key variables chosen were used following cluster analysis to put the pilot vineyards of the different V.U.s into homogenous groups and subsequently study which soil characteristics made them similar. This was done to enable the definition of the provisional vocation units (Tab. 1). The result of this analysis, which enabled the identification of provisional Vocation Units for each of the three vine-types being studied, is reported in figures 1a, 1b, and 1c.
For Sangiovese, the Vocation Units were put together in four homogenous groups whose characteristics are reported below.

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Tab. 1 - Principal chemical physical characteristics of the soils in the Cartographic Units, in relation to the Vocation, Units on the basis of the cluster analysis performed on guide variables.

Vine type	V	Locality	UC	Dept (h)	AWC (mm)	Clay (%)	Silt (%)	Sand (%)	Texture	Electrical Conductivity (mS/cm)
Sangiovese	SG1	Cardeta	CA	110	121	33.5	26.7	39.8	CL	0.07
		Belcontento	LP5	70-110	116	33.3	30.4	36.3	CL	0.15
	SG2	Mirabene	MI	110	90	21.3	25.4	53.3	CSL	0.07
	SG3	Pieve	LP2	80-90	127	16.3	31.7	52.0	LS	0.13
		Pascena	PS	110	118	14.3	26.2	59.5	LS	0.24
	SG4	Poggioni	CO	110	120	36.3	31.3	32.4	LS	1.1
Cabernet Sauvignon	CS1	Marchigiana	SC	120	84	27.7	33.2	39.1	CL	0.61
		Tavernelle	TA	100	88	34.3	17.2	48.5	CSL	0.14
	CS2	Marrucheto	PS2	60-110	87.5	16.3	30.0	53.7	CL	0.25
	CS3	Sorrena	SO	70	50.5	15.5	32.0	52.5	CL	0.08
Merlot	ME1	Fontaccia	CO	110	120	36.3	31.3	32.4	CL	0.5
		Voltalsalcio	VS	110	102	10.5	17.5	72.0	SL	0.1
	ME2	Poderuccio	SCE	80	80	30.7	32.2	37.1	CL	0.9

Variability Analysis of the Castello Banfi Viticulture Model (five-year period)

The viticulture model is composed of Year, Vine, and Vocation Unit and of the interaction between Year and Vocational Unit. These were used for the analysis of variance (ANOVA), which identifies to what degree the different components of the model influence the outcome of the vineyards being studied. In other words, we measured the influence of the Year (weather conditions), Vine, genetic factor; Vocation Unit, site of cultivation; and interaction of the latter with the Year. In this way, we measured the mediating role of the environment versus the climate conditions, on the yield and quality of grape production on the Castello Banfi estate. The circular diagrams summarize the results of the analysis of the viticulture model (Fig. 2), and next to the factors of the model, there is the heading "other factors" which in statistical terms means "residual variability". We believe that this "residual variability" can be reasonably and approximately attributed mostly to the difference among the plants, as well as to those factors that could not be evaluated during the course of the study. When observing the set of graphs it is possible to acquire a lot of information about the Castello Banfi vineyards. First, it is evident that the viticulture model adopted accounts, in most cases, for about 50% of the variability registered, thus confirming its validity. Specifically, in this study, it becomes evident that climate conditions, which in general are a strong factor of variability, revealed their influence mostly on the acid profile of the musts and on the grapes' anthocyanin content. As was to be expected, the varietal differences have a determining influence on bunch and berry weight and on plant vigor, expressed as pruned wood, in addition to substantially determining the content of the coloring substances. Within the zonation project, it is desirable to highlight the effect of the Vocational Unit in itself and in interaction with the Year, which is important to determine productivity and vigor, and consequently, the vegetative-productive balance of the vine, evaluated using the RAVAZ index. Even more worthy of consideration is the effect of V.U. and its interaction with the Year on sugar accumulation in the grapes, as well as the significant role played in determining the pH values, the tannin indexes of the grape seeds and the pH 3.2 extractable anthocyanins.

Vine Type Responses in the Vocation Units

The validity of the Vocation Units, identified using the abovementioned working plan, was carried out with the help of polyfactorial linear statistical methods (ANOVA) performed on the data gathered in the Pilot Vineyards, separated for each variety. This study was followed by a cross-check to establish the significance of the differences which emerged between the averages compared using the Duncan Test.
The compared results of the averages for the five-year period of the different Vocation Units of each vine type are reported in Table 2. These data supply considerable information about the genotype- environment interaction, which is the object of this study. First of all, it is important to emphasize how the three vine types respond differently to changing soil, climate and agricultural conditions. For example, Merlot was less responsive than the other two vine types to changing conditions. In the two units, for this variety, the vegetative-productive responses differed in a statistically significant way for a reduced set of parameters compared to Sangiovese and Cabernet Sauvignon, demonstrating that Merlot is more adaptable to the agricultural conditions found on the Castello Banfi estate. Upon closer inspection, this vine type responds to agricutlural conditions with a change in its vegetative production and the sugar content in the musts. (For an in-depth analysis of the differences between the various V.U.s, please see the section dedicated to the description of the V.U.s in this publication.)
Regarding the interaction between Cabernet Sauvignon and its agricultural environment, according to the data reported in the table, the vegetative-productive responses of this vine type were influenced by agricultural conditions as much as, if not more than, the Merlot. For this variety, the V.U. was a significant determining factor in influencing the acid profile of the musts and the contents of pH 3.2 extractable anthocyanins, while there were no significant differences for sugar content. This fact once again confirms, as if it were necessary, this vine's elevated ability to attain optimal levels of sugar content even in very different conditions. Finally, for Sangiovese, which is the main variety in the Montalcino area, the results confirm that this vine is very responsive to the agricultural environment. As with the preceding varieties, the Vocation Unit influenced Sangiovese's vegetative- productive responses at a statistically significant level, but in this case, many of the differences recorded for the grape quality parameters were also statistically significant. Upon closer observation, these differences were recorded for the sugars, the pH, titratable acidity, and the content of pH 3.2 extractable anthocyanins.
In conclusion, based on the data gathered, we can affirm that the agricultural site is generally decisive for determining the vine's vegetative-productive response, independently of the vine-type being considered, while for the quality parameters of the musts the responses are not so unequivocal. This demonstrates, once again, how the genotype-environment interaction is fundamental for characterizing the quality aspects of enological production.

Tab. 2 - Comparison of the different Vocational Units identified according to each vine type under study. The comparisons were carried out separately for each single vine type and the means followed by the same letter were not statistically significant.

Vocation Unit	SG1	SG2	SG3	SG4	CS1	CS2	CS3	ME1	ME2
Shoots N°	11 a	9 a	12 a	19 b	22 a	28 b	22 a	11 a	18 b
Bunch N°	18 ab	12 a	12 a	23 ab	44 a	41 a	38 a	19 a	39 b
Fertility	1.5 a	1.3 a	1.1 a	1.3 a	2.0 c	1.3 a	1.7 b	1.9 a	2.4 a
Production per plant (kg)	3.2 a	3.2 a	3.6 a	4.0 a	5.2 b	4.5 b	2.9 a	2.7 a	4.7 b
Bunch Weight (g)	231 b	332 c	300 c	158 a	135 b	107 a	81 a	131 a	106 a
Berry Weight (g)	1.7 a	1.8 a	1.7 a	1.2 a	1.1 a	1.0 a	0.86 a	1.1 a	0.82 a
Pruned Wood (kg)	1.05 b	0.95 ab	0.92 ab	0.76 a	1.07 a	1.46 b	0.87 a	0.64 b	0.38 a
Ravaz Index	2.8 a	5.3 bc	3.7 ab	5.8 c	6.4 b	2.9 a	3.7 a	3.5 a	8.4 b
Sugars (° Brix)	21.7 a	21.8 a	22.0 a	24.2 b	22.6 a	22.4 a	22.2 a	22.4 b	19.8 a
pH	3.47 b	3.49 b	3.37 a	3.36 a	3.36 a	3.45 b	3.52 b	3.57 a	3.51 a
Titrable acidity (g/l)	6.34 ab	6.24 ab	6.74 b	5.66 a	6.29 b	6.09 b	5.14 a	6.15 a	6.06 a
Malic Acid (g/l)	1.5 a	1.7 a	1.6 a	1.3 a	1.7 a	1.6 a	1.3 a	1.1 a	1.1 a
pH 3.2 Extract. Anthocyanins (mg/l)	610 a	678 ab	696 ab	790 b	951 ab	873 a	1003 b	780 a	706 a
pH 1 Extract. Anthocyanins (mg/l)	1238 a	1230 a	1314 a	1275 a	1771 a	1696 a	1914 a	1435 a	1360 a
Tannin Index of grape-seeds	38.1 a	30.2 a	28.4 a	37.6 a	25.6 a	26.1 a	33.2 a	32.6 a	40.9 a

Evaluation of environmental vocation through sensory analysis

As already mentioned, a salient point of the zonation study is the evaluation of the organoleptic characteristics of wines produced from the different Vocation Units. Using these analyses, an attempt is made to determine the sensory parameters of wine that best describe the effect of "terroir" on the finished wine. Wine tasting, carried out by a panel of expert tasters, was performed using the form shown on page 101. The data gathered during the five-year period was statistically analyzed to verify its validity and to underscore the existence of statistically significant differences among the various V.U.s.

The statistical methods used, for each of the three vine types, are the following:

- Standardization of the data, for each taster and for each wine tasting session, using the method of normalized points. The first step in the elaboration of the data required the elimination of the subjective differences that each taster had when using the non-structured scale of the tasting notes.
- Principle component analysis (PCA). Using PCA, the various descriptors utilized in the non-structured parametric tasting notes are grouped in categories that can best describe wine characteristics.
- Analysis of the variance components. The model of V.U., the year's weather conditions, and their interaction with each other was used to determine and evaluate their effects on wine characteristics grouped together using PCA.
- The validity of the V.U.s for the sensory parameters was realized with the help of polyfactorial linear statistical methods (ANOVA) performed separately for each variety on the data gathered during the wine tasting sessions. The data emerging from this study were checked to establish the significance of the differences found among the means under comparison by Duncan Test.

SANGIOVESE

Three statistically significant functions were identified for this vine, using the analysis of the main components. Compared to the single descriptors used in the tasting notes, they are able to describe, in the most complete and immediate way, the olfactory and taste characteristics of the Sangiovese wines produced in the five-year period. In the first function (that accounts for more than 19% of the variance) the vegetal/herbaceous and fruited olfactory descriptors are those with the greatest impact (apple in particular) (Tab. 1). The second function (accounting for 17.9% of the variance) has more subtle descriptors, typical of this variety: Floral, Red Fruits, Cherry (later grouped together under the heading Red Fruit) and Spice; for the third and final function (accounting for 15.8% of the variance), the chosen descriptors are taste and tactile: Astringency, Persistence, and Structure. Regarding a hierarchy of the factors of the model adopted (V.U., YEAR and their interaction) the results furnished by the analyses of the components of the variance (Tab. 2) show how the YEAR, as expected, had a predominant influence on characterizing the aromatic profile of the wines. In fact, the YEAR explains most of the variability registered in the five-year experiment for the first two functions particularly tied to olfactive sensations, while its effects on the F3 taste and tactile descriptors was not significant. On the contrary, the findings for the V.U., although they accounted for a lower variance percentage for the first two descriptive functions of the wines' aromatic profile, always had a significant effect. In addition, the YEAR- V.U. interaction had a statistically valid influence in all three cases. This fact highlights, in case it were necessary, the importance of vineyard location in determining the organoleptic characteristics of Sangiovese. The mean values of the three functions for each Vocational Unit, obtained by analyzing the principal components, are described above.

An analysis of these results highlights how the single V.U.s differ, in a statistically significant way, for the aromatic profile and for the taste characteristics of the wine. During the five-year period, the SG1 V.U. produced wines that were characterized by particularly vegetal and ripe fruit sensations, with mean values, which were statistically superior to the other V.U.s. However, the descriptors, which were most typical for the vine (Function 2), were less pronounced in the olfactory profile. For the notes related to taste (Function 3), the wines of this Unit were, strictly speaking, not excessively astringent, possessed good structure and persistence differing statistically only from those related to the SG4 V.U.
On average, during the five-year study, the wines of the SG2 V.U. had a complex aromatic profile, typical of the variety and without any particular characterizing notes that made them different from the other V.U.s. In particular, the products of this zone had medium-low values of Function 1 (Vegetal-Ripe Fruit) and medium values for the Spice, Red Fruit and Floral notes (Function 2). The taste of the wines was persistent, moderately astringent and had good structure. The wines produced with the grapes from SG3 V.U. distinguished themselves, positively and in a statistically significant way, for the descriptors which were typical of the variety grouped in Function 2 (Floral, Red Fruit and Spice) while they had low values for the green vegetal notes. On the palate, the wines had good structure, persistence and were not particularly astringent without differentiating themselves from those of the V.U.s previously described. Finally, the wines of the SG4 V.U., as could be expected from the analysis of the musts and grapes, were those with the significantly highest mean values for Function 3, showing it had very good structure and persistence with tannins (astringency) that were almost excessive. The aromatic profile of these wines revealed the lowest values for vegetal and ripe fruit descriptors, while for the values tied to Function 2, they had a high intensity of the descriptors typical of Sangiovese.

Tab. 1 - Matrix of the components for the PCA carried out on the Sangiovese descriptors. Only the more important descriptors are reported in the three significant functions and the values are highlighted in bold print and underlined.

	Function 1	Function 2	Function 3
Floral	0.058	**0.774**	0.045
Vegetal/Herbaceous	**0.768**	0.108	-0.112
Cherry	0.407	**0.509**	0.155
Red Fruits	0.300	**0.708**	0.007
Ripe Fruits	**0.658**	0.106	0.116
Spicy	0.455	**0.730**	0.113
Structure	0.180	0.277	**0.717**
Persistence	0.091	0.266	**0.737**
Astringency	0.128	-0.169	**0.824**

Tab. 2 - The three factors that make up the model: percentages of the variance of the single factors and their interaction, for the three functions using PCA.

	Vegetal Ripe Fruit	Floral Red Fruit Spicy	Structure, Persistence Astringency
Year	28.9	16.5	n.s.
VU	2.9	1.3	9.8
Year × VU	10.5	8.9	4.4
Other Factor	57.7	73.3	85.8

CABERNET SAUVIGNON

Using PCA, it was possible to identify for this wine as well three significant functions that grouped the sensory characteristics of the tasting session. This accounted for about 58% of the variance registered in the wines of the various Vocation Units during the five-year study.

In this case, the first function, which explains over 27% of the variance, sums up the Spice and Red Fruit olfactive descriptors with the acidic sensation (Tab. 3); the second function (which accounts for 15.7% of the variance) was tied to the vegetal olfactive descriptor and the third (14.9%) to the cooked fruit olfactive descriptor. For Cabernet, the vine farming model adopted (Tab. 4) shows an even greater influence of the YEAR in determining the organoleptic characteristics of the wines compared to the results for Sangiovese. The V.U. does not have a statistically significant influence on the first function, while for Function 3 (cooked fruit), the results obtained show the preponderant role the V.U. plays in determining the intensity of this note in the wines. What has been said about the V.U. can also be applied to the interaction between it and the YEAR. These data confirm, once again, the adaptability of this vine type, which enables it to adapt to different soil, climate and cropping conditions.

As is evident when observing figure 2, there are also differences between the Vocation Units for Cabernet Sauvignon. In particular, CS1 V.U. provides wines with an olfactory profile positively characterized by descriptors typical of the vine type (ripe fruit and spicy) grouped in the first function, while vegetal descriptors are less intense (Function 2), contrary to what was reported for the other Units. This confirms the optimal ripening of the grapes in this V.U. and this information was further corroborated by the mean values of Function 2 (cooked fruit), where the wines of this V. U. have intermediate values compared to the other two V.U.s. On the contrary, these other V.U.s are characterized either by a high intensity of the cooked fruit descriptors or by its complete absence; in the case of CS3 V.U., as previously described, this high intensity is due to water stress at ripening which produces grapes that tend to be overripe. The complete absence of these descriptors in CS2 V.U. is due to a late technologic ripening of the grapes, caused by the soil-climate characteristics of the unit, as already mentioned in the paragraph on grape ripening. Besides standing out for the lower mean levels of Function 3 (cooked fruit), the V.U. had an aromatic profile characterized by vegetal descriptors (Function 2) and by those descriptors characteristic of the variety - Function 1 (ripe fruit, spice). Finally, as already mentioned CS 3 V.U. had the highest five-year levels of cooked fruit descriptors and had the highest levels of Function 2 - (vegetal) and low values of Function 1 (ripe fruit, spice and acidic sensation). This confirms, once again, that a less-than-optimal grape maturing trend is reflected on the aromatic profile of the wine.

Tab. 3 - Matrix of the components for the PCA carried out on the Cabernet Sauvignon descriptors. Only the more important descriptors are reported in the three significant functions and the values are highlighted in bold print and underlined.

	Function		
	1	2	3
Ripe Fruit	**0.554**	-0.306	0.449
Jammy	0.500	-0.040	**0.698**
Vegetal	0.302	**0.712**	0.025
Spicy	**0.631**	0.526	-0.113
Acidity	**0.612**	-0.098	-0.448

Tab. 4. - The three factors that make up the model: Percentages of the variance of the single factors and their interaction, for the three functions using PCA.

	Spice Fruity Acid	Vegetal	Jammy
Year	31.7	16.1	9.1
VU	n.s.	0.9	1.8
Year × VU	n.s.	n.s.	5.8
Other Factors	68.3	83.0	83.3

MERLOT

For Merlot, as in the case of the preceding vine types, the principal components were analyzed, enabling identification of three significant functions which grouped together the main organoleptic descriptors utilized during wine tasting. The sum of the variance of these three functions was greater than 57% and of these, about 24% can be attributed to Function 1, tied to the tactile and taste descriptors of structure, persistence and astringency. Another 18% is attributable to Function 2, tied to the olfactive notes, which are typical of the vine type: spice and balsam. The remaining 15% can be attributed to Function 3, which is related to the red fruit's olfactive descriptors (Tab. 5). Regarding the influence of the single factors which make up the vine cropping model adopted and their interaction, in the case of Merlot, results show that the Year had a preponderant influence in determining the characteristics of the wine produced. In fact, this has a statistically significant influence on tions identified (Tab. 6). For the V.U., the other component of the vine-cropping model, only the second function, including the descriptors typical of the wine, proved to be significant. Furthermore, for the V. U. – YEAR interaction, the only noteworthy statistics were in Function 1, which pertain to the tactile and taste descriptors of the wine. In this case, as for the Cabernet Sauvignon, the data tend to confirm the consistency with which the so-called ubiquitous varieties furnish the products with organoleptic characteristics that recur in different vine farming locations.

Contrary to what was found for the vine types previously discussed, for Merlot no significant differences between the means of the two V.U.s were found regarding the three functions. It is, however, possible to highlight how the two V.U.s have different, contrasting aromatic profiles. The mean values of the two V.U.s for the five-year period are presented as bar graphs for comparison. The analysis of the data shows that ME1 V.U., which had the best grape-ripening trend and the best quantity-quality data at harvest (data reported in other paragraphs of this publication), had the most intense and typical olfactive profile of the vine type, and the highest values for Functions 2 and 3. Moreover, the wines of this Unit had the very best structure and persistence of aroma, accompanied by an intense tannic sensation, which was never excessive. On the contrary, the average five-yearthe values of all the other three func- period profile of the ME2 V.U. was poor and, in particular, typical descriptors of the vine were poorly pronounced, while the wine was markedly astringent. As in the previous case, there are close ties between the characteristics of the grapes and the aromatic characteristics of the wine.

In conclusion, it is necessary to underline how the sensory characteristics of the wines are determined firstly by weather conditions (YEAR), but that in good measure they are also the result of the interaction between the soil climate characteristic of the location (V.U.) with the vine type. Moreover, this becomes even more evident with a more reactive vine being studied, as is the case with Sangiovese, where the different properties of the soil found in the four V.U.s had a clear and profound influence on the sensory profile of the wine.

Tab. 5 - Matrix of the components for the PCA carried out on the Merlot descriptors. Only the more important descriptors are reported in the three significant functions and the values are highlighted in bold print and underlined.

	Function 1	Function 2	Function 3
Balsamic	0.167	**0.798**	0.213
Spicy	0.006	**0.845**	-0.145
Forest Berries	0.041	0.208	**0.786**
Astringency	**0.716**	-0.078	-0.317
Persistency	**0.822**	0.302	-0.103
Structure	**0.897**	-0.009	0.064

Tab. 6 - The three factors that make up the model: Percentages of the variance of the single factors and their interaction, for the three functions using PCA.

	Structure Persistence Astringency	Spicy Balsamic	Red Fruit
Year	1.6	33.5	6.3
VU	n.s.	1.5	n.s.
Year × VU	28.0	n.s.	n.s.
Other factors	70.4	65.0	93.7

Reflections on the Interaction Between Vine-Weather-VU and its Impact on Grape Ripening

During the five years taken into consideration, in the vegetative period of the vine that extends from April to October, there were extremely variable weather conditions. These differences intensified during the months of August- September, which in this zone correspond to the phenological phase lasting from the onset of grape ripening to the harvest. This is a critical period for the production quality characteristics. In particular, rainfall differed substantially in the April to October period, with a minimum in 2001 of 226 mm/9 inches of rain, and a maximum in 2002 of more than 480 mm/19 inches. There were also substantial differences in active temperature (>10°C/50°F). The coolest year was 2001, reaching a sum of active temperatures for the April-October period of 1892 °C/3437°F, while 1999, with a sum of 2176 °C/3949°F, had the highest values of the Winkler index.

These diverse weather conditions caused extremely diversified kinetics of ripening in the three vine- yards over those years. The significant effect of the year is clear because of the weight it has in determining the different parameters of the technologic and phenolic maturation of the grapes (Fig. 2 of paragraph Viticulture Model, on page 123). One aspect of the interaction between Year and V.U. is reported in the bar graphs in Figures 2a and 2b. For each V.U. of the three vine types being studied, the five-year period mean, maximum and minimum values are reported for the sugar content, and the content of extractable anthocyanins at pH 3.2, which are respectively the most representative parameters of the technologic maturation, and of the phenolic maturation, of the grapes. According to an initial interpretation of these data, it is clear that during the experiment, the fluctuation of the average values are due to substantial fluctuations between one year and the next, and not to a constant fluctuation over the years. These annual variations do not fluctuate uniformly for the single vine types or for their different V.U.s, revealing the interaction between Year, Vine and Farming area. In addition, the two parameters in consideration have different ranges of oscillation for the different years, and in particular, the phenolic maturation is more unstable over the years compared to the technologic maturation. Figure 3a and 3b clearly illustrate the above statements as they report the percentage deviation from the average maximum and minimum values of the three vine types registered for the five-year study period. There is a more moderate

fluctuation of the sugar content parameter in the three vine types, ranging from about -10% to 13%, while the extractable anthocyanin content diverges more drastically from the average, going from a minus 30% to a plus 40%. Once again, these data underscore the importance, for modern enology, of a proper evaluation of the phenolic maturation of the grapes, and shows how this is clearly influenced by the yearly weather conditions.
Further study of these data reveals that the three vine types under study interact in substantially different ways with the changes in climate conditions over the years. The Cabernet Sauvignon has, by far, the most stable results, with the lowest divergence, both negative and positive, from the five-year average for both parameters, with oscillations equal to about +/- 5% for sugars and +/-25% for the anthocyanins. The other 2 vine types were much more responsive to the vintage effect, particularly in Sangiovese's case, where the phenolic maturity of the grapes has the greatest oscillations, going from a minus 30% to a plus 40% compared to the average of the five-year period. There were no substantial differences in the breadth of oscillation for the sugar content of Merlot and Sangiovese, but the data reveal how the two vines behaved differently. Sangiovese generally reacts much more positively to favorable conditions, increasing over 10%, while Merlot reacts very negatively to unfavorable conditions with a decrease in sugar content of over 10%. These data confirm that the Cabernet Sauvignon vine is the most adaptable and is able to yield quality production despite varying weather; while on the other hand, the Sangiovese vine is not very adaptable, furnishing its best production results only in specific favorable conditions. Returning to the data reported in figure 2, and analyzing each vine's response to the V.U, it is evident that the different V.U.s have different levels of interaction with the year; for example, the CS2 V.U. has almost no variations in sugar content, compared to the five-year average, showing high stability, while on the contrary, for Cabernet Sauvignon, the CS3 V.U. varies more during the years, proving to be rather unstable The following two indices of phenotypical stability, normally used in statistics, were used to evaluate the different stabilities of the V.U.: the Deviation Standard (D.S.) and the "b" index. The value of the indices is proportionally inverse to the stability of the V.U. as indicated by the data used to evaluate their performance. The results of this study are reported in table 2 accompanied by a brief judgment on the stability of the V.U. These studies demonstrate that the V.U. with the greatest stability for Cabernet Sauvignon is CS3, which is stable for the anthocyanin and malic acid concentrations of the grapes, and for the mean berry weight, while it is unstable for the sugar content of the musts. The other two units furnished stable results for each of the two parameters over the years; CS2 V.U. was stable for the anthocyanins, sugars, and CS 1 for the mean berry weight and the content of malic acid in the musts.

The results of the two Merlot V.U.s show that the ME 2 tends to be unstable in all the parameters considered, while the ME1 V.U. is stable.

Finally, the Sangiovese SG 2 and SG 4 V.U.s have the greatest continuity in their production performance and in particular, SG 2 is stable for all the quality parameters and SG 4 is unstable only for the coloring substance. The results for anthocyanins and malic acid content of the SG1 V.U. were inconsistent, while they were constant for the other parameters. The SG3 V.U. was particularly responsive to climate conditions, furnishing stable values only for the contents of extractable anthocyanins at pH 3.2. In conclusion, it is necessary to add that while the evaluation of phenotype stability is still a "quality" judgment of the characteristics of the various V.U.s, it goes hand in hand with analyses of the results obtained from the single plots. An explanation about the SG3 V.U., which was unstable for sugar content, is necessary. This V.U. should be evaluated positively because it has a greater variability compared to other V.U.s, but this is due to the highly favorably interaction with accumulation conditions. Thus, conditions of greater stability do not, by themselves, guarantee better results, but they do influence the interaction, in the present case of the Vocational Units, with the climate conditions, and therefore provide an additional tool for evaluating the characteristics of the "terroir."

Tab. 1					
Year	1998	1999	2000	2001	2002
Rainfall (mm)	246	274	331	226	481
IH	2808	3011	2758	2784	2678
Winkler	1960	2176	1906	1892	1860
Selianikov	1.25	1.26	1.73	1.19	2.58

Tab. 2 - Comparison among the different Vocation Units of each vine type for the stability indices: Deviation Standard (DS) and "b" (angular coefficient of the regression curve of the population values and those of a single V.U.).

Varietal	VU	Indices	Extractable anthocyanins at pH 3.2	Average berry weight	Sugars	Malic Acid
Cabernet Sauvignon	CS1	DS	207	0.25	0.64	0.29
		"b"	1.03	0.84	1.28	0.84
		Evaluation	Unstable	Stable	Unstable	Stable
	CS2	DS	167	0.30	0.11	0.46
		"b"	0.96	1.65	0.22	1.65
		Evaluation	Stable	Unstable	Stable	Unstable
	CS3	DS	141	0.15	0.85	0.70
		"b"	0.96	0.64	1.60	0.64
		Evaluation	Stable	Stable	Unstable	Stable
Sangiovese	SG1	DS	148	0.46	0.85	0.56
		"b"	1.17	0.78	0.81	1.63
		Evaluation	Unstable	Stable	Stable	Unstable
	SG2	DS	126	0.55	0.77	0.16
		"b"	0.93	1.2	0.53	0.31
		Evaluation	Stable	Unstable	Stable	Stable
	SG3	DS	108	0.61	1.31	0.54
		"b"	0.79	1.24	1.51	1.26
		Evaluation	Stable	Unstable	Unstable	Unstable
	SG4	DS	166	0.35	0.82	0.21
		"b"	1.11	0.74	0.8	0.11
		Evaluation	Unstable	Stable	Stable	Stable
.	ME1	DS	184	0.26	1.02	0.49
		"b"	0.78	0.81	0.54	0.58
		Evaluation	Stable	Stable	Stable	Stable
	ME2	DS	196	0.28	1.44	0.52
		«b»	1.1	1.36	1.22	1.2
		Evaluation	Unstable	Unstable	Unstable	Unstable

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SANGIOVESE VOCATION UNITS

VU SG1

This vocation unit consists of the pilot vineyards of Belcontento and Cardeta, which represent the cartographic units LP5 and CA.

Landscape

This unit is located on terraced and slightly inclined linear slopes. This area, where earthmoving activities and human operations have never occurred, is characterized by a prevalence of fluvial origin soils with alluvial terraces, conoids, and connecting surfaces between the terraces and the alluvial valley floor, with small areas characterized by high terraces of subsoil. The soils are well preserved, pedologically developed, with forms that are often recognized as Alfisoils.

Soils

Deep, cool with a clay-loam texture, high available water content, and skeleton ranging from absent to abundant, low salinity.

Vegetative-productive aspects

The vegetative and productive potentials are strong; though the latter is reduced by the low mean, weight of the grape bunches. The vegetative-productive equilibrium suffers from the plant's excessive vegetative development. The root system is well developed in the soil's surface layers, while it is less developed in deeper layers.

Ripening of the grapes, quality aspects

Technologic ripening of the grapes is delayed during the first phase while they reach good levels of sugar concentration balanced with acidic content at harvest. The accumulation of coloring substances in the grapes is good but phenolic ripening is not complete either in relation to the content of extractable anthocyanins or that of the tannins in the grape seeds.

Sensory and polyphenolic profile

The olfactive descriptors, which characterize the wines of this unit, are vegetal and ripe fruit, while the phenolic and spicy notes, such as red fruits, are barely present. On the palate, the wine has good texture and consistency, with a not-so intense and sufficiently soft tannin. The anthocyanin and tannin content in the wines are within the norm, while color tones were found to be slightly higher, with a lower stability of the color.

Cultivation guidelines to optimize the interaction between vine and environment

Based on the results gathered during the fifteen years of experimentation and on the soil climate traits of this vocation unit, the farming guidelines that can be derived for this area call for anticipation of grape ripening and the balancing of plant vigor. Therefore for these soils it is recommended to choose rootstocks that do not promote great vigor (420 A, 41B, 110R, 161-49), carry out artificial turfing with plants that do not compete for water, and keep vineyard density fairly low to enable the vines to fully express their vegetative potential. Fertilizer should be applied in relation to the degree of nutrient removal. Water should be used exclusively as an emergency tool, and only from fruit set to ripening.

VU SG2

The Mirabene vineyard is part of this unit; it represents the MI cartographic unit.

Landscape

The area has experienced moderate earthmoving activity and some human intervention in the form of moderate leveling, with surfaces characterized by slightly inclined, linear slopes with some erosion, and slightly convex slopes.

Soils

Deep, cool and with a sand-clay-loam texture, the available water content is fairly high, skeleton ranging from absent to abundant, low soil salinity.

Vegetative-production aspects

The productive potential is in the norm due to low bud fertility although there is a high mean bunch weight. The vegetative potential is also in the norm. There is good equilibrium between the plant's vegetative and production phases. The roots are poorly developed both in the superficial and deep layers of the soil profile.

Ripening of the grapes and quality aspects

Ripening has a slightly earlier start but then over time slows down, sometimes resulting in cases of blocked accumulations. These conditions cause the grapes, at harvest, to have good but not excellent technologic ripening. For phenolic ripening, thanks both to a high percentage of extractable anthocyanins of the total present and to an optimal polymerization of the tannins in the grape seeds, optimal conditions are reached at harvest.

Sensory and polyphenolic profile

The olfactive descriptors that best characterize this unit are spice and red-fruit, with some vegetal notes. On the palate, the wines have a good persistence, thanks to the balance between the product's structure and acidity, with tannins that are intense yet not astringent. These wines have an above average color intensity with sufficient levels of potential stability. The tannic content is in the higher r ange. These tannins also have a good level of polymerization.

BANFI

Dedicated to a finer wine world

Cultivation guidelines to optimize the interaction between vine and environment

The farming guidelines that can be derived for this area, suggested by the results obtained over the years of research and by the characteristics of the territory, also call for anticipation of ripening and balancing plant vigor. Therefore on these soils it is recommended to choose rootstocks that do not induce great vigor (420 A, 41B, 110R, 161- 49); carry out artificial turfing with plants that do not compete with water and do so on alternate rows to further limit the sod's water competition, and planting the vines to medium density (4500 stocks/ha). This enables the vines to fully express their vegetative potential. Fertilizer should be applied to replace nutrients. Water should be applied exclusively in emergencies, and only from fruit set to ripening.

VU SG3

The pilot vineyards of La Pieve and of Pascena are Part of this unit; they represent the LP2 and PS cartographic units.

Landscape

This unit is located on the terraced slopes and the slightly inclined linear slopes. This area, with little or no human intervention or earthmoving activity, is characterized by soils of prevalently alluvial origin with alluvial terraces, conoids, and connecting surfaces between the terraces and the alluvial valley floor, with small areas characterized by high terraces of subsoil. The soils are well preserved and pedologically developed, with forms that are often recognized as Alfisoils.

Soils

Ranging from medium to deep, with a sandy- loam texture, high available water content, skeleton ranging from scarce to abundant, low soil salinity.

Vegetative-productive aspects

The productive potential is in the norm; due to the buds' low fertility although there is a high mean bunch weight. The vegetative potential is also in the norm. There is a good balance between the plant's vegetative and productive phases. Root development was optimal both in the superficial and deeper layers of the soil profile.

Grape ripening and quality aspects

Technologic ripening of the grapes is slightly earlier. Later in the season, due to constant sugar build- up and acidic breakdown, the harvesting period is reached with ideal ripening values characterized by an optimal sugar-acid balance. Even phenolic ripening, proceeding regularly during the period from the onset of grape ripening to the harvest, enables the grapes to reach the harvest period with a higher content of extractable anthocyanins and tannin polymerization.

Sensory and polyphenolic profile

The wines produced here have the variety's distinctive aromatic traits, distinguished particularly for the intensity of the descriptors: floral, spicy, red fruits (both cherry and berries), followed by slight traces of cooked and toasty descriptors. On the palate, these wines have a good structure and are well balanced in their acidic content, with an intense tannin content, which, however, does not produce high astringency or bitterness. The wines have an above average color intensity with good levels of potential stability. They have lower tannin content but a good degree of polymerization of these substances.

Cultivation guidelines to optimize the interaction between vine and environment

Based on the data collected, the farming guidelines for this area aim to stabilize the unit's vegetative-productive results over time. Therefore, for this unit it is recommended to choose drought-resistant rootstocks that are not too vigorous (110R, 420
A, 41B), manage soils through artificial turfing between the rows, and maintain vineyard density between medium and high (4500-5500 stocks/ha) to permit a good vegetative-productive balance. It is also recommended to limit application of mineral fertilizer and water.

VU SG4
The pilot vineyard of Poggioni is part of this unit. It represents the CO cartographic unit

Landscape

These are areas heavily modified by human intervention, characterized by subsoil emergence or soil removal and filling in of valley depressions which lead to the formation of regular slopes; manually developed areas with the elimination of rises, filling of adjacent valleys with the formation of flat areas and terraces. The soils are poorly developed from a pedogenetic standpoint, very young, frequently high in saline, with subsoil emergence. Often these do not have distinct surfaces except those areas that have been trenched or plowed.

Soils

Deep, with a clay-loam texture, high available water content, skeleton ranging from absent to moderate, high soil salinity.

Vegetative-productive aspects

Reduced production potential, due to a low mean weight of the bunch and berry, and reduced vegetative potential. There is a sufficient vegetative- productive equilibrium even though a greater development of the canopy would be desirable. Root systems demonstrate a reduced development both in the shallow and deeper layers of the soil's profile.

Grape ripening and qualitative aspects

The beginning of ripening is extremely precocious and fast. A build-up of sugars and extractable anthocyanins remains high through to harvest. The grapes are also characterized by low malic acid content and by a high percentage of tannins in the grape seeds. Both technologic and phenolic ripening in these conditions is not only the result of the normal physiologic trend, but also of concentration phenomena caused by water stress.

Sensory and polyphenolic profile

The wines are particularly characterized by their mouthfeel, having a high persistence and a good balance between alcohol and acidity. The tannic structure is always very strong and, when excessive, causes a bitter sensation. The aromatic profile is characterized by the variety's typical descriptors such as berries and spices, with cherry jam followed by toasty notes. The color intensity of the wines is clearly above average, with optimal levels of potential stability. In addition, tannin content is significantly higher, though not always matched by optimal levels of polymerization of these substances.

Cultivation guidelines to optimize the interaction between vine and environment

For this V.U. the farming guidelines, as a result of research, tend to go beyond the limits imposed by the soils of this area. For this reason, the choice of the rootstocks is limited to the 1103P; soil management is carried out through temporary turfing which favors soil structure; the vineyard density tends to be high (5500 stocks/ha) to enable smaller plants to easily reach a good vegetative-productive balance; organic matter should be spread out evenly throughout the years; and emergency irrigation is recommended from fruit set until and beyond ripening.

Merlot Vocation unit

VU ME1

The pilot vineyards of Fontaccia and Voltalsalcio are part of this V.U.; they represent the CO and VO cartographic units.

Landscape

These are areas heavily modified by human intervention, characterized by soil removal and filling of valley depressions with the formation of regular slopes or slightly inclined colluvia connected to the valley floor. The soils are poorly developed from a pedogenetic standpoint, very young, frequently high in saline with emergence of the subsoil.

Soils

Deep and usually cool, with a texture ranging from clay-loam to sandy-loam, available water content ranging from medium to high, skeleton ranging from absent to abundant and soil salinity from medium to scarce.

Vegetative-productive aspects

There is a medium productive potential as a consequence of reduced fertility and a superior mean bunch weight. The vegetative potential is adequate; there is an optimal balance between the plant's vegetative-productive traits.

Grape ripening and qualitative aspects

Grape ripening is characterized by an early beginning of sugar build-up, which continues evenly until harvest, causing the grapes to have higher sugar content. In addition, the acidic breakdown is regular during the entire period from grape-ripening to harvest, which enables optimal technologic ripening. On the contrary, the increase of coloring substances in the grapes is delayed, but thanks to its kinetic regularity, at harvest time, the grapes have optimal levels of phenolic ripening.

Sensory and polyphenolic profile

The wines have a wide aromatic spectrum with marked varietal specificities. This spectrum is characterized by balsamic and spicy scents, followed by hints of berries and toast. Furthermore, on the palate, the wines show an optimal structure and a balance between alcohol and acid with intense and sweet tannins. The wines' anthocyanin and tannin content is above average, and the characteristics of color stability are potentially very high. Even the tannin polymerization degree is higher.

Cultivation guidelines to optimize the interaction between vine and environment

The farming guidelines for this V.U., as for the characteristics of this vine-type, based on gathered data; aim to stabilize, over time, the area's vegetative-productive results. Therefore for this unit it is recommended to choose rootstocks that are drought-resistant but not too vigorous (such as 110R, 420 A, SO4, and in some particular cases the 1003P). Soil management should still be carried out through artificial turfing between the rows, either on the entire surface or on alternate rows. Vineyard density should be between medium and high (4500-5500 stocks/ha) to enable good vegetative- productive balance. It is also recommended to limit any soil nutrient and water applications.

VU ME2
The pilot vineyard of Poderuccio is part of this V.U. It represents the SCE cartographic unit.

Landscape

The area is characterized by signs of moderate earthmoving activity and human intervention related to slight leveling which form surfaces that are slightly inclined linear slopes, which are subject to slight erosion, and slightly convex slopes with emergence of subsoil.

Soils

They are shallow, and tend to be dry and crack in summer. They have a clay-loam texture, low available water content, skeleton ranging from absent to scarce, and medium high soil salt content.

Vegetative-productive aspects

The vegetative potential is very reduced; the productive potential is also reduced due to a low bunch and berry weight, only partially compensated by a good fertility. The balance between the vegetative and productive phase is inadequate because of poor canopy development.

Grape ripening and qualitative aspects

The sugar build-up begins slightly late and halts as ripening proceeds, thus preventing optimal technical ripening of the grapes. Even the acidic breakdown has abnormal kinetics, with extremely low values in initial stages and remaining stable almost up to harvest time, thus contributing to an insufficient technologic ripening. On the contrary, the build-up of color substances begins very early. However, this process also slows down early, so that at harvest the grapes have an incomplete phenolic ripening caused both by low extractable anthocyanins and by the grape seeds, which greatly contribute to release of tannins.

Sensory and polyphenolic profile

The wines produced here distinguish themselves with a particularly persistent mouthfeel. This is the consequence of the sensations of alcohol and astringency that they give, which in some years can produce bitter sensations. The olfactive profile is not very ample. Notes of jam and berries are noticeable while the balsamic and spicy ones are hardly perceptible. The anthocyanin content is within the norm, giving the wine sufficient color stability. The tannin content is lower with fairly sufficient polymerization.

Cultivation guidelines to optimize the interaction between vine and environment

For this V.U. the farming guidelines, based on the zonation project results, seek to mitigate the limits imposed by the soils of this area. For this reason, the choice of the rootstock is limited exclusively to 1103P; soil management is carried out through turfing, also temporary, which favors the soil structure; the vineyards tend to be dense (5500 stocks/ha) to allow smaller plants to easily reach a good vegetative-productive balance. Organic matter should be spread out evenly throughout the year, and emergency irrigation is recommended from fruit set until and beyond ripening

Cabernet sauvignon VOCATION UNITS

VU CS1

The pilot vineyards of Tavernelle and Marchigiana are part of this V.U.; they represent the TA and SC cartographic units.

Landscape

These are hilly areas characterized by sandy and sand-lime sediments with conglomerate central Pliocene layers and leveled areas with subsoil emerging in layers. The area has undergone minor earthmoving activity and human intervention connected to slight leveling of the terrain with the formation of surfaces characterized by slightly inclined linear slopes subject to erosion, and slightly convex slopes.

Soils

Ranging from fairly deep to deep, with a texture ranging from sandy-clay-loam to clay-loam. The available water content ranges from medium to poor, skeleton ranges from absent to abundant and soil salinity from medium to poor.

Vegetative-productive aspects

The vegetative potential is fairly high. There is a high productive potential thanks both to a superior bunch and berry weight as well as higher bud fertility. The vegetative-productive balance is optimal.

Grape ripening and qualitative aspects

The sugar build-up is early and continues, in a fairly regular way, until harvest, giving the grapes a high sugar content. At the same time the acidic values follow a steady degradation in kinetics. However, as the acidic values are very high at the onset of ripening and harvest, the grapes have higher than average acidity. All of these trends contribute to an overall extremely positive technologic ripening. Even concerning phenolic ripening, one finds a precocious beginning both of anthocyanin build-up and of tannin polymerization. As ripening proceeds, thanks to kinetics within the norm, harvest is reached with high anthocyanin content and good polymerization of the grape seed tannins, thus also reaching an optimal phenolic ripening of the grapes.

Sensory and polyphenolic profile

The wines are characterized by a wide aromatic profile, distinctive of this variety. The notes that best describe this product are those of spices and ripe fruit, followed by jam, toast and balsamic, whereas the vegetal notes are scarcely present. Even for the tactile descriptors, the wines produced here have an optimal intensity. In particular, persistence and structure are in the high range, followed by acidic and tannic sensations; the latter is intense but never bitter. The anthocyanin content of the wines is superior and potential color stability is optimal. Even the tannin content is higher and has good levels of polymerization.

Cultivation guidelines to optimize the interaction between vine and environment

For this V.U. the farming, guidelines, indicated by the zonation results, mostly aim at consolidating the area's vegetative-productive results. Therefore it is desirable to choose mildly vigorous rootstocks (420 A, 161-49 and only in particular cases the 1103P), carry out soil management through artificial turfing between the rows, and keep vineyard density between medium and high (4500-5500 stocks/ha) to enable a good vegetative-productive balance. It is also recommended to limit nutrient and water applications.

VU CS2

The pilot vineyard of Marrucheto is part of this V.U. It represents the PS2 cartographic unit.

Landscape

This area occupies slopes, which are characterized by a slight incline. There are areas where signs of human intervention prevail, characterized by the emergence of subsoils or soil removal and filling of valley depressions with the formation of regular slopes. The soils are poorly developed from a pedogenetic standpoint. They are very young and frequently skeleton-rich.

Soils

Medium-deep to deep, with a sandy-loam texture, medium available water content, skeleton ranging from medium to abundant and poor soil salinity.

Vegetative-productive aspects

The vegetative potential is high and the productive potential is fairly high, based on the mean weight values of both bunch and berry and to reduced bud fertility. There is a good vegetative-productive balance, even though the canopy is slightly lush in respect to the plant's productive potential.

Grape ripening and qualitative aspects

There is a late start of the ripening phase; the grapes have low sugar and anthocyanin contents; later on, thanks to an intense sugar build-up near harvest time, figures reach levels that are more than acceptable. These levels, compared to the acid content, which at harvest are medium, enable the attainment of a very good technologic ripening.
The same cannot be said for the anthocyanin content, which is low even at harvest time together with the tannin index of the grape seeds. This causes a slightly incomplete phenolic ripeness, particularly regarding color.

Sensory and polyphenolic profile

There is a wide olfactive profile, with high intensity of the vegetal-balsamic notes, followed by the ones of ripe fruit and spices, while the aromas of jam are not present. This is a trait, which gives the products high aromatic freshness. On the palate, they possess an optimal alcohol-acid balance with sweet and intense tannin sensations giving the wines an impressive structure and persistence. Color is high and has a very good degree of stability. Even the tannin content is higher and has a good level of polymerization.

Cultivation guidelines to optimize the interaction between vine and environment

The farming guidelines for this area aim at inducing earlier grape ripening. For this reason, the most appropriate rootstocks, such as: 110R, 420 A, SO4 and, in some cases, even the 1103P, will have low vigor and good resistance to summer water stress. Soil management must be carried out through turfing, using plants which need little water (fescue grasses and/or leguminous plants); the vineyard density should range from medium to high (4500-5500 stocks/ha) to enable a good vegetative-productive balance. In addition, fertilization is advisable only for replacing elements that have been removed. Due to the soil characteristics, only emergency irrigation should be performed.

VU CS3
The pilot vineyard of Sorrena is part of this V.U.; it represents the SO cartographic unit.

Landscape

These are areas modified by human intervention, characterized by subsoil emergence or soil removal and filling in of valley depressions, which lead to the formation of regular slopes. The soils are poorly developed from a pedogenetic standpoint. They are very young, frequently high in skeleton. Often they do not have horizons except the trenching and plowing ones.

Soils

Superficial, with a sandy-loam texture, low available water content, skeleton ranging from medium to abundant and low soil salinity.

Vegetative-production aspects

It has a low vegetative potential, and a low productive potential due to low mean berry and bunch weight. This is only partially mitigated by bud fertility, which is within average range. There is a sufficient vegetative-productive equilibrium, even though it is caused by a reduced productivity related to a sufficient vegetative development.

Grape ripening and wines' qualitative aspects

The onset of ripening occurs very early and, in this phase, high sugar content and low acidity are recorded. As ripening proceeds, the sugar concentration increases fairly evenly while the acidic concentration remains almost unvaried. At harvest, the grapes have a high, yet unbalanced, degree of technologic ripening. Even phenolic ripening occurs fairly early with anthocyanin build-up and continues with a high build-up so that the grapes attain superior values. At the same time, tannic ripening in the grape seeds is not as intense, causing an incomplete phenolic ripening.

Sensory and polyphenolic profile

The wines show a sufficiently wide aromatic profile which is characterized by jam descriptors to which vegetal, toast and spice notes are added. They are highly structured on the palate due to an intense sensation of alcohol, not always balanced, and also to the notable astringency that in some years, particularly the dry ones, can be excessive. The wines' anthocyanin and tannin content is lower, but the potential stability of the color and the percentage of polymerized tannins are good.

Cultivation guidelines to optimize the interaction between vine and environment

The farming inputs for this V.U. aim at reestablishing a more even vegetative-productive balance. For this reason, the choice of the rootstocks must favor those with good resistance to water stress, but that do not exceed in vigor, such as 110R, 41B, 44-53M and 1003P. Soil management should be carried out through turfing, using varieties with low water needs (fescue grasses and/or leguminous plants); vineyard density should be high (5500 stocks/ha) to enable greater vigor in each plant. Organic matter should be spread evenly throughout the year. Fertilization should replace removed nutrients and emergency irrigation is recommended from fruit set until and beyond the onset of ripening.

CLONAL SELECTION OF THE SANGIOVESE VINE

A. Scienza, L. Brancadoro

Sangiovese: origin and history of a great Italian vine

The history of this vine is difficult to trace beyond the 16th century due to lack of reliable information prior to that time. Soderini, in his treatise "La Coltivazione Delle Viti" (The Cultivation of Vines) is the first author to cite it, calling it Sangiogheto or Sangioveto, describing the vine as remarkable for its regular productivity. Trinci in his "Agricoltore Sperimentato" (1738) subsequently praises the vine. Gallesio also speaks of it at length in his treatise "Pomona Italiana" (1830), dedicating an entire chapter to this variety.
The origin of the name is still unclear, though the hypothesis that it derives from Sangiovannese, San Giovanni, is not without foundation. As the vine sprouts early, the words in dialect used in south- eastern Liguria (Sarzana) and Corsica, respectively "sangiovannina" and (San) ghjuvanino, which mean "early grapes" could be a plausible origin of the name (Hohnerlein and Buchinger, 1996). The semantics of the name could also be tied to the term "jugum" yoke, originating in Romagna ("sanzves"). It refers both to the summit of the mountain and to the hilly landscape of the Tuscan-Romagna Appenines. The French terms jouellé (row of vines) and jouelle (pole that connects the two vines) that derive from the Latin "jugalis" could be a plausible source in the same manner as Schiave, where the name of the vine derives from the way it is cultivated.
The derivation from "sangue," blood, is an interesting idea (Sanguegiovese-Sangiovese) both when related to the term yoke ("blood of the small yokes of a hilly terrain= sangue dai gioghetti di una terra collinare"), and when addressing Jove (Jupiter). One also draws a correlation to Saint John ("Giovanni"), as the occurrence of two feasts coincide in time: the pagan "vinalia," dedicated to Jove, and the Christian feast day of St. John, patron saint of vine growers, June 24 and August 29.

Diffusion of this vine-type and intra-varietal variability

This vine is characteristic of the Romagna region and some areas of Tuscany, and since the 19th century it has been called by different names: Prugnolo (gentile) in Montepulciano, Brunello in Montalcino, Morellino in the area around Grosseto, Sanvicetro, Nervino, Calabrese in Arezzo and Sangiovese or Sangioveto in the Chianti area. In the 1800s Sangiovese began to spread towards Emilia, Umbria, Abruzzo, parts of Lazio, northern

Puglia and western Campania. In southern Italy it is often called Montepulciano, the area from which it originated, giving rise to misunderstandings because of the synonymy with the homonymous vine-type (Viala, Vermorel, 1901-1910; Molon, 1906; Demaria e Leardi, 1875).

The correspondence of the Tuscan Sangiovese with the one from Romagna and with Prugnolo, Brunello, Morellino and Calabrese has been demonstrated ever since the 18th century by numerous scholars and technicians, even if the vine has an elevated phenotypical intravarietal variability. This confirms a polyclone origin of the variety (probably caused by the ancient propagation by seed) which created an ample genetic base. The effects of an accumulation of genetic mutations, interaction with the environment, and selective pressure with different productive aims have further widened the variability (Rives, 1961). Both Villafranchi (1713) and Acerbi (1825) were the first to sense the correspondence between Sangiovese and Prugnolo. In 1877, 1878 and 1883, the Siena Ampelographic Commission ascertained that without any doubt Sangiovese, Brunello and Prugnolo were the same vine and they suggested calling it Sangioveto. More recently, Marzotto (1925) Casmo (1948) and Breviglieri and Casini (1965) confirmed that Sangiovese's variability can be attributed to the subpopulations in the variety. These can be detected especially by noting the size of the berries and leaves.

In 14 ancient varietal populations located in the traditional productive areas of Tuscany, Campostrini et al., (1995) have recently revealed the existence of 5 ecotypes which have differing production characteristics and must quality. In particular, berry weight was the most effective distinguishing criterion between the biotypes, together with bunch size. As the latter is a strongly inherited polygenic trait and highly correlated to the quality characteristics of the must, it can be an efficient evaluation parameter in the clone selection carried out using the weak selection pressure method. However, the five biotypes occur with very different frequency in the three fundamental areas of cultivation of Sangiovese in Tuscany. In the Montalcino area, type B prevails, followed by type C, which together amount to about 60% of the genotypes present, while in Montepulciano, type A is prevalent, followed by type D (together they amount to 56% of the biotypes present). In Rufina in Chianti, the frequency of the biotypes is more homogenous and varies from 16% of type D to 23% of type A. Naturally, these morphological differences among bunches correspond to a different composition of the must, above all with respect to the titrable acid (tartaric acid) and the coloring substances.

The distribution of the 600 clones identified in Tuscany, and described in their morphological and compositive characteristics, enabled the identification of a group of biotypes that are common to the three areas of vine cultivation and still other biotypes that are different. This is probably related both to the specific selection pressure which occurred in the past and to the variation of the interaction between genotype and environment. Even Calò et al. (1995) identify and describe, above all from a vine-type standpoint, six biotypes of Sangiovese, which are common to different geographic areas (three in Tuscany, one in Romagna, one in the Marche and finally, one in Corsica). This confirms the prevalent role that the interaction with the environment played in causing the phenotype differentiation of the biotype, due to the selection of the propagation material. Parallel analyses carried out on DNA polymorphism using PCR-RAPD and isoenzyme technique did not confirm the differences highlighted through study of the leaves (phyllometry). Proof of the intravarietal variability, which was used in various Sangiovese clone selection programs in Italy, can be found in Silvestroni and Intrieri (1995). Studying a set of 12 certified clones using statistical analysis, they classified at least 3-4 groups of clones that are well-differentiated from each other by evaluating leaf morphology traits and production characteristics.

However, all these studies confirm the existence of the two fundamental types of Sangiovese described in the past; they can be traced back to a so-called “big-berried” Sangiovese to which the majority of the biotypes cultivated in Romagna and Tuscany correspond, while the “small-berried” Sangiovese corresponds to the Sanvicetro found in the Casentino area. Naturally, within these two fundamental biotypes there are other variants with a medium cluster and big berries, and some with a small cluster and big berries. Usually the types with small bunches are less vigorous, have smaller five-lobed leaves, and produce musts that are more acidic and a lower sugar content. They have basal fertility but a good phentoype production stability.

Clonal Selection and Selection Methods

By definition, clonal selection is the isolation and multiplication of single plants, within a variety, that have certain valuable characteristics. Numerous experiences of clone selection (Rives, 1961; Valenti et al., 1990, Brancadoro, 1995) have highlighted the existence of an elevated variability within the population of the vines being cultivated. In particular, the differences between individuals are very marked when dealing with very old vineyards or ones that have been cultivated for a long time in environments that are climatically very different (Valenti et al., 1990).

This research leads one to consider the traditional cultivar of vines for wine as a population of plants deriving from "ortet", which is a concept comparable to that of mother plants with clones. The notion of polyclones is fascinating since its historical origins go back to the Neolithic age, when primitive farmers grew vines that were similar to each other (Bogoni et al., 1993). Most of these varieties are probably the result of the process of selection on the oriental varieties imported in Europe and on the local wild populations. They are also the result of gene introgression of the imported vine- types into the local ones (Scossiroli, 1988; Scienza et al., 1990). Because of the homogeneity of the phenotypes and the difficulty of making an accurate ampelographic identification, the varieties remain in the multiple form of polyclones (De Lattin, 1939; Levadux, 1956; Rives, l c.). The incidence of virosis of the local plant population and the mutations, which occur spontaneously, have also helped to increase variability.

To date, polyclonal origin of the cultivar has not been proven, even though molecular biology techniques have increased the potential to thoroughly investigate genetic heterogeneity within the varieties of vines (Mullins et al., 1992). In traditional strategies of clone selection, the genetic base of the initial variety-population has often been synthesized in a small number of genotypes that exhibit the greatest number of positive traits. This method (looking for super-clones, suited for every enological demand and environmental situation) seems very difficult due to a series of factors. The most important factors are: the strong influence of the growing environment which disguises the expression of the genotype; the reduced frequency of combined positive factors, which then become difficult to identify; and, often, positive factors are associated with negative factors, which causes the exclusion of the genotype of the selection. Moreover, this type of selection contributes to genetic erosion, which drastically reduces the variability of the vines that undergo clone selection.

Numerous studies in recent years have demonstrated how clones obtained using this type of strategy (strong selective pressure) represent only a minimal part of the variability investigated and have a reduced adaptability to the different soil-climate conditions of cultivation (Campostrini, 1993). Besides this, wines risk simplification, as they tend to flatten themselves according to the prevailing characteristics of the narrow group of clones certified for that particular vine-type (Brancadoro, 1998). This situation has induced winegrowers, in various winegrowing areas of Europe that are more sensitive to problems of quality, to take a negative stance on clone selection. This has led to the use of propagation material originating from mass selection (Scienza, 1993). Although this solution should undoubtedly be rejected, considering the disease implications (potential virus contamination), it may be the only one suited to the problem.

Even though the study and use of intravarietal variability can be more challenging and require more time, it can be a useful tool for satisfying the needs of modern viticulture. However, using the potential of the genetic background of the single varieties does not mean (as has happened in the recent past) mixing a certain number of clones in variable proportions, according to the "terroir" or to the wine one wishes to obtain. The assembly of the clones, which in most cases come from different geographical areas, has not led to a real, widespread improvement of the wine. The reason for this failure is related to poor compatibility between those clones that were isolated and propagated to be used alone, as each was a good compromise between yield, sugar content and/or the titrable acid. Thus, clone compatibility cannot be based on the results of comparisons of clones of varied origin, but must be based on a specific objective. A re-elaboration of the basic theory of selection for the genetic improvement of plants proposed by Gallais (1990) has identified a different strategy for the genetic improvement of the vine by clone selection: the weak selective pressure method. Weak selective pressure aims to identify groups of clones, as opposed to single genotypes, which together can contribute to widespread progress with respect to the starting population. The single individuals that become members of these clone families are selected not only on the basis of their performance, but above all because of their complementarity. This method intends to preserve the variability, both functional and morphological, of the varieties that undergo clone selection. In addition, maintaining the genetic base of the vines accomplishes two fundamental objectives: 1) to preserve certain characteristics that are infrequent or hard to determine, yet are unquestionably valuable, such as anthocyanin content or particular aromatic characteristics; and 2) to reduce the interaction between the vine and the cultivation site, thereby allowing for a greater stability of the results in the different environments and over the years.

Results of the "Weak Selective Pressure Method" on Sangiovese

Because of its history and diffusion, Sangiovese is surely one of the Italian varieties best suited to undergo the implementation of this new method of selection. The initial survey, performed by the Department of Plant Production of the University of Milan, able to take advantage of such a wide genetic base, identified more than 600 single plants of this vine-type. Morphological and organoleptic characteristics of the grapes were of particular interest. The study of this material was performed in some of the most important growing areas for this vine, such as the D.O.C.G. zones for Brunello di Montalcino, Chianti Classico and Nobile di Montepluciano, in very old vineyards where the original variability had not been lost. Starting with this material and going through further genetic and disease-free selection, about 200 presumed clones were identified and planted in clone test vineyards, one of which is located on the Castello Banfi estate.

A preliminary study was conducted on this material to evaluate the breadth of the genetic variability gathered. This was the first step towards the selection of the Sangiovese clones through the "weak selective pressure" method. A study performed on the 200 initial genotypes enabled the quantification of the elevated variability within this variety. It confirmed the hypothesis that Sangiovese is a "population vine". This approach made it possible to identify a pool of clones that represents the initial population. These studies considered the plant's morphological aspects and its macro-quality characteristics (sugar content and acid profile of the musts). They also enabled evaluation of the variations, found in Sangiovese, of the finer parameters such as the polyphenolic content and the aroma descriptors, which characterize the wines. In particular, it is essential to acquire information about the sensory characteristics of the wines using organoleptic analysis, performed by a panel of expert tasters trained to acquire information about the sensory characteristics of single-clone wines. This is essential when operating in "weak genetic selection" because the complementary nature of the clones affects the olfactory characteristics of the wine. A multivariate statistical method was used to interpret the differences identified among the various single-clone wines and to maintain objectivity. The results are shown in Fig. 6 as a graph. This highlights how the clones under study are different, forming three clearly distinct groups. The first group includes BF10 and 20, Tin 20, and Janus 30, and is organized by phenolic and

ethereal scents, as well as the flavor sensation of red fruit; the second, which includes Janus 10, and Tin 10 and 40, is organized by structure and the flavor sensations of fruit and tobacco; the third and final group has characteristics that lie between the first two. As the reference clone is centrally positioned, it has average organoleptic characteristics.
As previously stated, following the "weak genetic selection" method with a mix of different clones, each with its own peculiar characteristics, will make it possible to obtain more complex and harmonious wines. To exemplify this concept, the results obtained with a mix identified for making wines for medium to long-term ageing are reported. This mix was obtained using the TIN 50 and JANUS 10, 20 and 50 clones in different percentages that were expressly identified to obtain a wine with both good structure and longevity. Each of these clones is characterized by one or more organoleptic parameters, including tannic sensation for Janus 10, structure for Janus 50, typicity for Janus 20, and complexity and red fruit flavor for Tin 50. This complementary nature is evident if one compares the spider graphs (Fig. 7). These represent the sensory profile of the different single-clone wines and highlight how the clones integrate with each other, furnishing the multi- clone blend with superior characteristics compared to the reference clone. The data gathered and reported demonstrate how the "weak selective pressure" method of clonal selection helps determine and best use the potential within vine populations. The clonal mix is thus made up of truly complementary individuals and is no longer the result of clones chosen more or less haphazardly. Synergies among genotypes are thus formed, leading to the production of wine with organoleptic characteristics superior to those achieved by less selective mixtures or from single- clone vineyards. This study has enabled the registration of 11 clones with complementary agronomic and enological characteristics for developing various clone mixtures best suited both to the different soil-climate conditions and to the winemaking goals to which this great vine must respond.

In Depth Analysis of the Characteristics of Selected Clones

The certification of a clone is not the conclusion of a work, but only the first step in the process of genetic improvement by clonal selection. Modern viticulture requires increasingly more detailed and specific information about innovations in the field and the adaptive responses of clones to different environments. For this reason, the research carried out at the Castello Banfi estate monitored the quality and yield results of three clones which were selected using the "weak selection method". These were BF 30, Janus 10 and Janus 50, which were compared to the same reference clone used during the selection process. These clones, grafted on 420A rootstock, were all cultivated in the same soil and vineyard, trained to spurred cordon, and planted to a density of 4166 stocks/ha. During the period from 1998-2001, the ripening kinetics were monitored, taking into consideration both the parameters of the technologic and phenolic maturation of the grapes. Moreover, the vegetative- productive responses of these clones were monitored, and by means of mesovinification (1 ton of grapes per clone), the chemical and sensory characteristics of the wine they produced were evaluated. A comparison of the ripening kinetics of the four clones furnished useful information for evaluating the precocity of different clones in an environment like the Banfi estate. Reported below in Fig. 8 are the average trends for the four-year period being studied, showing the three representative parameters of vegetative-productive development (mean berry weight), technologic ripening (sugar content), and phenolic ripening (pH3.2 extractable anthocyanins). These graphs demonstrate how the four clones have different average ripening trends. In detail, clone Janus 10 has the latest technologic and phenolic ripening of the grapes, while Janus 50 has the earliest. This latter fact is further confirmed when using the berry weight parameter, because this clone has an early development of the grape in the first phase and successively loses weight when nearing harvest, probably due to over-ripening. Furthermore, when observing the data concerning the phenolic ripening parameter, which is of extreme interest for a vine like Sangiovese, the clones have different kinetics. The BF30 and Janus 50 clones show accumulations of extractable coloring substances, which appear quickly in the first phase and then tend to stabilize, while the development of Janus 10 and the reference clone is slower and more regular. However, at harvest, it reaches values, which are similar to those for the other clones. Finally it is necessary to stress how the mean values at the different sample dates, for the different parameters analyzed, can generally have even very high standard variations. This can certainly be ascribed to the strong influence that the passage of the season has on the productive and quality responses of Sangiovese. Moreover, the standard deviation values vary considerably from one clone to another, indicating the clones' different reactions to the weather conditions. For this reason, the stability of the clones regarding these parameters has been evaluated. Two indices of phenotypic stability were used: standard variation and coefficient "b" of the regression curve, where lower values indicate a higher degree of stability. The combination of these two indices enabled the evaluation of each clone's stability by furnishing a certain result over the years and/or in different environments. The results, together with the mean four-year values of each clone for each parameter at harvest, are reported in Table 1. Observing and comparing these data, the four clones have a different constant for the various parameters used to evaluate grape maturation. In particular, the Janus 10 clone had the greatest potential for adapting itself to climate changes during the four-year period, yielding consistent results for both technologic and the phenologic grape ripening. The other clones, instead, reacted more to climate conditions, particularly BF 30, which was erratic in both the phenolic and technologic values of ripening. The reference clone had erratic levels of phenolic ripening of the grapes, but consistent technologic ripening ones. Finally, Janus 50 was consistent for some parameters used for evaluating the phenolic and technologic ripening of the grapes. The results of the statistical analysis at harvest (Tab. 2) show how there is a statistically significant differentiation of the four clones regarding the macro-qualitative parameters of the musts. This is also true for the fertility and vigor values demonstrated at pruning, thus confirming the influence of the clone choice on the quality of wine production. These data also confirm the different characteristics that the clones had shown during the phase of clone selection in the clone test plots. This result shows how the characteristics presented by the clones are largely genetically determined and that the selection methods used were effective for evaluating the clones during the selection phase. Furthermore, sensory analysis results, carried out during the four-year experimentation on the single-clone wines produced, show that the clone effect is highly significant. The mean values of the single-clone wines are illustrated as a graph, and this data, using ANOVA, highlights a significant effect of the clone on the ripe fruit, spicy, acid, structure, and persistence descriptors. Moreover, these data confirm the results obtained during the studies carried out for the clone certification. In particular, Janus 50 furnished wines with an ample aromatic profile, characterized by typical notes of the vine-type while the reference clone had less intense aromatic characteristics, with a prevalence of floral and red fruit notes.

In conclusion, this deeper study of the quality and production characteristics of the grapes and wines of the four clones underscores how the choice of clone is fundamentally important when planting a new vineyard. The different characteristics these clones presented subsequently became differentiated in a highly significant way. In addition, it became evident that it is necessary to start planting poly-clonal vineyards to take advantage of the greater complexity of the production these vineyards furnish. Doing so also helps mitigate the vintage effect on the quality and production characteristics; the vintage may have a different impact on the performance of each clone.

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Tab. 1 - Evolution of the phenotype stability of the four clones under study.

		Anthocyanins at pH 3.2	Anthocyanins at pH 1	Seed Tannins Weight	Average Berry	Sugars	Malic
Referen-ce Clone	Average Variation	648.2	1248.9	38.4	2.4	19.8	1.6
	Standard b	121.4	171.0	10.6	0.10	0.73	0.36
	Stability Rating	1.20	1.52	1.44	0.42	0.72	0.44
		Unstable	**Unstable**	**Unstable**	**Barely stable**	**Stable**	**Stable**
Janus 50	Average Variation	656.2	1372.1	35.3	2.2	19.7	1.5
	Standard b	125.0	69.1	9.7	0.19	0.49	0.38
	Stability Rating	1.24	0.80	1.31	1.89	0.71	1.17
		Unstable	**Stable**	**arely stable**	**Unstable**	**Stable**	**Unstable**
BF 30	Average Variation	689.5	1272.9	35.4	2.2	20.2	1.6
	Standard b	113.2	147.0	9.7	0.06	1.53	0.38
	Stability Rating	1.02	1.65	0.85	0.60	1.98	1.46
		Unstable	**Unstable**	**Barely stable**	**Stable**	**Unstable**	**Unstable**
Janus 10	Average Variation	660.3	1349.9	29.1	2.2	18.9	1.2
	Standard b	76.8	89.3	6.4	0.14	0.28	0.29
	Stability Rating	0.50	0.01	0.36	0.04	0.2	1.04
		Stable	**Stable**	**Stable**	**Stable**	**Stable**	**Barely stable**

Tab. 2 - Comparison of the different clones for the vegetative-productive and quality parameters gathered at harvest (mean values for the four-year period). The values followed by the same letter were not statistically different.

Parameters	BF 30	Reference Clone	Janus 10	Janus 50
Vine production (kg)	3.2 a	2.6 a	3.2 a	2.4 a
Pruned wood (kg)	0.98 ab	0.91 ab	0.79 a	1.07 b
Average bunch weight (g)	334 a	365 a	369 a	323 a
Fertility	0.85 a	0.90 ab	1.0 b	0.79 a
Sugar (°Babo)	22.3 b	21.5 a	21.8 ab	22.4 b
pH	3.46 ab	3.53 b	3.43 a	3.52 b
Total Acidity (g/l)	6.45 b	6.60 b	6.15 ab	5.76 a

THE WILD VINE AND THE ORIGINS OF CULTIVATED VARIETIES

A. Scienza, O. Failla, R. Anzani

When walking through the hillside woods of Maremma along the border between Tuscany and Lazio in autumn, or by the fields of harvested wheat at the foot of Mount Amiata, where pools of water collect in the ancient faults of the clay soil during the rainy season, the keen observer, aware of Nature's more subtle manifestations, will notice various vines. Some are quite large and wrap themselves around the giant oaks, reaching and colonizing the tree-tops. Hunters, well aware of this particular aspect of Mediterranean flora, use the vines as natural bait to catch blackbirds and thrushes. Some rare specimens of these vines are still found on the slopes of Mount Baldo in Trentino, Italy's northernmost region, in the last section of woods of the moranial hills that separate the Adige depression from the southern part of Lake Garda and extend from the valleys at the base of the Lessini mountains to the plains of Verona. Are these vines really useful specimens, survivors of the destruction wrought by glaciers, or, instead, were they spontaneously sown by birds that ate cultivated grapes? The answer, although seemingly obvious, can be drawn from the acute observations made by Levadoux (1956) concerning the vine types and ampelographic aspects and from Sereni (1981) for the cultural-semantic perspective. The wild vines, although related in some ways to the cultivated types, from the point of view of both genetics and the domestication process, are nevertheless distinct.

The wild vines, currently threatened by the strong pressure of "human progress," which limits their diffusion, are the last heirs of those primitive vines that managed to survive the glacial pulsations, finding refuge in numerous areas of Mediterranean and Atlantic Europe. Starting from the Neolithic era, they were used first for berry gathering, and then in primitive cultivation for the first vinification.

The Origin and Classification of Cultivated Vines

The origin of the *Vitis* genus, to which both the wild and cultivated vine belong, goes back to the Upper Cretaceous period, coming from older genera such as the *Cissus* and the *Ampelopsis*. This genus was very widespread then and could be found in the arctic areas of Europe, eastern Asia, the Americas and Greenland. During the last two ice ages, all the northern species disappeared and only a southern specie, the *Vitis vinifera*, remained in Europe. In Northern America, due to a different disposition of the glaciers along the Rocky Mountains, the glacial relics were more numerous. Even today this is proven by the greater wealth of spontaneous species found in the North American flora. After the continental drift, completed in the Miocene era, and after the separation of the North American continent from Europe and the creation of Africa and Australia, three groups of species were formed. They are currently represented by the Boreo-American (with 28 species), the Oriental-Asiatic (with about 40 species) and the Euro-Asiatic group, composed exclusively of *Vitis Vinifera*.

The first vines appeared in the Pliocene era. Later, during the ice age, the Vitis vinifera retreated to refuges around the western Mediterranean and partly in the east (Caucasia), fragmenting its area of origin during the course of the successive ice ages. This explains why there is a substantial unity of the species but a contemporaneous geographic diversity of its forms. The vine later made its way up north and in the hot period of the Neolithic, it reached the 50°-52° latitude (Southern Sweden and Denmark). From the oldest remains (the grape seeds), it is easy to understand that V. v. silvestris is the subspecies that appears earliest, while the V. v. sativa appears only at the end of the Bronze Age and the beginning of the Iron Age. The hypothesis of monophylogenesis of the Vitis genus is the most probable. The parental form of the genus was monoecious with hermaphrodite or polygamous flowers from which the dioecious species (V. v. silvestris) derived. According to De Lattin (1939) and Levadoux (Ibid.), the European cultivated vine types and their parental wild types were the result of the glacial pressure of the Quaternary period on the southern areas of the Continent. In this way, two centers of vine variability were formed. There was a Mediterranean one, which includes the big peninsulas and islands of the Mediterranean, Asia Minor and North Africa, and a Caspian one, which corresponds to the mountainous regions between the Black Sea and India. This hypothesis partially modifies the earlier one put forth by Vavilov (1926). This Russian scientist was the father of the theory of the center of origin and of the diversity of plants. He hypothesized a single center of origin for the vine, located around the Caspian Sea, basing his hypothesis on the abundance of this species in the Trans-caucasian regions.
Rives (1974) affirms that, from a genetic point of view, the origin of the cultivated vines came about through a domestication of the V. v. silvestris and through a gene introgression of the V. v. sativa in this subspecies. Levadoux (Ibid.), however, rejects the distinction between the two subspecies, which he considers two evolutionary stages of the same species, the V. v. vinifera, whose evolution began first in the Eastern Mediterranean and Caucasian Region about 5.000 years B.C. due to better environ- mental conditions and a more precocious cultural development of the population in those regions. In fact, he asserts that the taxonomic position of the V. v. silvestris compared to the Vitis v. sativa is neither that of an autonomous species, nor of a subspecies, but can be identified with the V. v. sativa. The latter is no more than a collection of varieties which, if allowed to grow wild, would end up identifying themselves, at last, with the wild forms. The dioecious character of the wild vine is not a distinctive characteristic of the cultivated vine since this sexual expression is also found in some cultivated vine types of Western Europe and it is even a very widespread trait in the cultivated varieties. For example in Nuristan and in Afghanistan, due to the favorable climactic conditions, during the blooming period the gynoecious flowers do not compromise regular productivity. The dioecious type is more favorable for the diffusion and adaptation of a wild species since it guarantees a greater variability and the constant appearance of new genotypes. Moreover, often the wild dioecious vines that are cultivated become gynodioecious since the pistils in the male flowers develop completely, while in the female ones there is no reappearance of male fertility.
De Lattin (Ibid.) makes a further distinction between the western and the Mediterranean wild vines, called Silvestris, and the Armenia and sub- Caspian ones called Caucasia.
The classification in varieties of the Vitis vinifera is very complex. The seeds and the shoots of the cultivated varieties, the most widespread means of agamic propagation known since ancient times, were brought from one region to another. Together with certain forms of wild vines, selected on the spot, they formed the ampelographic platform of the European vine growing zones up to the present, notwithstanding impoverishment due to genetic erosion. This process began parallel to the great migrations of past populations, and has not yet been completed. This makes it extremely difficult to separate the aboriginal vines from the foreign ones. Only by analyzing the DNA polymorphism of the wild and cultivated vines of a region is it possible to understand which types have been imported and which are truly indigenous (Imazio, 2004).

Vine types are most commonly classified according to their geographic origin. Subconsciously, subdividing the types by region of cultivation takes into account two fundamental aspects that are innate in the domestication of a plant species: the interaction with the environment in the expression of the phenotype traits that are of agricultural interest, and the cultural level of the population that makes the selection.
Vine types coming from a certain region have common traits that make them recognizable.

The value of these assertions is, however, circumscribed on the one hand by the varieties deriving from the domestication of V. silvestris occidentalis in western Europe, which gave rise to the vine types that can be traced back to the so-called Lambrusche, and on the other by the varieties of the V. silvestris orientalis in the regions of Transcaucasia and Mesopotamia, from which stem most of the vine types currently cultivated in the world. There is another group of varieties, whose distinctive traits are not known, which originate by gene introgression (Rives, Ibid.), that is, from the encounter between the genetic heritage of the eastern vines with the western ones, and the subsequent gamic multiplication. The difficulty to identify a common cultural and geographic origin of the vine types in Italy is intensified by the imposing influx of the eastern genes, which took place during the colonization of the southern part of the Italian peninsula and Sicily, and by their later diffusion towards other western European areas. Following a process of acclimatization, the selection of the material, often imported as grape seeds, resulted in the creation of new varieties better suited to the environmental conditions of the new areas of selection when compared to the original ones. The correspondence between the area of origin, the ampelographic and carpological characteristics, noted also in the past, even by the Georgic Latins (the Aminee coming from Tessalia, the Bituriche from Epiro, the Allobrogiche from the western Alps, the Etesiaca from Arezzo, etc.) was developed first by Negrul (1946), De Lattin (Ibid.) and later by Levadoux (Ibid.) on the basis of Vavilov's theories (Ibid.) relative to the primary and secondary centers where the genetic variability of the European vine had developed.

From Wild of Cultivated Vine

The archeological proof, though slight, as Forni defines it (1975, 1996, 1999, 2000), shows that before becoming "sedentary," the wild vine was a shrub among the many producers of edible and fermentable berries (cherry, rowan, elderberry, cornelian cherry, etc.) and the product obtained was inebriating because of its alcoholic content, and it was also easy to preserve. The ethnological study of contemporary peoples provides ample evidence of a widespread use of fermentable sugary drinks of different origin: birch lymph, milk, honey diluted in water, malt, as a continuation of prehistoric traditions (Fedele, 1991).
But in a certain historical phase that coincides with the birth of human settlements, where the climatic conditions were favorable for the cultivation of the vine, for example in the Mediterranean area, the grapes and the wine obtained from them prevailed over other raw material used for producing fermented drinks. "In other words, man and vine are considered two agents that, in certain conditions, react in symbiosis." (Forni, Ibid.) Viticulture begins as a long process of cohabitation of man with the vine, during which man observes and analyzes the behavior and characteristics of the plant, first protecting it, then finally cultivating it. This identification of the primitive farmer with the vine is still found in primitive African farmers, as Frobenius affirms (1938) and leads man to "think along with the plant."
This personal relationship between man and plant provides the basis of the domestication of many other wild plants, above all, those which thrived among a village's waste, since it allowed for a continuous observation that lead to the isolation and multiplication of the most productive plants and of those with best-tasting fruits. This was a long process which lasted at least one thousand years in the near East, beginning from the late Neolithic age, around the fifth millennium B.C. (Zohary, 1995, Gorny, 1989), as proven recently by the finding of calcium tartrate crystals in a small jar dated to the late Neolithic era

(Mcgovern et al., 1995). The finding was confirmed by Renfrew's discovery (1995) of grape seeds dating back to the sixth millennium B.C. in a region of Greece where some of the seeds had some of the morphological traits of cultivated vines, even though they came from wild plants.

Analogous to other plant species, the domestic vine grows in the dump heaps of prehistoric villages. It follows that, in these humid and fertile places where the vine could develop easily and climb on other fruit trees, the dump heap model, because of man's selective action, favors the female plants, and above all the hermaphrodite one, which makes up a small minority of the population (around 5-6% of the total population) (Scienza et al., 1992, 1993). This possibility of selection was also favored by the high degree of heterozygosis of the vine, which is evident in its seed spreading and in its easy agamic reproduction. For this reason, primitive viticulture is called "by protection or antrophily."

The process of domestication that coincides with the change-over from primitive hunter/nomad to sedentary farmer, and thus the need for a continuous presence in a given place ("by domesticating the vine, man domesticated himself"), also benefited from the introduction of the plow in the primitive agriculture of the Neolithic-Eneolithic era in Western Europe. This caused a real socio-economic revolution as the development of cereal cropping and cattle raising created conditions of well-being within the villages, which not only allowed the rise of new professions (blacksmith, craftsman of terracotta, leather and cheese, etc.), but also favored the production and trade of wine. Evidence of the cultivation of these vines- also called domesticoids- has been traced back to the Late Neolithic period in various regions of the Mediterranean (Walzer, 1988; Castelletti et al., 1987; Costantini e Costantini Biasini, 1999). As the Asian peoples gradually colonized the southern and eastern coasts, these vines were replaced by completely domesticated varieties of the Near East, where village formation began much earlier, and thus the domestication process evolved faster. In the inland areas and along the periphery of the territories most affected by colonization, domesticoid vines remained under cultivation much longer. Even today, it is possible to recognize them in primitive forms of viticulture (the lambruscaie of Maremma).

Cases where there was a passage from the wild vine to the domestic one, highlighted by the length/ width ratio of the grape seed (index of Stummer, 1911), can be related to the growing presence of domesticated vines among the domesticoids, and also to the phenomena of gene introgression. Gene introgression, mostly in Southern Italy, occurred because of the considerable input of previously domesticated genotypes, coming from Greece. In the older Mediterranean languages, the presence of residual traces, which associate wild vine with dump heaps, is singular. In Etruscan-Nuragic (Pittau, 1984) the word for village (spur-, spure) and for filth (spurie), of which dump heaps are made, are related to the word in Sardinian dialect for wild vine (spurra, ispolu, isporula). Even today, in some farming communities in Lower Maremma some extant forms of the wild vine of the domesticoid type can be found (called Lambruscaie). These forms require a specialized cultivation for spontaneous plants of a considerable age (200-300 years old) present in the woods along the borders of clearings or drainage ditches. The fruit setting of these vines that grow on the big oaks is aided by limiting the competition of the tutor-plants. The most invasive branches are cut and every 3-4 years; the more developed vine shoots are pruned. This is the only human intervention. The grapes produced are not harvested every year, but only when a boy is born in the community since the wine obtained is consumed for his wedding, after 25-30 years. Such is the length of time this wine lasts both for its abundance of tannins and color.

Historical, Cultural, Literary and Paleo-Botanical Proof of the Wild Vine in Europe

When using traditional academic methods and models to determine the vine's role and importance in the history of European viticulture, it is necessary, at first, to draw a line between history and myth, between traditional folklore and archeological and semantic evidence.

The earliest literary evidence of the origin of the labrusca (the wild vine) is furnished by Virgil in the Eclogues (V,6), "Aspice ut antrum silvestris raris sparsit labrusca racemis" and in the short poem Culex (51) "Pendula proiectis carpuntur et arbusta rais densaque virgultis avide labrusca petuntur". The first verse describes a vine shoot, while the second deals with the wild vine's fruit. Labrusca is a Latin regionalism of the Po river valley used to define the wild vine and comes from the paleo-Ligurian culture of which Virgil, a native of Mantova, was a connoisseur. These were followed by "Romance terms" ones, not only in the spoken languages of Italian (abrostina, abrostola, raverusto, zampina, etc.), Provençal, French and Corsican, but also in the Catalan llambrusca and the Romanian laurusca (Sereni, Ibid.). Rolland (1900) lists more than one hundred terms used to indicate the wild vine. The term labrusca, in its semantic contents, predates not only the Roman presence in Northern Italy, but even the Etruscan colonization and the Celtic invasion. Its persistence shows the role played, above all, by the Po valley populations in the domestication and use of this grape as an edible and fermentable fruit, before Greek culture asserted itself in Italy.

In Italy and in Western Europe in general, the evidence of a distinction between wild and cultivated vine is found only in the late Roman age, and until the first half of the 19th Century, at least in some areas (for example Emilia), it remains very hazy. In the ancient world, especially the eastern one, the cultivated vines and the wild vines have long since been considered to belong to different taxonomic groups. Dioscoride, commented by Mattioli (1571), in the first century B.C., makes a distinction between cultivated vines (Oenophoros ampelos) and wild vines (Agria ampelos), previously described by Teofrasto in his "History of Plants". The noticeable differences are not only due to the degree of domestication, but also to the fact that the wild vine category had non-fruit- bearing types because they were dioecious and the flower of the male members often served the purpose of giving aroma to the wine, which was obtained from the hermaphrodite varieties. After citing some of the Latin Georgics, it is necessary to wait until the Middle Ages, when Pier De Crescenzi (1495) mentions wild vines again ("white and black labrusche that grow on the trees, have small and sparse bunches which could produce much more if they were cultivated".) Their use improved the quality and longevity of the wines. Bacci (1596), neo-Latin georgic poet and papal physician, in his Italian oenography refers to the "cultivation of white and reddish lambrusche to produce sparkling wines." Tanara (1644) when describing the viticulture of Bologna speaks of Lambrusca as a seed reproduced vine "which in the wild is perfect." From his observations, it is easy to presume that in the Po valley area, the lambrusca were not considered cultivated vine types and that their propagation was carried out using seeds. In the 1800s, the descriptions of the wild vines become increasingly detailed, even if the literary sources are less frequent, mostly due to the creation of the important ampelographic collections and because of the interest shown by the experts of those times, above all, in the French varieties. Acerbi (1825), rightly held to be one of the foremost among the first modern ampelographers because of his geoponic classification of grapes, furnishes an organic description of the numerous Italian lambrusche found in his collection of Castelgoffredo. In particular, among the Po Valley's lambruschi, he describes a Lambrusco present in the area of Brescia called ua *ozilina* which was not cultivated but grew spontaneously wrapping itself around tall trees. Its grapes were acidic, unless they remained on the plant for a long time and became over-ripe. Among the grapes in the province of Verona, he speaks of a Lambrusca also called *oselina* that grows naturally in the shrubs and sometimes is used to make "*vino eletto*". He also describes the Tuscan *Abrostine*, supposing they are the lambrusca described in the Latin Georgics, the *Lambrostega* found around Trento and *Lambruscat* of the northern Pyrenees harvested in the botanical gardens on Geneva. Even Beretta (1841), Zantedeschi (1862) and Perez (1882), when speaking of native vine types of the Veronese hills, mention the white and red lambrusca, as cultivated varieties. There is a wealth of documentary evidence showing both the presence of the vine as a wild species in Europe (France, Spain, Germany, Hungary, Turkey, to cite some of those with most documents) and its ancient cultivation, especially in southern and Atlantic France, and in Corsica.

The Variabilities of Germoplasm of the Wild Vine in Italy: Strategies for Exploration, Collecting, Description and Conservation

The methodical census, begun in 1984 by some of the researchers of the Institute of Arboreal Cultivation of the University of Milan, has discovered, to date, over 150 sites in Italy where 372 individual plants have been identified. The technique used was to maximize the number of sites explored rather than to analyze the sites in depth. This enabled the evaluation of a wider variety of phenotypes, even regarding the mixed type of reproductive systems common to the wild vine, following the hypothesis that inside each observation site, the prevailing reproduction method is the vegetative one. The area of greatest diffusion is central Italy (southern Tuscany and northern Lazio). To study the ampelographic and genetic traits and to counter the strong genetic erosion to which the wild vines are exposed in Italy, collections *in situ* have been created and, to avoid *state conservation* that characterized the *ex situ collections*, areas particularly rich in natural variety have been studied and protected, such as the Ombrone bank located at Banfi in S. Angelo in the territory of Montalcino and Grosseto.

The Possible Relationship Between Cultivated and Wild Vines: The Contributions of Classic Ampelography, Chemotaxonomy and Molecular Biology

This problem is particularly complex and almost twenty centuries of vine growing history and tradition have not yet resolved it. If some of the evidence rooted in myth supporting the opposing theories is eliminated, what remains can be divided into three main groups, the richest of which is the historical-literary one. The most reliable sources are the archeological and paleobotanical findings, while the most promising results come from the fields of chemotaxonomy and molecular biology. An interdisciplinary approach to the study of the origin of the cultivated varieties is needed that will draw from the fields of archeology, botany, genetics, chemistry, anthropology, agronomy, and linguistics. Normally, the main sources of information and study are represented by the remains of plants (principally grape seeds and pollen) obtained from archeological excavations and from the study of individual species considered to be the ancestors of the cultivated varieties.

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Historical-Literary Sources

Currently the term "lambrusco", used to designate varieties of cultivated vines, is geographically more limited and semantically different from the past, since it is used to identify a group of varieties cultivated in the Po Valley. However, it is impossible to ignore that in the past the primitive area of diffusion of the lambruschi (Piedmont, Lombardy, western Veneto, and Emilia) corresponds roughly to the area populated in the proto-historical era by paleo-ligurian peoples, and thus represents the results of the first domestication of the wild vine. Moreover, in the 19th century cultivated vines, known for their rusticity, with small berries, a highly colored skin and strongly colored leaves in autumn were often generically called "lambrusche". In vast areas of Piedmont and Lombardy the varieties that produced bitter (rustic) wines, were frequently called Crovet, Croà, Crova, Crovattina, synonymous with lambrusco and associated with the Lambruschi also because of their enological traits. In Campania, in the fields around Aversa, an area of ancient Etruscan presence, the name of the vine type Asprino (slightly bitter) has an analogous semantic meaning as Cruet or Crovet. To support the theory of living guardian, the practice of biennial pruning in the area of Caserta (like that for the lambrusche of Modena) should not be underestimated, nor should the almost exclusive presence of the term cianfrusco, a popular continuation of lambrusco, in the southern region. An anonymous Lombard author of the 19th century reflects on the local wild vines, called Oselete, and going beyond simple ampelographic descriptions or enological destinations, he affirms that certain widely cultivated vines, such as Pignole, Corbine, and Rabbiosa, (or Rabosi) were very similar to the wild vines.
It is not always easy to understand, when reading viticultural reviews and books on botany or medicine of the 1800s or even earlier, the ambiguity concerning the varieties recognized as lambrusche. For certain varieties, such as the ue ozeline or the ue salvadeghe in Brescia, or the Refoschi in Friuli or the Ambrosche around Verona or the Raverusti in Tuscany, there was never a distinct delimitation between vine varieties and cultivated wild vines. It would otherwise be difficult to explain why a great number of vine types, most of which have disappeared nowadays, that despite having quite different characteristics, were known by the generic name of "lambrusco." This aspect is not found in other varieties, where the name of the vine type is accompanied either by an area of selection or cultivation, or by the characteristics of the leaves, of the grapes, or by the name the breeder. Also other cultivated vines in very old European vine areas show evidence, though less explicitly than the lambrusco, of their origin from a domesticated wild vine: Savignin, Sauvignon from plant sauvage, Barbaroux from the Latin barbarius, savage, Jaquere from the late-Latin gascaria, uncultivated land, Servadou from the Latin silvo, forest, Fer from the latin Ferus (wild), Riesling from the German reissende Tiere (wild animal), Chenin from the Latin caninus, Cabernet, also called Acheria in Basque, which means fox, and finally, Petit Verdot, synonymous of Lambruschet (Levadoux, Ibid.).

When describing the multitude of vines that phylloxera soon wiped out, many ampelographers highlighted the close morphological tie between the wild vines still present in the shrubs and woods. In some areas, these wild vines were looked after rather perfunctorily to use either the male flowers, to be infused after they had withered for the production of so-called Enontini wines, or for the berries, used to strengthen the color of the grapes of the cultivated vines.
The association and close identification of the vine with the tree is very suggestive and emblematic not only for the vegetative-productive traits of lambrusca, which almost cannot bear any form of pruning, but also because of the ideal contiguity between the "ancestor" wild vine that remained in the woods and those that were domesticated and cultivated. The Arbustum gallicum, a cultural trait of paleo-Ligurians and Etruscans, described later by many Latin georgics, was the model of vine cultivation in central and northern Italy where the cultivated vines derived from domesticated wild vines.

In contrast with this is the form of cultivation called *ad vinea*, or trellised, which was introduced together with the vines of eastern origin in southern Italy by the ancient inhabitants of Magna Graecia and by the Mediterranean seafarers, bearers of the myth of wine.

The Sources of Paleo-Botany

Besides being documented by the usual multi- disciplinary descriptive-taxonomic analysis, the origins of the wild vine are also documented by the study of the spatial distribution of the remains studied by the so-called *archeology of the inhabited areas*. This allows for a better understanding of the relationship between a site being examined and the surrounding territory. Regarding this, the information derived from the grape seeds, and in some cases from the pollen, is very important, as they are often the only traces remaining from the pile-dwellings and from the *terramare*, ancient villages surrounded by the sea. The oldest evidence dates back to the Lombard Neolithic (Rivarolo Mantovano, recent Vho culture findings, about 3980 years B.C.; Barche di Solferino, Antique Bronze Age, around 2000 years B. C., Bande di Cavriana, Bronze Age and Valeggio on the Mincio, Late Bronze Age, around 1100 years B. C.) (Forni, 1975). For the study of fossilized grape seeds, the length/width ratio, also called Stummer index, was used. Usually the lower values are related to the cultivated varieties (0.44-0.53) while the higher ones to the wild varieties (0.76-0.83). Even the palynological investigations (although in limited case studies), make it possible to trace not only the era in which a vine appeared in a certain site, but also to what type it belonged. These indications, together with the contributions of paleoclimatology and phytopaleontology, indicate that the last important event concerning the evolution of the wild vine goes back to the last Ice Age, called the Würm, that pushed the vine's area of diffusion towards the southern part of the European continent. In this manner, two secondary centers of diversity or refuge were created (that gave rise to corresponding geographic families) one of which was Mediterranean, while the other was southern Caspian. On the basis of these considerations it is possible to distinguish the wild vine of a western or Mediterranean area (called *silvestre*) from an Armenian, and sub Caspian (called *Caucasica*). Furthermore, Negrul (Ibid.) affirms that east of the Caucasian regions V. v. *Silvestris* are no longer recognizable, but only spontaneous individuals belonging to V. v. *sativa* that were planted together with the cultivated varieties in primitive forms of agriculture. The existence of a new type, called *aberrans*, with characteristics intermediate between the two, has also been hypothesized. After the Ice Ages, the vine conquered the temperate northern regions once again, overtaking the present northern limit in the hotter Neolithic Era, as shown by findings of grape seeds and palynological analyses carried out in southern Sweden, Brandenburg and Denmark. This botanical boundary was identifiable, until the "Little Ice Age" of the 14th century, with the boundary of cultivation that went up to Scotland and the Alps, making it economically viable to plant both the vine and the olive tree up to 1500 meters above sea level in the Valtellina, a region located in the Lombard Alps.

Results of Research in the Fields of Ampelometrics, Chemotaxonometrics and Molecular Biology

The classical approach to phylogeny, which is based essentially on common metabolites shared by two individual species that also have morphological analogies, is usually represented by the diagram called *anthropomorphic*. This diagram has its roots in Greek philosophy and has been used by generations of naturalists and botanists, even modern ones, who have studied and applied ampelography as the key to understanding the origin of the cultivated vine.

According to this diagram, the wild vine can be considered the progenitor of the most of the cultivated varieties. Neither the existence of differences between the varieties nor their differing geographical origin is easily proved using solely techniques of morphological evaluation. Recently, chemotaxonomic techniques have been added to the classical tools of ampelographic analysis. Starting from the presence of certain so-called secondary metabolites, such as the isoenzymes and the anthocyanins of the skin, it is possible, on the one hand, to analyze the phenotype variability present in the Italian wild vine populations, and on the other hand, to evaluate their phylogenetic relationship with the cultivated vines (Scienza et al., 1990a and 1990b, Mattivi et al., 1990 and 1993). In particular, wild vines were found to lack esterificated anthocyanidines more frequently than cultivated ones, and in general, the variability of their anthocyanic profile is inferior to that of the cultivated vines. Furthermore, among the wild vines, there are none in which peonidin 3-O- glucoside is present in a significant concentration, which is instead characteristic of vine types of oriental origin. However, in the anthocyanic profile of wild vines, cyanidin 3-O-glucoside is found in greater concentrations. By comparing the analysis of the anthocyanic profile of some native vine types, grouped according to their geographic provenance, with wild vines found in the forests of the same areas, the vine types found in Emilia and Tuscany bear a remarkable similarity to the ones found near Veneto and Trentino, as well as to the Lambruschi. However the north-eastern Italian vine types have a simplified profile in which malvidin 3-O-glucoside prevails. The profiles of southern vine types are quite different, and peonidin 3-O- glucoside is prevalent, while it is absent in wild vines and in the lambruschi. Comparing some vine types from the northern Venetian-Po Valley to each other and to wild vines found in the woods of Mount Baldo and of the Lessinia area, it has been possible to highlight characteristics of marked similarity between the wild vines and a group of Verona's vines no longer being cultivated, such as Dindarella, Pelara, Quaiara, Rondinella, and Oseleta as well as Trentino's Lambrusco a foglia frastagliata (now called Enanzio). This leads one to believe that many vine types which were cultivated in the past around Verona and the surrounding areas derived from the direct domestication of the wild vines, which were found in the areas of the Lower Lake Garda and the middle tract of the Adige river at the end of the first post Ice-Age epochs, as endemic relic of the glacial pulsations (Scienza et al., 1990).

If, on the one hand, by analyzing the polymorphism of the iso-enzymatic profiles of some proteins of the pollen's walls, the endosperm of the grape seeds and of the root apex, using the bands of the proteic sub-units and iso-enzymatic ones relative to alcoholdehydrogenase, glucose 6-phosphate dehydrogenase, acid phosphatase, phosphoglucanase, it was possible to clearly distinguish the wild vines from the cultivated ones. On the other hand, it was not possible to find analogies between wild and cultivated vines of the same geographical origin (Scienza et al., 1994). A direct analysis of the amplified genetic sequences makes it possible to set up a data bank where one can compare and distinguish a great number of varieties. With this technique, it is possible to analyze the DNA variability, both nuclear and plasmidial, using the polymorphism of the restriction fragments (RFLP) or the micro-satellites (SSR) and the chain reaction of the polymerase (PCR). The initial, and certainly not the most complete, results show that it is possible to distinguish fairly well not only the members belonging to two subspecies, but also the different geographic provenances of the wild vines, highlighted by particular aplotypes (Grando et al., 1995 Grasso et al., 2002 and 2003).

But the most interesting aspect, which recently emerged, is the irrefutable proof, highlighted for the first time, that the wild vine contributed to the formation of the cultivated vine types of Western Europe. This result was achieved through the use of an interdisciplinary approach, based on anthropology, linguistics and molecular biology. When dealing with the problem of the origin of the types of vine, which is very different

from that of cultivated cereals, it is impossible to ignore the contribution of works by Gimbutas (1997), on the one hand, and those of Renfrew (2001) on the other. Two distinct theories derive from studying the interdisciplinary research carried out by the American researcher of Lithuanian origin. The first one states that the origins of European culture are marked by a strong polarity on the level of values and symbols (sedentary farmers versus nomad stock-breeders) and the second asserts that this polarity has had a precise correspondence on the level of linguistic expression: the languages of the nomadic breeders of the plains were Indo-European while the farming societies of ancient Europe spoke non- Indo-European languages. Of what value are these two statements for genetic research in viticulture? They are fundamental since they generated innovative lines of research and caused lively debate from which emerged the population of modern Europe as we know it today. The vine types present therein are the result of the interaction of various traits, transmitted by non Indo-European societies, with the values of the nomads of the steppes. Another well-known archeologist, Colin Renfrew, counters this thesis. Although he does not deny that European Neolithic societies had similar characteristics, which were quite original and not found in the following ages, he ascribes the evident social and spiritual changes that divide the ancient European societies of the classic age to divisions rather than further stratification due to new vast-scale migrations. Without going into further detail, Gimbutas and Renfrew's hypotheses about the migration of Indo-European people, after an in-depth analysis by linguists and archeologists, agree totally and represent only the phases of a single evolutionary process brought about by populations, which, coming from the steppes, gradually adapted themselves to the environmental and social conditions of the peoples they met.
Thus, next to the hypotheses that postulate the oriental origin of some types, the concept of the domestication of the vine in the Neolithic age is gaining ground, also due to the growing acceptance of the "native" theories. If the objective is to design a map of the varietal population correlated to the territories of Europe, based on the gene frequencies evaluating nuclear and mitochondrial DNA polymorphism, in order to know the paths and temporal developments of the diffusion, it is not only necessary to gather all the oriental germoplasm, but above all, to locate and safeguard the wild European vines from an inexorable erosion, because it is in these, as Levadoux said, that the secret of the origin of our viticulture is hidden.

The Wild Vines of the Castello Banfi Estate: Census and Conservation Strategies

Research began in the '80s (Scienza, 1983) and covered a fairly large area that extended from the foot of Mount Amiata to the banks of the River Ombrone. Damp areas, watercourses (even very small ones), the borders of cultivated fields, where fruit trees or isolated oaks grew, were all explored. For descriptive and cataloging purposes, the indications suggested in Scienza et al. (1986, 1989), and Anzani et al. (1990) were used. Particularly, there are summary data relative to phytosociology, such as the type of vegetation and the kinds of plants that are the guardians of the vines, and about the ecological characteristics, such as the kind of environment and the level of human impact. At each site, the vines were classified in relation to the plants' development and sex, whether observed or presumed. Corresponding to the ripening period of the grapes, samples of bunches were taken to determine the fruit characteristics of the plants. During the winter, material was gathered for the vegetative propagation. Below are the brief descriptions, above all photographical, of the most significant sites as they appeared during the on-site inspections carried out between 1985 and 1996.

The Madonnino Site

Located on the Banfi estate near the farmhouse of the same name. The vines grow along a country lane together with oak-trees and brambles. Nine plants are present and at least four of them are female. Some plants were reproduced and are in the estate's ampelographic collection.

The Collupino Site

Located on the Banfi estate near the farmhouse of the same name. The vines grow along a depression. There are at least six male plants and 4 female ones.

The Canalone and Canalone Sotto Sites

Located on the Banfi estate near the Voltalsalcio area. The vines grow along a depression in which a big hedge grows, dividing two cultivated fields. There are more than ten vines, with at least two females, one of which bears white grapes.

The Ombrone Site

Located on the Banfi estate along the bend of the Ombrone River. The vines are considerably developed, with the riverside vegetation of poplars and willows. They are mostly male plants.

The Badia Ardenga site

Near Badia Ardenga, next to a country lane at the border of a cultivated field, along a small stream and at the border of the forest, there are two female plants, one of which is presumed to be hermaphrodite.

The Ponte site

Along the Provincial Road Traversa dei Monti near a bridge that spans a little stream, and along the stream itself, more than ten vines, mostly male, have been found.

The Pioppeto site

Along the Orcia River, near Sant'Angelo Scalo, between a stand of poplars, the river, and the edge of a forest, with poplars, whitethorns and maple trees, four vines — two male and two female — have been found. The sites around Poggio di Sasso d'Ombrone: Adelio, Chiesetta, I terzi, Reppi (Guinzone, Rigonsano, Sanguinello, 322, Albegna, Rosselle)

These are the most interesting sites. In most of these cases, very large plants were found in the domesticoid state. For these plants cultivation is maintained for the sole purpose of their preservation. Phenotypically and genotypically they are wild vines and grow along the hedges of cultivated fields, on wild plants (holm-oaks, elms, maples) but also on cultivated plants (pear-trees, walnuts). At least at one site (Adelio) the female vines were, at the time of the inspection, harvested and the grapes were processed separately from the cultivated ones. Besides being widespread in the area from Tuscany and northern Lazio, the wild vine also grows in other Italian regions. In fact, thanks to the valuable cooperation of the Forestry Service, it was possible to visit many other sites of great interest because of the environmental context and the types of plants found.
Among these sites, the following are of particular interest:

The Cinque Terre (La Spezia)
Many plants, mostly male, were found in the lower part of a big canal, and thus very close to the water. The environment is very interesting because there is no sign of the passage of man.

Bosco della Mesola (Ferrara)
A real population of wild vines, with very numerous plants, some quite large.

Foresta Umbra (Foggia)
A nucleus of wild vines located inside the Umbra forest, far from the passage of humans. It was not possible to observe the vegetation of the plants close up, and in particular, their blooming and/or fruit setting, as they develop in height.

Rossano and Cropalati (Cosenza)
In the countryside and along the edges of the woods there are some groups of wild vines, with a certain percentage of female plants (about 1/3 of the total).

San Nicola dell'Alto (Crotone)
Nucleus of wild vines with different members, but not very developed, also because the woods are periodically cut back.

Staiti (Reggio Calabria)
Nucleus of wild vines with different individuals (50% male, 50% female), not very developed because the woods are periodically cut back.

Monte Arcosu (Calgliari)
A real population of wild vines that grows along the course of the river and along the rivulets that flow towards the valley. Extremely interesting as the natural environment is unique (well-developed Mediterranean underbrush extending over a large area).

Cantoiera Ortuabis (Nuoro)
Some individuals of wild vine identified along the road that crosses a very interesting natural area (protected woods in the territory of Gennargentu).

Gennargentu (Nuoro)
Along the two depressions that descend in the "Flumendosa" River, in the heart of the massive Gennargentu. This is an area of great environmental interest, in which hunters and herders are still allowed. In particular, the few individuals found along one of the two depressions represent an exceptional finding as the plants, which climb up along the alders, are very developed and reach almost one meter wide, which testifies their advanced age, as they are probably centenarians like the alders on which they grow.

Dorgali (Nuoro)
A nucleus of wild vines that grow on high trees (alders) along the river are of great interest. It is almost impossible to observe the vegetation up close.