BANFI

Dedicated to a finer wine world

Evolution of Productive technology in the vineyard

SOIL MANAGEMENT AND PLANT NUTRITION

S. Miele, M. Marmugi, e. Bargiacchi, I. Foschi

Soil-Plant Testing and Vine Nutrition

Nutrition is a critical aspect for vine quality, because it has a profound influence on the development and ripening process of the grape. At the Castello Banfi estate, even before planting a vineyard, fertilization is managed through a careful choice of soils, using pedological research. From an agronomic standpoint, after this first phase, the selected areas undergo physical-chemical analysis of the 0-40 cm stratum and then follow a course of "agronomic improvement" that can take several years and go through various phases before the vineyard is finally planted. In short, distinct from smaller wine producers who do not have much if any choice of the timing and area of planting Castello Banfi has the ability to develop optimal drainage and fertility conditions of each plot over due course, without forcing the natural cycles. To illustrate this philosophy, one example is sufficient. The estate's second most important crop, after the vine, is fodder – alfalfa and Sulla, both of which are organically grown. This demonstrates great concern for the environment: the fields of such legume forage crops are, first of all, a natural source of fertility, since the rhizobia are responsible for fixating the nitrogen from the atmosphere. Secondly, the meadows increase the level of organic matter in the soil thus improving its structure, and making available many macro and micro nutrients (nitrogen, sulfur, phosphorus iron, boron,etc.). Thirdly, they help reduce the so-called soil seed bank, meaning the quantity of weed seeds, thereby reducing their harmful presence in the new vineyards.

Soil analysis is just one of the diagnostic tools available to the technical staff that manages plant nutrition. Fertility levels measured using these tools represent, in fact, only a potential figure, that under practical conditions may actually be reduced more or less by concomitant negative factors (for example, the difficulty of the root system to grow deep, unfavorable climate conditions, etc.). Therefore, to identify the plant's actual nutritional status, the vineyards, starting from the phase of initial production, are regularly monitored by analyzing the petiole of the nodal leaf, opposite the grape- bunch, during the initial fruit setting. Nearly 20% of the area under vine at the Castello Banfi estate is monitored each year using this method. The selection process to determine which vineyards should undergo this analysis is carried out in two stages: a first set is identified during the "harvest review meeting" in terms of yield and quality; a second set is chosen in springtime, based on the first cellar results and the growing trend after spring sprouting.

Agronomic classification of the soils

The agronomic analyses performed on the established and newly planted vineyards show that the sandy-loam and clay-sand-loam textures prevail, even though nearly 20% of the soils can be defined as clay-loam.

The C.E.C. for 80% of the studied cases ranges between 20 and 34 meq/100^{-1} g, and therefore fall within normal range. Most of the soils have a pH higher than 7.7, with variable concentrations of total lime (from 100 to 400 g kg^{-1}), though the "active" fraction always has a low impact: actually in more than 50% of the cases it ranges from 30 to 50 g kg^{-1} . Banfi's principal agronomic characteristic is its widespread lack of soil organic matter (organic C x 1.724). In fact, a little more than 10% of the soils can be defined as rich (C >12 g kg^{-1} for a sand-loam texture). This fact contributes to the frequently low levels of total Nitrogen and available Phosphate, due to the strict correlation between these two parameters (r=0.85** and r=0.56**, resp.). Moreover, a good 50% of the soils have, in fact, values lower than 10 mg kg^{-1} P (Olsen). Even the availability of exchangeable Potassium is low in almost 70% of the cases and positively correlated (r=0.43**) to the soil's organic C content while Sulfur, Calcium and Magnesium are almost always present in sufficient quantities. Examining the Ca/Mg, Ca/K and Mg/K ratios shows that the available Magnesium is never reduced by absorption competition from Calcium and Potassium. Passing on to the microelements, one notes that more than 95% of the soils are lacking or severely lacking in soluble Boron (<0.40 mg kg^{-1}).

Regarding this, one observes a highly significant correlation (r=0.59**) between the soil's C.E.C. and the concentration of soluble Boron, proving the fact that the deficiency of this element in the area is primarily associated with soils having a sandy texture. The quantity of available Iron is variable and well distributed in all the frequency classes; this too is positively correlated (r=0.59**) to the C.E.C. and the pH, especially with values higher than 8.0. One must note, however, that phenomena of iron chlorosis is almost absent in all of Banfi's vines and vineyards: this is due mostly to the soil's being highly permeable to air and water, and subject to careful agronomic management (maintenance of the superficial and deep structure). Soil pollution from Copper is practically absent, since only 15% of the soils have over 3 mg kg-1 of available Cu. Good levels of available Manganese are frequent, unlike other Italian vine areas (e.g., Veneto), while over 50% of the soils are deficient or very deficient in available Zinc. Sodium may be a problem to be dealt with in slightly less than 8% of the analyzed vineyards (areas of Poggioni, Marrucheto, etc. Its concentration is positively correlated to that of Magnesium, confirming the same marine origin.

Analysis of the petioles

Since 1994, the average nitrogen content of the plants has gradually increased, primarily due to the reduction of the vineyards' average age, following the start of production of the new vineyards. The year 2003 was an exception, mostly because of the long, severe drought that had a negative influence on the mineralization of the organic matter and on the absorbance of nitrates, even where emergency irrigation was carried out. Regarding Phosphorus, decreasing concentrations were recorded until 1998, after which there was a change in the trend. Phosphorus consolidated during the following years, also thanks to specific fertilizing integrations (both organic and mineral) in the vineyards (minus-variants). Maximum care was used for the level of phosphate fertilization to avoid excess of vigor and absorption antagonism towards other elements (Fe, Zn). In addition, 2003 was an unusual season that reduced phosphorus concentrations in the plants, thereby halting the positive recovery trend. One of the estate's objectives is, in fact, to maintain concentrations in the petioles between 1 and 1.5 g P kg-1 d.m, regardless of the vine type.

As expected, the trend of Potassium concentration has been, over time, rather variable, because it is strictly correlated to numerous factors such as the annual yield, berry development, and the general water level of the plants. At the single vineyard level, the trend curves make it possible to understand how the general nutritional status of the plants is proceeding. This information, together with yields and quality traits, provide the basic parameters for an eventual post-harvest fertilization program (in the present case: integration treatments of only phosphate or potassium-based fertilizers or

PK and in all cases The annual NPK one), in terms of choice of the fertilizer analysis (ratio N: P2O5: K2O) and its dosage. To provide an example, the recorded annual trends are shown for the concentrations of Nitrogen and Potassium in the petioles of some of the vineyards of the estate. The analytical data are also important for identifying possible deficiencies that will require action during the season with appropriate foliar treatments. Boron is among the most frequently identified deficiencies on all the vines regardless of type, while Magnesium and Calcium may be a problem for the whites (particularly Chardonnay). Photos, subsequently digitalized (wide-angles and Details), of the vineyards during the period of removal of the plant-samples and at the end of season (leaf fall) is a useful tool to complete the diagnostic picture. Also being studied is the possibility of combining methods of photo-biologic research and computerized elaboration of images, both aimed at predicting yields.
All these activities are aimed at making the agronomic approach to the challenges of fertilization as objective as possible, reducing the margins of error and enabling easy control over such a vast and agronomically complex area planted with vineyards.

Tab. 1 - Linear correlation coefficients betwen the physical-chemical parameters.

	Sand	Silt	Clay	pH	CEC	Total Lime	Active Lime	COrg.	Ca/Mg	Ca/K	Mg/K	N	P	K	Ca	S	Mg	B	Fe	Cu	Mn	Zn	Na
Sand	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silt	-077	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clay	-0.77	0.19	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	0.32	-0.43	-0.06	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CEC	2	-0.24	0.22	0.28	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Lime	0.22	-0.11	-0.23	0.31	-0.07	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Active Lime	0.24	-0.26	-0.10	0.42	0.15	0.81	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C Org.	-0.09	-0.14	0.28	0.17	0.01	-0.13	0.01	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca/Mg	0.03	0.12	-0.16	-0.19	-0.26	0.08	-0.12	-0.17	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca/K	-0.11	0.16	0.01	0.07	-0.05	0.11	-0.01	-0.23	0.46	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg/K	-0.06	-0.14	0.23	0.35	0.25	-0.05	0.08	-0.06	-0.42	0.31	1	-	-	-	-	-	-	-	-	-	-	-	-
N	-0.08	-0.09	0.21	0.11	0.19	-0.13	0.08	0.53	-0.32	0.25	0.06	1	-	-	-	-	-	-	-	-	-	-	-
P	0.15	-0.42	0.20	0.40	0.37	-0.01	0.36	0.58	-0.39	-0.24	0.20	0.71	1	-	-	-	-	-	-	-	-	-	-
K	-0.14	-0.01	0.23	0.09	0.03	0.08	0.24	0.43	-0.29	-0.43	-0.16	0.39	0.42	1	-	-	-	-	-	-	-	-	-
Ca	-0.21	0.16	0.17	0.13	-0.01	0.21	0.14	-0.07	0.30	0.87	0.33	-0.09	-0.07	-0.06	1	-	-	-	-	-	-	-	-
S	-0.09	-0.01	0.13	-0.31	0.02	-0.13	0.18	0.11	-0.07	-0.06	-0.16	0.20	0.40	0.09	0.07	1	-	-	-	-	-	-	-
Mg	-0.12	-0.25	0.41	0.36	0.13	-0.02	0.21	0.21	-0.63	0.13	0.72	0.37	0.44	0.34	0.43	-0.05	1	-	-	-	-	-	-
B	0.43	-0.34	-0.30	0.30	0.51	0.01	0.20	0.12	-0.08	0.11	0.08	0.18	0.30	-0.05	-0.05	0.06	-0.05	1	-	-	-	-	-
Fe	0.44	-0.58	-0.07	0.62	0.59	0.06	0.46	0.13	-0.45	0.12	0.34	0.35	0.69	0.02	0.04	0.19	0.31	0.54	1	-	-	-	-
Cu	-0.12	0.08	0.10	-0.07	-0.16	-0.18	-0.07	-0.20	0.07	-0.08	-0.14	0.21	0.27	0.09	-0.05	0.48	-0.09	-0.07	0.06	1	-	-	-
Mn	-0.07	0.03	0.06	0.11	0.02	-0.13	-0.20	-0.06	0.11	0.03	0.06	-0.06	-0.14	-0.14	-0.11	-0.25	-0.08	-0.10	-0.16	-0.05	1	-	-
Zn	0.08	-0.28	0.15	0.42	0.35	0.04	0.26	0.16	-0.28	-0.06	0.20	0.32	0.42	0.06	-0.08	0.05	0.20	0.18	0.47	0.11	0.07	1	-
Na	-0.07	-0.26	0.35	0.31	0.06	0.16	0.41	0.29	-0.41	-0.06	0.34	0.40	0.53	0.39	0.34	0.13	0.70	0.01	0.36	-0.08	-0.17	0.29	1

Fertilization programs

Newly planted vineyards

The basis for a good start is provided by a post- trenching fertilization plan that makes it possible to increase the content of soil organic matter, phosphorus and potassium, without promoting weed development. Sometimes corrective fertilizers are also needed (sulfur, calcium and magnesium). However, the fundamental product for this phase remains cattle manure, to which the necessary correctives are added (either in the pile during fermentation or during the spreading). Recently, in an effort to improve particularly poor soils, a mixture of manure and superphosphate was prepared in the same way as at the beginning of the last century. The actual fertilization of the new vineyards is carried out using N P K fertilizers with a 1:3:6 or 1:3:3 ratio, broadcasted, just before the planting, and nitrogen in doses not exceeding 15-20 kg ha^{-1}, in most instances. The possible integration with nitrogen is postponed until the period of development of the young vines. Nitrogen can be spread manually or mechanically when it is necessary to make the vineyards more uniform (in terrains that are markedly different) or by using liquid fertilizer. The latter method is particularly suited for the management of young vineyards, mulched with a plastic film. When dealing with new vineyards, treatments of foliar fertilization are usually carried out only when they are mulched without drip irrigation, but this situation is increasingly less frequent.

Vineyards in Production

Based on the plant-soil analyses and the indications received from scouting, fertilization plans are prepared for productive vineyards and they typically include:

- fertilizer treatment localized on the row and distributed between winter and early spring, generally with a 2:3:1 NPK;
- a subjective treatment, once again between winter and early spring, carried out at a varied frequency, according to the vigor and productivity of the plants. This can include the entire area or just the more difficult parts, to make the developing conditions of the plants as homogeneous as possible;
- a possible supplementary post-harvest treatment, guided by the results of plant analysis (in general on the basis of phosphorus and/or potassium);
- foliar treatments with microelements.

The analyzed levels of available phosphate and exchangeable potassium in the soil are always evaluated on the basis of an interpretative model, which considers two important characteristics of the soil: for phosphorus, the organic carbon content; for potassium, the C. E.C.
On the estate, the microelements most frequently applied on the productive vineyards include Boron (via leaves and soil) and Zinc (via leaves), while Iron is applied only in some areas and during periods of strong light intensity, the goal being to prevent chlorosis and improve color intensity. For productive vineyards, liquid fertilizer is generally used only as an exception to sustain vines that do not have a sufficient equilibrium from a vegetative-productive standpoint. The possibility of intervening during the maturing phase, to modify the composition of the musts, is being studied.

IN-DEPTH ANALYSIS

Physio-Chemical analysis of the soil for agronomic purposes.

According to the aim of the analysis: zonation or agronomic management, the methods of soil sampling change greatly, as do at times the presentation of the analytical results as well. In the area to be "zonated" it is important to define the variation points in order to develop qualitative maps of the soil, highlighting the principal properties and characteristics. This helps to correctly evaluate the advantages of traditional deep plowing, which overturns the layers, compared to other techniques of pre-planting cultivation (trenching or deep ripping, where there is a rocky subsoil and it is not convenient to bring layers with poor characteristics to the surface). However, soil analysis for good agronomic management requires a survey of the average properties of a given soil, according to a sample grid corresponding to plots that can be treated as independent units from an operative standpoint.

The concept of Agronomic Sampling Unit (A.C.U.)in the particular case of Banfi is closely tied to the code of the vineyard[1] and thus, with each code, at least one characterizing agronomic analysis is involved. This analysis is usually performed in the pre-planting stage. In this case, the sampling procedures follow the classic "non-systematic X or W sampling grid" method (Mi.P.A.F, 1999) meaning that each sample derives from a mixture of 10-15 sub-samples gathered on the plot, according to a figure which is approximately comparable to X or W. At the Castello Banfi estate, to create a uniform method of sub-soil sampling, a core sampler with a 10 cm diameter was built and set on a tractor's three-point hitch. This makes it possible, among other things, to simplify operations and optimize work hours. The "control analysis" is carried out periodically, and examines the parameters, such as the pH factor, most likely to vary over time. This kind of analysis is usually performed to evaluate the effect of particular treatments, such as corrective use of sulfur products when dealing with alkaline or calcareous soils, or calcium and magnesium products when dealing with acid soils.

Analytical tests follow the official Italian Methodology (Mi.P.A.F., 1999 and 2002) and essentially consider the following parameters: texture (sand, silt and clay, based on the USDA granulometric classification), pH; Cation Exchange Capacity; total and "active" lime, organic carbon, Ca/K, Ca/Mg and Mg/K ratios; total Nitrogen; available Phosphate, exchangeable cations (K, Ca, Mg and Na); sulfate Sulfur; soluble Boron; available microelements (Cu, Fe, Mn, Zn), and Electrical Conductivity of the soil's paste's saturated extract, in those cases where the tenor of Na is equal or greater than 200 mg kg^{-1}. In Figure 38 there is an example of a certificate of soil analysis of Banfi's soils. For the sake of clarity, these certificates have a graphical interpretation of the analytical figures.

Vegetative Analysis as a guide to vine fertilization

The analysis of plant tissue provides useful information about the nutritional condition of the plants and can thus be used to identify and correct abnormal nutritive conditions as well as to improve the development of the crops and the quality of their production. Most analytical tests are used to determine the concentration of chemical elements in dry plant matter. Relating to this, plants have a marked capacity for maintaining these concentrations in a rather restricted range, so long as they are healthy and grow in the presence of an unlimited supply of nutrients. However, in conditions of scarcity, the nutrients initially tend to decrease in concentration, and then stabilize or even apparently increase, with a concurrent and significant reduction of the dry matter produced (it is important to remember that the concentration of an element derives from the ratio between it and the dry matter).

The nutritive elements, once absorbed by the roots and translocated in the xylem to the canopy, can be transferred in the phloem or removed and deposited in the root cells, stem/trunk and leaves. The excess absorbed is stored in different parts of the plant or lost by guttation of the canopy, excretion from the roots, or death and abscission of the dried plant parts. In perennial species, partition, storage and mobilization of the nutrients are frequently associated to a particular physiological stage. For example, the Nitrogen absorbed by the vine post- harvest, but before leaf drop, is concentrated in the permanent wood and in the roots during the dormant period, but is readily mobilized in spring to stimulate the development of the canopy in the phases that precede flowering, the moment from which the soil Nitrogen uptake becomes significant (Conradie, 1991). For this reason, tissue analysis performed between flowering and fruit set furnishes a picture of the interaction between the availability of Nitrogen during the preceding season and the developmental conditions of the current year. Nutritional elements have a different phloematic mobility, and thus a different capacity to redistribute themselves towards the parts that are actively growing, after they have been accumulated, for example, in the adult leaves. This is a point that deserves to be highlighted, because it profoundly conditions the methodology and timing of the application of the nutritive elements (soil and plant treatments). Nitrogen, Phosphorus, Potassium and, to a lesser degree, Magnesium have good mobility, while Calcium, Manganese, Iron and sometimes, even Boron, need to be continuously available over time, as they are practically immobile in most of the species. Other elements, like Sulfur, Copper and Zinc have variable levels of mobility that are closely related to the plant's Nitrogen nutrition. Without going into detail, the definition of the optimal and critical concentrations (that is those under which there is a significant reduction in yield and quality) for the vine, as for other crops, takes place through a process of "backward chaining", starting from the identification of the optimal production and going back in time to the nutritional condition of the plants that yielded this production. Obviously, to have data that can be compared over time, the methodology and the phenological phase of the sampling must be constant.

The analysis of the petiole of the basal leaf opposite the bunch, in the flowering-initial fruit-setting phase, is by now a well-established technique in the principal viticultural districts of the world. Compared to the diagnosis carried out on the leaf and following protective treatments, there are fewer risks of aberrant data and a greater discriminatory capacity when dealing with many elements such as Nitrogen, Potassium, Magnesium, and Boron. Once the results are available, usually at the end of June, it is possible to intervene on the production of the current year only with foliar and fertigation treatments. However, a valid interaction with the production of the following year can be initiated by planning the post-harvest fertilization and the overall future treatments.

FIRM: **BANFI Srl** Address: **CAST. DI POGGIO ALLE MURA** City: **MONTALCINO** Province: **SI** Telephone: **0577-840111** Fax: **0577-840268** VAT registration num: **00841650526** Through: **BANFI**	Sample code: **P 402** Sample Material: **SOIL** Collected by: **LIZIO** Collection date: **01/24/2004** Arrival date: **01/28/2004** Municipality: **MONTALCINO (SI)** Locality: **POGGIO ALLE MURA** Field: **MARCHIGIANA P 402** Cultivation foreseen: **VINE** Fertilization advised: **S**

BANFI

Dedicated to a finer wine world

CHEMICAL-PHYSICAL RESULTS				AGRONOMIC JUDGMENT
Parameter	Value	Unit	Method	
TEXTURE:				SANDY CLAY LOAM
SAND	485	g/kg	hydrometer	
SILT	190	g/kg	hydrometer	
CLAY	325	g/kg	hydrometer	
pH C.E.C.	7.93		1.2.5 in acqua	SUB-ALKALINE WITHIN
TOTAL LIME	31.2	meq/100 g	$BaCl_2$+TEA	THE NORM STRONGLY
ACTIVE LIME	270	g/kg g/kg	D.M. 13/09/99	CALCAREOUS LOW
ORGANIC CARBON	23	g/kg	D.M. 13/09/99	WELL ADAPTED
Ca / Mg	13		Walkley-Black	HIGH
Ca / K	12.06			HIGH
Mg / K	65.81			HIGH
	5.45			
NITROGEN tot. (N)		g/kg		Very Low Low Normal High Very High Toxic
PHOSPHORUS ass. (P)	1.1	mg/kg	Kjeldahl	••••••••••••••••••••
POTASSIUM exch. (K)	10	mg/kg	Olsen	••••••••••••••••••
CALCIUM exch. (Ca)	122	mg/kg	$BaCl_2$+TEA	•••••••••••••••
SULFUR (S)	4.116	mg/kg	$BaCl_2$+TEA	•••••••••••••••••••••••••••••••••••
MAGNESIUM exch. (Mg)	262	mg/kg	Da solfati	•••••••••••••••••••
BORON water sol. (B)	207	mg/kg	$BaCl_2$+TEA	•••••••••••••••••••••••••••••
IRON ass. (Fe)	0.30	mg/kg	D.M. 13/09/99	•••••••••••••
COPPER ass. (Cu)	2.1	mg/kg	Lindsay-Norwell	••••••••••
MANGANESE ass. (Mn)	3.3	mg/kg	Lindsay-Norwell	••••••••••••••••••••••
ZINC ass. (Zn)	130	mg/kg	Lindsay-Norwell	••••••••••••••••••••••••••••••••••••
SODIUM exch. (Na)	1.59	mg/kg	Lindsay-Norwell	••••••••••••••••••
	35		$BaCl_2$+TEA	••••••••••••••••••••••

BANFI

Dedicated to a finer wine world

Tab. 2 - Mean concentration of nutrients in the petioles of the leaves opposite the basal graper bunches in the vineyards of the Castello Banfi estate. Decade average does n include 1994-1998 data.

	N g kg^{-1}	P g kg^{-1}	K g kg^{-1}	Ca g kg^{-1}	S mg kg^{-1}	Mg g kg^{-1}	B mg kg^{-1}	Fe mg kg^{-1}	Cu mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	N mg kg^{-}
MEANS DECADE	10.84	1.18	17.21	18.85	3218.38	4.66	9.12	30.86	21.60	57.80	40.07	149.77
1994	6.70	2.47	18.55	23.18	2084.62	6.53	11.15	57.15	130.06	108.95	44.02	573.22
1995	11.55	1.58	17.41	5.40	1146.71	2.85	4.79	66.13	38.21	164.00	80.75	381.42
1996	8.71	1.52	19.55	18.84	2951.52	5.81	8.96	85.33	44.74	48.33	48.78	69.78
1997	7.21	1.32	20.81	18.36	3115.61	5.26	8.71	81.15	56.83	50.95	93.71	162.44
1998	9.18	1.07	25.32	24.79	2912.81	8.41	8.11	71.57	53.70	87.81	72.49	118.62
1999	11.74	1.10	18.42	17.20	3320.88	6.17	8.47	50.56	52.38	66.97	80.25	168.38
2000	12.13	1.20	14.06	14.53	3028.67	7.85	8.86	30.52	3.79	78.12	53.52	190.24
2001	12.45	1.35	9.72	13.00	3303.39	4.38	10.13	92.23	39.13	58.48	75.71	161.00
2002	12.83	1.46	23.15	25.42	3006.66	5.52	9.40	14.51	6.09	51.80	27.49	138.80
2003	8.83	0.98	17.79	25.38	3349.68	4.53	8.45	48.58	12.32	76.61	72.29	137.65
2004	10.71	1.13	18.20	18.93	3225.15	3.00	8.79	10.74	33.47	71.79	11.06	185.32
2005	10.68	1.16	23.42	22.63	3306.47	3.33	9.50	9.84	14.74	59.16	7.82	114.92
2006	11.46	1.22	21.85	22.06	3222.10	3.19	9.80	14.86	15.34	46.87	14.36	143.80

BANFI

Dedicated to a finer wine world

The microelements and the vine

While referring the reader to specialized texts for eventual in-depth studies, the principal aspects related to the micro elements that are most important for the cultivated vine in central Italy will be dealt with here: Iron and Boron.

For the former, the choice of the correct rootstock, in relationship to the characteristics of the soil (lime content, degree of compaction, soil humidity, etc.), and the correct agronomic soil-plant management (tillage, use of cover crops, pruning, etc.) make it possible to avoid many problems tied to the so-called "iron chlorosis," as Banfi's experience has demonstrated over the years. However, when there are abnormal seasonal conditions (persistent low temperatures at sprouting and high light intensity just before color setting), temporary deficiencies can arise, with a reduction of chlorophyll synthesis, which has a negative influence on photosynthesis and, in general, on the process of maturation. Generally, it is best if Iron foliar fertilization is used as a preventive treatment, with formulations that are non-phytotoxic when applied as low-volume sprays and stable when diluted in "hard" waters. An important role is played by Fe-DTPA formulations, applied during the periods of maximum light intensity (July), and eventually also during post-harvest, to the benefit of the next season's sprouting. The latter make it possible to avert the problem better than spring treatments carried out in emergency conditions when the Chlorosis is already in progress and there is little leaf surface to intercept the spray. In the Castello Banfi vineyards, so far, it has not been necessary to intervene with the application of Iron to the soil or in fertigation.

Boron deficiency is, on the other hand, more difficult to control with the sole aid of agronomic means. In essence, only a good availability of soil organic matter and water (emergency irrigation in periods of water scarcity) are able to reduce the extent of this phenomenon, which manifests itself with symptoms that are immediately perceptible, including flower dropping and "acinellatura," or the presence of developed and undeveloped grapes on the same bunch; sometimes there are also unspecific manifestations involving the leaves (decoloration/discoloration which tend toward red in the red vine types). Fertilization is thus indispensable in most conditions, every year and for every vine type, also because the analysis of the petioles can hardly pinpoint concentrations greater than 10-12 mg/kg B. The soil application causes an unpredictable response and, in our conditions of cultivation, its effect is absolutely limited in time. Thus, it must be considered as a simple contribution to the principal application mode, which is the foliar spray. Because of Boron's scarce mobility when applied in this manner, it is essential to repeat the treatments at least 4 times, of which 2-3 must be applied before flowering. Over time at the Castello Banfi estate, there has been a change from using Sodium Octoborate to sodium-free formulations, easily added to low-volume mixtures. Experience has taught us to avoid using mixtures with crop agrochemicals contained in PVA bags, because of the well-known inhibiting action of the Boron.

MANAGEMENT OF PLANT NUTRITION

New Vineyard

If possible: before planting new vineyard, plan a cultivation of pluriennial or annual forage crop: alfalfa, sulla, clover (soils poor in organic matter); sudangrass (salty soils), lolium (soils that are too fertile).

- Perform a soil analysis after deep plowing (or after the main tillage) based on agronomic sampling. Parameters: texture, CEC, total and "active" lime, organic C, total N, available P, total S, exchangeable Ca-Mg-K-Ng, soluble B, available Fe-Cu-Mn-Zn.
- Add organic matter (manure, compost) and correctives (sulfur, dolomite) to make the area which will be planted as uniform as possible.
- Manage the superficial and deep drainage. Try to anticipate events to avoid erosion at the heads of the fields, by choosing the right turf plants.
- Plan a pre-planting fertilization (on the entire area) with low to nil addition of readily available nitrogen, to reduce the incidence of weeds. Ideal ratios: 1:3:3 or 1:3:6.
- A careful choice of the vine-type and rootstock, in relation to the soil-environment and the management, avoids many potential problems.
- Apply readily available nitrogen only when rooting has been verified. It is best to use fertigation, and in any case, always localized on the row, to make plant development uniform.
- Possible foliar fertilizing treatments usually have modest results, unless used on mulched, unirrigated vineyards where there is no other possible alternative for adding nutrients.

Training

Apply moderate and balanced NPK fertilization, both placed along the row and applied by fertigation (where available).

- Based on plant development, identify the "poorer" and more difficult areas of the soil where targeted amending treatments to boost plant growth can be performed after leaves have fallen. The aim is not to force the plants, but to make the vineyard uniform.

Production

Perform fertilizing treatments proportional to the uptake (previous yields) and likely to guarantee a good vegetative-productive equilibrium

- The timing of the soil fertilizing operations are: end of winter (N-P-K-MG) and post-harvest (P-K- Mg). In Central Italy it is not advisable to intervene after sprouting (low efficiency of fertilizer use).
- Operate by localizing the fertilizer along the row, to avoid damaging the cover crop between the rows, and stimulating weed development in the tilled ones.
- Fertigation (N or N-K-Mg) can be efficient if the fruit set (=productivity) is higher than expected.
- Monitor the nutritional condition using petiole analysis carried out in the period between fruit set and the beginning of berry enlargement, and act consequently (foliar treatments and in post- harvest). The sequence of photos indicates which petiole to collect and the quantity to send to the Laboratory.

- Some microelements must be taken into consideration, as a rule, in the program of foliar fertilization; Boron, Iron and in more difficult soils, Zinc. Treatment should not be delayed until there is evidence of defficiency
- The fertilization program must be planned after careful analysis of the yields (quality-quantity), the past climate trends, the results of analysis of the petiole and the cellar, keeping in mind the effective operating restrictions (soil type cover crops, machinery effectiveness, presence of micro-irrigation, etc.).

MANAGEMENT OF "SALTY" SOILS

A considerable portion of the Castello Banfi vineyard estate, roughly 150ha/370 acres, is made up of soils (25°C EC) that range from 400-800 mS/cm^{-1} and higher (for example Casenuove sampling area L, Poggioni, Campogiovanni). These are often small and spread out areas characterized by an electric conductibility of the saturated soil extract (25°C EC). These levels are deemed "very salty", making these areas challenging to manage. Although the vine can be considered moderately sensitive to the saltiness of the soil and irrigation water (Maas et al., 1977), salinity tends to discourage photosynthesis and biomass production (wood, leaves, grapes) and – when present in rootstocks which are scarcely capable of excluding sodium and chlorides – may alter the sensory evaluation of the wines, making them too sapid. Nevertheless, the main problem connected to soil salinity and sodium content, especially in the presence of medium-high soil clay contents, is represented by the loss of structure (low physical fertility) that causes the plants' root development and absorption to decrease. The clay's dispersion, together with untimely operations or the transit of heavy machinery on the soil, may in turn cause deep compaction, superficial crust, and difficulty of water infiltration.

Most of the estate's so-called "salty soils" are characterized by a clay-loam texture, clay-silty-loam or definitively clay. These are usually poor in organic matter and have exchangeable Sodium and Magnesium contents higher than 200-250 mg kg^{-1}. At ionic chromatography, the extracts in BaCl +TEA of the soil also plainly reveal high concentrations of Lithium, which is an indicator of the "salty" characteristics.

At Banfi, the agronomic challenges of such areas affected by salinity are dealt with by excluding such areas from new vineyard planting, at least where technically possible. However, in the areas where it is essential to plant new vineyards, it may be necessary to take measures to considerably improve the soil's superficial and deep structure. This is done by setting down a meadow of sulla (Hedisarium coronarium L.) for at least 2 years. Once the period of conversion has ended, and before the final superficial tillage of the soil, manure is spread, based on the results of the soil's analysis. At this stage, it is essential to combine organic substance – if the soil is decalcified – with correctives sufficiently reactive for their fineness and/or chemical form, capable of supplying exchangeable calcium (e.g., sintered magnesia lime), being careful to avoid over-calcifying. The use of gypsum, even though desirable, is often unpractical both because of the volumes required and the difficulty associated with handling a powdery product.

The choice of rootstocks such as the 1103P, able to significantly exclude chloride and sodium from the grapes during ripening, is a further tool to preventively reduce the physiological damage caused by the soil's saltiness and sodium content.

As for management of the vineyard during production, it is necessary to plan operations to maintain good soil structure. This requires periodic intervention with deep tilling on alternate rows (i.e., mole plow or ripper); manuring, controlled turfing, mulching with straw and residues of the turfing, carefully managed microirrigation and, in particular, ensuring that the water penetrates the ground, if necessary with the help of soil structuring and/ or stabilizing agents.

IN-DEPTH ANALYSIS

Soil and water saltiness

A first effect of saltiness is the increase in osmotic pressure of the soil solution, caused by the salts that are dissolved in it. This may lead to phytotoxic effects on the plants and in general to negative effects on the physical and chemical fertility of the soil.
The second effect is the direct evidence of the dissociation of the minerals dissolved in water. The determination of the saltiness of water is therefore a measure of the chemical compounds in the same, present in ionic form. A salt is responsible for a certain share of salinity depending on its concentration and dissociation levels, the latter being related to its solubility constant.
The salts that are most frequently found dissolved in the soil's solution, which are to blame for the problems concerning saltiness, are essentially nitrates, chlorides, sulfates, carbonates and bicarbonate of the alkaline elements (Sodium, Potassium, Lithium, etc.) and alkaline-earth elements (Calcium, Magnesium, etc.). Furthermore, due to their possible effects on the vegetation, some single elements like Boron, Chlorine and Sodium (Na), are very important.
Sodium is frequently the worst, because it is directly toxic to plants and can create a strong alkaline reaction. Moreover, with the same Na content, carbonate is more damaging than chloride (alkaline waters are rich with carbonates, those which are salty in chlorides).
Generally in order to evaluate the saltiness of the soil and /or the water, it is necessary to know:

- The total salt concentration or saltiness, or its indirect measure:

– for the soil by the electric conductibility (ECe) of the soil's saturated paste at 25°C, that tends to rapidly increase when the exchangeable Sodium passes the threshold of 200 mg/kg^{-1}.
– for the water by the water electric conductibility (ECw), still at 25°C.

- The concentration of Sodium in relation to that of other cations or sodicity.
- The anionic composition, and especially the concentration of carbonates and bicarbonates.
- The level of Boron and of other potentially toxic elements, if greatly present.

Definitions

- Salty soil: a soil that has less than 15% of its cationic exchange capacity saturated by Sodium, and pH between 7 and 8.5, excess of Calcium, Magnesium and Sodium in form of Chlorides or Sulfates. The ECe is higher than 4 mS cm^{-1} at 25°C, versus 0.6 of a "normal" soil (even though salinity effects begin to be evident at 1.5-2 mS cm^{-1} at 25°C).
- Sodic soil: a soil with more than 15% of its cationic exchange capacity saturated by Sodium, pH between 8.5 and 10 and an ECe of 3-3.2 mS cm^{-1} at 25°C.
- Salty-sodic soil: a soil that has intermediate characteristics between the two: pH near 8 and ECe up to 16-17 mS c-1m at 25°C.

Causes

Salt buildup in the soil is due both to the natural composition of the soil and to the intensive use of irrigation waters that progressively accumulate salts because of infiltration of seawater or natural concentration of solute. This is caused by water evapotranspiration from the soil-crop system that is not adequately reintegrated with irrigation water.

Effects

Salt stress reduces plant development and production. This depends on:

- the reduction of available water for the plants (physiological drought) caused by the soil's higher osmotic potential (Table 2);
- the increased concentration of toxic ions (sodium, chlorine) in the plant's tissues;
- alteration in the ionic absorption due to problems of competition, usually between sodium and chlorines on one hand, and potassium, calcium and nitrates on the other;
- deterioration of the soil's structure, consequence of the deflocculation of the clay colloids, with loss of permeability to water and air.

Crop management: the estate's developmental phase

I. Bonato, M. Marmugi

1978-1984: Formative years, major projects

This was no doubt the most tumultuous, frenetic period in which many important choices for the future were made. In the 1970s in Montalcino the cultivated vines were Sangiovese, Moscadello and Trebbiano Toscano, trained in a traditional spurred cordon. In these hills, the vineyards were small and irregularly shaped, frequently alternating with forests, olive trees and sloping hills. Vineyards with a larger and more regular surface could be found only on less sloping or flat terrains. Given these conditions, the primary phase of the ambitious Castello Banfi project undertook the important processes of uprooting old vines, moving earth, and leveling terrain in order to secure larger plots on surfaces with different inclines. This enabled the new vineyards to be, as much as possible, planted along the main slope of the hill without obstacles for aerial treatment by helicopters. At the same time, a new road network was created to connect the various plots with the estate's headquarters and the artificial lakes, guaranteeing water resources needed for crop treatments and emergency irrigation during the summer.

BANFI

Dedicated to a finer wine world

The first varietal choices

Most of the cultivated area was planted with Moscadello (White Moscato) to obtain scented, cool, fruity wines with slight effervescence, which were in high demand on the American market at that time. International white-grape vines, such as Chardonnay and Sauvignon, were also introduced; and foreseeing new market trends, Pinot Grigio was also planted for the first time. Among the red-berried varieties, Cabernet Sauvignon, Merlot, Syrah, Pinot Noir and Montepulciano were added to Sangiovese.
Many rootstocks were used, including 1103 P, 420 A, SO4, K 5bb, 3309, 110-R, 161-49, 101-14; often they were chosen based on availability of the plants at the nurseries as a great number were needed each year. The most used variety was certainly the 1103 P, because it adapted well to the estate's difficult soils, sometimes high in sodium and rarely uniform due to the various soil preparation. The fact that it generates basal shoots during the entire growing season is its only negative trait.

The choice of the first training technique: the "Casarsa"

In Montalcino, the vine was grown on a traditional spurred cordon. The poles were sometimes made of chestnut wood, but more commonly were of re-enforced concrete with holes; wires were attached to the first and last poles but were never stretched tight between the poles due to lack of anchorage on the outer pole. The vines often had a twisted bearing along the trunk and the wire because they lacked sustainers. Along hills, the vineyard rows often did not follow the slopes, but were diagonal and sometimes even followed the contours of the hills. Following the main slope helps mechanization, even though it may sometimes cause erosion problems. Following the contour lines helps men or animals, as they can walk up and down the rows without getting tired. Diagonal slopes with more than an 8-10% incline do not, on the other hand, allow machines to operate. For these reasons the traditional spurred cordon training method did not allow mechanization: it only allowed harrowing of the soil, uprooting and plowing operations along the rows and hoeing under the rows to keep weeds under control. Moreover these operations often created steps between adjacent rows. The need to mechanize the most important operations in the vineyard required a more simple form of training the vines. As it was necessary to mechanize operations, the choice fell on the "Casarsa" training method. The distance most often used was 2.80 x 3.50 m (9 x 11.5 feet), the shorter distance being between the posts of the same rows and the larger distance being the width of the lane between each row, with a vine planted on either side of the post, resulting in a crop density slightly over 2.000 vines/ha. The permanent cordon height was 1.60-1.70m (63-67 inches), on which 3-4 shoots were pruned with a length of 6-8 buds and left free. The vegetation was left unbound, part of it hung on the overhead wires, while the grape producing branches, under the grape´s weight, bent and thus naturally controlled the vine's natural height.

This way of training the vine was a good compromise between the expanded forms (tendone and pergola) and the more compact ones (Guyot and spurred cordon), with good results in terms of both quality and quantity. It also allowed for operations to be fully mechanized. In this hot, arid climate, artificial lakes were created to provide water for this growing technique. They were equipped with fixed tubes that brought water to the various plots, using hydrants with bayonet joints for emergency irrigation with mobile water guns. By late 1984 the estate managed about 500 ha (1.236 acres) of vines under Casarsa and nearly 200 ha (494 acres) under the old spurred cordons, 80% of which were Sangiovese.

The greatest organizational challenge was to simultaneously plant the young vines, set the poles, and lay out the wires, along with preparing the young vines for summer and winter growth and, all along, dealing with two distinct growing techniques.

1985-1991: The estate reorganizes to meet new goals

Optimizing the management of existing vineyards and better organizing estate operations were the principal objectives in this second phase of the estate's development. The Casarsa training system was chosen mainly because of its low maintenance costs and because it yielded the desired quality.
Weed control was carried out using harrowing and plowing operations. Towards the end of the 1980s, in order to reduce the time spent on mechanical operations, herbicides started being used under the rows, combined with tillage between the rows. Pruning was performed by hand and was either short (1 or 2 buds) on the old traditional spurred cordons of Sangiovese; or medium-long on the Casarsa-planted vines, depending on the fertility of the varieties and the objectives for quality.
The harvest was performed manually by groups of at least 24-36 people directed by a squad leader, who was in turn directed by a field technician. In coordination with the winery, and depending on ripening conditions, the vineyards to be harvested were selected, and the personnel and transportation for the grapes was organized. To fully underscore the organizational challenges of this process, it is enough to consider that in order to remain on schedule, in some years more than 500 workers a day were needed.

With the choice of the Casarsa method, summer pruning operations were reduced to a minimum. These consisted of a single mechanical topping-off in the areas with the greatest vigor. Tests performed at the estate by the University of Milan (Brancadoro et.al. 1997) showed that repeated topping did not improve the quality of the grapes. In the traditional spurred cordon training method, manually bending and tying the shoots between two wires during the summer and cutting the long ones made vegetation walls.
In those years, for the first time thinning was carried out on the shoots and bunches of Sangiovese to improve the quality of the grapes destined for the production of Brunello. The greatest innovation at the time was the use of helicopters to carry out agro-chemical treatments. Strategically located storage areas for pesticides and water enabled rapid performance of these operations. The ability to treat large areas quickly and the benefit of cutting down on equipment and manual labor made the use of helicopters a natural choice. Helicopters were used until 1988, when the efficiency of this type of treatment came into question over a variety of restrictions, including:

- they were unable to operate in high winds and bad weather;
- they were unable to operate in the many areas of the estate where electric and telephone wires passed over the vineyards;
- legislation restricting the substances that could be distributed by helicopter severely limited their usefulness.
- aerial spraying of antioidium products was ineffective because it did not permit the product to sufficiently cover the grape bunches

In 1988 conditions were favorable for an out- break of Oidium. Because of the limitations of application by helicopter, a land-based treatment campaign was carried out using tractors and low- volume (100-200 liters per hectare/64-130 gallons per acre) sprayers.
Subsequently, the task was performed by 15-20 sprayers outfitted with 600-liter (159-gallon) tanks. These were refilled directly in the field by nursery tanks in which the pesticide had been previously mixed and was constantly stirred.

BANFI

Dedicated to a finer wine world

Experimentation in new levels of vine density: the Madonnino vineyard

A different type of vineyard was conceived with the joint goals of producing only the highest quality grapes and evaluating the effect of densely grown vines on management costs. Here, most field operations would be carried out by machine, and the vines would produce less. It was not meant to be the most economical in terms of investment and management costs, as the project's principal objective was grape quality. After various studies, a vineyard parcel was planted with a density based on the vineyards of the Bordeaux area. At that time, France was still the country of reference for the image and quality of fine wine and the development of mechanical operations in the vineyard.

The Madonnino vineyard was thus created and until 2004, it comprised an area of 17.42 ha (43 acres). The vineyard layout was of 1.40 x 1.00 m (39 x 54 inches) between the vines, with wooden stakes every 5 m (16.4 feet) along the row. It had a density of 7.142 vines/ha (17.641 vines/ acre) and 5 different varieties were planted, with different clones: Sangiovese, Merlot, Cabernet Sauvignon, Syrah and Colorino. Rootstocks that could keep plant vigor under control and increase the ratio of fruit to vegetation, such as 161-49, 101-14, 3309 and 420A, were adopted.

The training form uses a horizontal spurred cordon that leans on the first of the three steel wires 60 cm (24 inches) above ground, a second wire at 80 cm (32 inches) high, and a third at 120 cm (47 inches); the stakes are 140 cm (55 inches) out of the ground. During the planting phase, two more wires are set at the base, one on each side, called "lifting wires", that allow mechanical fastening of the shoots. A 1.40 m (4.6 feet) wide lane makes it impossible to use normal tractors; therefore the estate purchased a combination tractor/excavator/tool carrier. Depending on the operation that needs to be performed, various tools can be used:

- a pre-pruner for dry pruning
- a harvesting headpiece
- a fastener that lifts the "lifting wires" and staples them with plastic clips, holding the shoots in a vertical position
- a post digger
- other multilane tools for weed control and pesticide application.

A Caterpillar tractor was also purchased, 100 cm (39 inches) wide and with a 22 cm (8.6 inch) sole, for use with a ripper to break the compaction layer that occurs in these types of silty-loamy soils when the high clearance tractors pass up and down. A fertilizer spreader was used for chemical fertilization of the vineyard.

The grapes produced in this vineyard are of good but not excellent quality, though in seasons when bad weather preceded harvest, superior results were obtained. In dense vineyards with cordons near the ground, it is more difficult to obtain healthy grapes compared to vineyards with a medium density (4.000-5.000 vines/ha or 9.880-12.350 vines/ acres) and slightly higher cordons.

In dense vineyards with fertile soils, when dealing with mildly vigorous varieties, such as Sangiovese, low leaf-walls (grape weight: active leaf surface ratio < 1) are produced. In this case, grape quality is inadequate, especially in terms of phenolic ripeness, due to the height of the structure and the excess of vigor. Costs double when compared to a medium-density vineyard in the vine's growing phases not only because of the number of stocks (7.142/17.641) that have to be pruned and tied, but mostly because the cordon that is 60 cm (24 inches) above ground does not allow a comfortable harvest for the workers that have to bend or kneel to pick the bunches. It should be remembered that in order to form a cordon during the third year, manual labor is reduced by 30% the cordon is placed 80 cm (32 inches) above the ground. Time required for manual pruning and defoliation doubles and workers have a harder time on such low cordons.

Technically, for 17.42 ha (43 acres) a high clearance tractor is sufficient, but in summer, when treatments, tying, weeding, polling and soil operations are carried out, it is difficult to perform these operations quickly and correctly.

It is difficult to have a timely harvest because the harvester, which has to travel 7.142 m per hectare (19.295 yards per acre), takes from five to six hours. This problem has been resolved by using a second, faster, more compact harvester, to harvest during the ideal ripening period. A unit to carry out low volume pesticide treatments has also been added. All the problems concerning organization and management have been resolved, but the question raised was if, on such a large estate, it is worth extending this labor-intensive model, which demands high mechanical and economical input but has not exhibited significant improvement in grape quality. From the perspective of landscape and aesthetic quality for the image of the estate, the goal has certainly been reached.

1990s to present: Re-organizing to meet new standards for grape quality

A profound crisis in the wine world occurred at the beginning of the 1990s. This induced the estate to seek a strong improvement in product quality while at the same time attempting to improve production costs of its farming operations. It was necessary to make an effort on all levels, even in the smallest of the vineyards, to produce wines of the highest quality. Various micro-economical aspects of each plot were evaluated and analyzed to reassess and improve their production capacity and lower management costs.

In 1992 mechanical pruning was introduced, combined with manual finishing. In the Casarsa, with the help of a pruning bar it was possible to realize a

70% saving in manual labor. Using 6-7 mechanical pruners together with 20 workers (mostly women) organized and directed by a single technician, the estate is able to prune 500 ha (1.236 acres) of Casarsa during the 4-5 months of winter. This pruning technique was introduced by Professor Cesare Intrieri of the University of Bologna and based on his practical experience since 1965. The pruner with adjustable blades was perfected during the 1970s and 1980s, adapting it to the various forms of crop training. The introduction of a "cut-off slide" attached to the upper blade of the pruner was an important improvement. In this way, the vine shoots could be cut while avoiding the poles, which until then presented a complicated obstacle. Currently the spurred cordons are trimmed using pre-pruners and are finished by hand. This especially helps the off-shoot pruning operation, which reduced the hours required for the total operation by 50%. For organizational reasons, and because of the performance and efficiency of the blade pruner, there was a switch from long to short pruning for some vine types with fertile basal buds. In the Casarsa vineyards this change increased the quality of the final product. The pruner was used as an organizational tool for cost reduction and was also seen as a quality tool for some varieties where the length of the producing shoots was reduced. On the spurred cordons, mechanical binding with "lifting wires" was perfected as well as the polling associated with it. Mechanical and chemical polling were performed, but they were not final, as manual finishing was always required.

Tab. 1 - Hours of manual and mechanical pruning on different varietals, averaged over the years 1993/1994 to 1995/1996.							
Varietal	Manual Casarsa	Mechanical long spur. cord.	Mechanical short spur. cord.	Spurred cordon prepruned Pellenc	Manual spur. cord.	Minimum pruning	Period
Cabernet S.	85	30	20	3+37	80	7/8	93/96
Chardonnay	70	25	17	3+37	60	5/6	93/96
Pinot Grigio	90	29	19	3+37	85	5/6	93/96
Sangiovese			17	3+37	70	6/7	93/96

Defense against parasites: mechanical and organizational approaches

To better protect vineyards during the summer season, a weekly plant disease and pest scouting service is performed, together with a collection of climate data using monitoring units and pheromone-traps which make it possible to monitor the population of phytophages.

This enables optimal timing of treatment and the choice of the most effective active ingredient. One of the estate's principal objectives has always been to obtain a natural product, by carefully managing the natural resources. By reducing and carefully dosing the quantities of agro-chemicals and fertilizers used, the estate adopted the E.U. ordinance 2078/92 for a period of five years: from 1997 to 2001. During this period weed control in the young vineyards was difficult because use of residual pre-emergence herbicides was forbidden. To solve this problem, mulching with plastic film on the rows was performed. However, in the established vineyards systemic herbicides (glyphosate) or desiccant products (ammonium gluphosinate) were used. On an estate of this size, it is difficult to carry out operations in a timely manner, which therefore reduces their effectiveness. Furthermore, there was a development of weed mixtures that became more difficult to control.

Limitation of the use of some insecticides created problems with the management of moths. For an estate in which the vineyards are located at different altitudes and with diverse exposures, moth control with Bacillus thuringensis poses several challenges. Each plot requires a different optimal time of operation, creating great management problems. After 2002, the program no longer received funding, but the strategies of producing a natural and environment-friendly product were not abandoned. The estate increased plant-pest scouting, using more efficient preventive techniques. The use of sulfur powder as an anti-Oidium contact-type foliar pesticide was reconsidered. The machines used for this kind of operation are pulled dusters, with a 600 kg (1.323 pound) capacity, very narrow and practical. Summer treatments are performed from dawn to midday, when it is cooler and there is less wind.

Weather forecasting stations were placed in the various mesoclimatic areas of the estate in order to determine the best time of operation. The study of climatic data enabled a more rational program of pest and disease control. It was also possible to lower costs and number of treatments while still obtaining healthier grapes, with fewer residues. At the end of the '80s the need to increase grape and wine quality caused a rapid change of the vine types under cultivation. The area planted with Moscadello was reduced, and the plantings of Sangiovese, Merlot, Cabernet Sauvignon and Syrah were increased. To expedite the return to productivity of the vineyards formerly planted to Moscadello, they were double-grafted with Sangiovese. Thus the Casarsa was modified, lowering the cordons and performing a short pruning to obtain better quality grapes.

In-Depth Analysis on the preparation of anti-parasite treatments

Anti-parasite treatments are prepared in a way aimed at reducing the risks to a minimum:

a) Reducing risks for the workers:
Those workers (number varies from two to four) responsible for preparing the mixtures have attended training courses and are equipped with all the safety measures necessary for the safe handling of concentrated products.

b) Reducing risks of mixing and dosage:
Because the workers have followed specific training.

Mechanical harvest: a necessary choice to guarantee grape quality

Mechanizing both the harvest and pruning operations has reduced costs by almost 50% in terms of manual labor hours per hectare each year. It has reduced the management costs of productive vineyards by 20% as well. By the beginning of the 1980s a self-propelled harvester (Vectur France) had already been introduced by the estate, but mechanical harvesting on a constant basis was not practiced until 1993. This was performed using tractor-pulled harvesters. The estate chose partial mechanical harvesting essentially for economic (cost reduction) and organizational reasons: it was difficult to find many available workers during a brief period of time (40-50 days).
In 1992, the harvest required more than 500 people daily and the applications for the job were 600. By 2002, only a few dozen people applied for the manual harvesting job. These mechanical harvesters were followed by other models that proved even more sophisticated and reliable, able to harvest cleaner and less damaged grapes, which is a requirement for high quality wines. The self-propelled and multiple-use tractors are also used for agro-chemical treatments on two, three or even four rows at a time.
The use of mechanical harvesters on the estate, however, has raised some of its own challenges:

- Structural wear and tear (stakes and wires that were previously installed and are not adequate to support the rigors of mechanical pruning and harvesting).
- Loss of product (only for some more delicate varietals, such as Moscato)
- Need for more rapid delivery of harvested grapes to the winery (transportation of the grapes in small bins keeps the fruit in better condition for vinification).
- Need to reorganize pressing and processing sectors in the winery to accommodate greater daily quantities of mechanically harvested grapes.

On the other hand, many positive attributes of mechanical harvesting made it possible to obtain better quality grapes than by manual harvesting, taking advantage of better organization in the field together as well as at the winery:

- Identification of the ideal harvest time. Regular sampling of the grapes and closely following ripening trends enables more precise scheduling of optimal harvest time. The greater speed, capacity and efficiency of the mechanical harvesters make it possible to wait until the last minute to carry out timely operations.
- Harvesting grapes at lower temperatures and reducing the delivery time to the cellar. Harvest generally begins in mid-August, when it is very hot; machines make it easier to harvest at dawn or during the night when the grapes are cool. In early varieties such as Pinot Grigio, Chardonnay and Sauvignon quality levels have been reached which were unattainable before the use of the harvesters.
- Speed and timeliness of harvest. In years with abundant rainfall at harvest, the grapes could be harvested quickly during the few days of more favorable weather conditions. This avoided damage caused by inclement weather.
- On the organizational level, the estate switched from a system that employed a great number of people for the manual harvest to one that required only 20-25 people together with 7-8 machines, together with a technician to manage the harvest operations and transportation of the grapes to the cellar.

This type of organization has increased the value of each and every vineyard; overall wine quality has improved and is closely monitored starting in the vineyards.

Banfi's new viticulture: operational models and vineyards for the future

Annual renewal of the vineyards is designed to respond to changes in demand in a relatively short period of time (5-8 years). The uprooting of many areas of Moscadello grown in Casarsa and the need for more high quality red grapes, such as Sangiovese, Syrah, Merlot and Cabernet Sauvignon, have been the guideline for the replanting programs. With the acquisition of new planting rights, the area under vine has increased, and the areas planted with Pinot Grigio have also grown.
During vineyard renewal, priority is given to the substitution of vineyards that have either an out- dated structure (stakes and wires), a layout not fit for mechanization, poor manageability (drainage, levelling, road network), or those heavily affected by mal dell'esca, a plant disease that severely reduces a vineyard's capacity and longevity. Some minor operations to prepare the soil are performed in areas where the new vines are to be planted. These aim at rearranging the topsoil while trying to maintain the natural curves and inclines. The soil is broken up, removing the larger stones and boulders, which are recycled for underground or surface drainage. However, it is most important to avoid changing the position of the layers in the soil's profile with the so-called "double layer" tillage.
Some old vineyards, after uprooting, were not re- planted because their soil proved to be unsuited for vine cultivation, such as soils made up of high sodium clay. These areas were not replanted with vines but rather were set aside for other crops such as organically grown wheat and alfalfa.
Since 1995, the planting of new vines has been done with a laser-guided machine that lines up the rows parallel to each other. This simultaneously permits proper spacing for the vines and squaring off of the vineyard. The vines are then used as reference for laying the stakes, thus reducing manual labor and costs. Two viticultural models have been chosen for the new vineyards: one for the high quality red wines, and another for the less demanding white and red wines.
The model chosen for the high quality reds is the unilateral spurred cordon training form, with distances of 3.0 x 0.80 m, (10 x 2.6 feet) which produces a density of 4.166 vines/ha (10.290 per acre), optimal for the estate's environmental characteristics and for cost reduction.
The cordon is placed 80 cm (31.5 inches) above ground. This enables manual operations, from shoot

to bunch thinning, (which are essential to maintain the proper vegetative-productive balance and therefore high quality grapes) to be carried out without bending down. The lanes are 3 m (10 feet) wide to enable the passage of even powerful tractors, providing stability on erosive terrains and in counter-sloping conditions. To simplify organization, any tractor must be able to carry out operations in all the vineyards. Though the vegetative-productive balance of the plants might permit narrower rows, the row width is nevertheless maintained to avoid exchanging machines.

For the white vines, such as Pinot Grigio, Sauvignon Blanc and Chardonnay, where grape ripening is sometimes delayed and thinning not performed, the free cordon training system was chosen to achieve modest, though not too meager, production. This training model, developed at the University of Bologna in the 1980s thanks to the work of Professor Cesare Intrieri and his team, provides both the maximum mechanization level and good grape quality. The free cordon training model, initially called cortina semplice, consists of a single supporting wire secured to the stakes that stick 140-160 cm. (55-63 inches) out of the ground and reduce obstacles for the machines. In terms of economic investment, it is evident that it is the most cost-effective model considering both the hectare and the linear meter of production.

With the free cordon training model, pruning and harvesting are performed mechanically. Soil operations, pest treatments and certain canopy management (suckering and sometimes topping) are carried out during the summer utilizing the same machines for the vineyards trained with spurred cordons. This enables the management of high quality vine areas with less than 80 hours/ha (197.6 hours/acre) per year. In the free cordon training model the vegetation falls back and the photosynthesizing leaf area is higher than on models where the leaves are tied, such as the spurred cordon and guyot training models. This guarantees a good production level without compromising quality.

Tab. 3 - Changes in the surfaces occupied by vine-ypes from 1992 to 2002.

Varieties	Surface of the vineyards		Variatio
	1978-1992	2002	%
Sangiovese for Brunello	140.0	223.0	+59.28
Cabernet Sauvignon	93.0	155.0	+66.66
Sangiovese	17.0	99.0	+482.3
Merlot Syrah	19.0	65.0	+242.1
Montepulciano	33.0	59.0	+78.78
Chardonnay	14.0	24.0	+71.14
Pinot Grigio	106.0	96.0	-9.43
White Moscato (Moscadello)	31.0	60.0	+93.54
Sauvignon Blanc	122.0	33.0	-77.95
	28.0	28.0	-

Innovations in vineyard management

In the new vineyards, immediately after planting the vine cuttings, a weed control treatment using residual herbicides is performed on the rows. The most common active ingredients are: isoxaben, propizamide, and trifluralin, all of which perform well in the majority of cases. This is far more cost effective than soil tillage and also reduces water and nutrient competition for the vines. Special care is taken in all the manual phases during the first three years of growth, when few operations are mechanized. The materials used and the operation procedures, both in winter and in summer, are studied in detail. In order to reduce costs, and to obtain the proper balance between growing types and machines, a technician constantly monitors all manual operations.

On many Tuscan wine-producing estates, the vineyard's growing phase follows no precise rules, which can compromise efficiency, effectiveness and future profitability of the machines. This is also detrimental to both the fruit itself and the quality of the resulting wine. The layout and all the manual operations during the first 3-4 years in each training model has become a set doctrine, with the goal of maximizing mechanical efficiency as well as the longevity of the vineyard. Concerning irrigation, the old sprinkling systems have been gradually replaced by drip systems, starting from the first year, in order to guarantee plant recovery and uniform development of the newly planted vines. In Montalcino, severe summer (late June through early September) droughts often coincide with the onset of grape ripening. They are critical for the continuation of the ripening process. When water shortage occurs, the synthesis of polyphenols and a certain amount of water flow is either blocked or slowed down, and a certain amount of water is necessary to return to a regular grape ripening process, and thus good grape quality.

Under high temperatures, the vine must have water available as it lowers the temperature of the leaves by transpiration. Water's thermo-regulating function keeps the grapes from getting burned, even when they are exposed to the sun. Water, if dosed correctly, becomes a factor that ensures quality. Together with the University of Pisa, various emergency irrigation programs are being tested as quality factors, depending on the variety, age of the vines, soil type and environmental conditions.

Dedicated to a finer wine world

Irrigation

S. Miele, M. Bertolacci, M. Marmugi, e. Bargiacchi

The first experience with drip irrigation in the vineyards of the Castello Banfi estate was in 1986. This phase was characterized by a preponderance of vine training under a high spurred cordon. Based on the positive results, the area using this method of irrigation was increased annually, reaching the present 650 ha (1.606 acres) in 2006 on various vine types of different ages.

As the terrain is mostly sloping, the farm uses exclusively integrated dripper laterals, with a discharge of 2.1 l h^{-1} equipped with self regulating emitters, generally with one dripper per plant. The drip laterals are attached to a wire hung above the ground to support the irrigation tubing along the entire length of the grape row to avoid interference with the soil tillage and other field operations.

To evaluate the potential of drip irrigation, the estate implemented an experimental program aimed at identifying the techniques of irrigation management that can obtain and stabilize production at excellent levels of quality, despite the frequent conditions of severe water scarcity typical of the area. This program foresees reaching these objectives also through a more thorough understanding of the physiology of the vine types. The ultimate goal is to identify the water stress levels of the various crop phases during the seasonal cycle that will yield the desired productivity levels.

For this reason, three water levels, with the appropriate experimental design, are compared with a non-irrigated plot, strategically measuring the pre-dawn and midday leaf-water potential, using a pressure chamber and the gravimetric method. The figures obtained during the various phases of the seasonal crop cycle were then correlated to the results of production, with particular attention to the analysis of the musts and, above all, to the quality levels of the wines. Although the complete figures are not yet available, the 2003 and 2004 seasons have undoubtedly underlined that it is impossible to obtain both yield and quality without resorting to emergency irrigation. In 2003, the driest of the two years, the ratio of grape production between irrigated and non irrigated parcels was roughly 1:3 for the Merlot and of 1:3.5 for the Sangiovese. However, most significant are the organoleptic differences that can be found in the wines produced from these vineyards. Another preliminary finding shows that it is possible to obtain good production results even with irrigation levels that are slightly lower than those applied up to now.

Artificial water storage basins

To support the growing needs of irrigation and limit the need to draw water from the Orcia and Ombrone rivers, the estate has progressively increased the availability of water from man-made “lakes,” locating them strategically to serve the most important areas of production. The individual rainwater collection units are connected by underground pipes, which allow the water to be transferred to where it is, needed the most. The lakes, with their main technical characteristics, are indicated in Tab.1. The water is collected predominantly during the fall and winter rainy seasons. Only in exceptionally dry years is the natural rainfall not enough to fill the lakes. In these cases, it was necessary to draw water from the rivers, around the beginning of spring, at least to fill the smaller lakes. Periods when the irrigation water is of an excellent quality, because it is sourced exclusively from rainfall, can be followed by periods when the quality is inferior, because river water always has some level of suspended solids that cannot be completely purified by the filtration system. Furthermore, the analytical profile of river water shows it to be more alkaline and higher in bicarbonates and thus likely to obstruct the lines (Tab. 2). These considerations make it necessary to follow a careful program of system maintenance at the end of the season when the use of river-water has been more elevated.

Tab. 1 - Technical characteristics of the man-made lakes at the Castello Banfi estate.

Artificial basin	Construction year	Capacity (cu. m. water)
Tavernelle lake 1	1970	20.000
Collupino	1970	6.000
Poggio alle Mura lake 4	1975	100.000
S.Costanza lake 2	1980	150.000
S.Costanza lake 3	1980	100.000
Collorgiali	1980	120.000
Cardeta lake 5	2001	25.000
Total		521.000

IN-DEPTH ANALYSIS

After overcoming much prejudice and resistance, the concept of vineyard irrigation is now established as a cost-effective farming practice, even in those areas traditionally devoted to the production of high-quality wine. Though it is true that wine quality benefits from a certain measure of water stress, it is also true that when the stress exceeds certain thresholds, lower yields are coupled with an unbalanced composition of the musts, with negative repercussions on the quality of the final product.

The general objectives of irrigation vary from initial planting to a fully productive vineyard. In the initial planting phase, normal irrigation is carried out with the goal of keeping soil humidity constantly at optimal levels to assist the vines in taking root and rapidly gaining strength. On the other hand, emergency irrigation in an established vineyard aims to improve production quality, regulating stress with application as needed in the different phases of the season. In any case, defining the proper timing and rate of irrigation must take into account the physical, hydrological and slope characteristics of the land, as well as the climate trend and the crop's effective evapotranspiration in relation to the vegetative phase, the vine's training system, and the plot's exposure. The physiology of the different vine types and the estate's production targets must be kept in mind when determining emergency irrigation in the established vineyards.

Tab. 2 - Characteristics of some of the water used for micro-irrigation at Castello Banfi.

Characteristics	Test results units	Collorgiali	Madonnino	Ricciarde-Ombrone	Max value tolerated
Color		Cloudy	Cloudy	Cloudy	Clear
Odor		None	None	None	None
Temperature	°C	23.0	23.0	23.0	25
pH		7.91	8.02	8.01	6.5 - 8.5
Conductivity	mS/cm	801	674	1308	750
Specific weight at 15°C	kg/l	1.002	1.001	1.002	
Precipitates		Present	Present	Present	Nil
Alkalinity	ml/l HCl 0.1N	28.4	39.9	38.6	
Fixed residue at a 180°C	mg/l	471.2	402.4	774.5	150
Nitrates	mg/l	0.52	0.24	3.68	50
Chlorides	mg/l	76.41	57.76	94.84	200
Calcium	mg/l	80.73	97.76	252.81	100
Magnesium	mg/l	24.21	15.77	45.36	50
Sodium	mg/l	34.28	17.44	33.23	175
Potassium	mg/l	8.13	7.28	10.94	10
Boron	mg/l	0.30	0.25	0.24	1
Iron	mg/l	26	18	20	200
SAR (*Sodium Absorption Ratio*)		0.90	0.50	0.50	< 6

BANFI

Dedicated to a finer wine world

The estate manages irrigation by integrating the "consumptive use" technique measuring the soil water content, the water tension in the petioles of the leaves closer to the bunches, and the bunches' developing trend (Pict.11a, 11b, and 12).
A precise and specialized research plan is well underway to achieve and maintain the highest levels of quality. This research is based on a test plot, starting from the vineyard and ending in the cellar, correlating irrigation techniques with the quality of the final product.
For each vine type, the timing of irrigation and the appropriate water dosage are evaluated and identified in order to reflect the entire potential of a territory, which is at times challenging to – yet certainly well-suited for - growing vines. There is a constant effort by Castello Banfi to capture and transmit in the wine all the scents of this unique environment.
The method best suited to irrigate vineyards is undoubtedly "drip" irrigation, both for its ability to save water and other distinguishing characteristics:

- positioning the emitters makes it possible to optimize the distribution of water, and eventually of fertilizers, close to the roots of the plants
- partial wetting of ground surface reduces water loss caused by evaporation and run-off, and also limits weed infestation
- a wide range of choice in discharge capacity and emitter spacing enables the irrigation system to be adapted to soil types with varying filtration rates and slopes
- irrigation water does not touch the leaves of the plants and this reduces the risk of fungal diseases

the vineyard is easily accessible for carrying out farming operations, even during or immediately after irrigation

- effects of the wind on water loss and on the evenness of distribution are extremely limited, extending daily use; so, with appropriate sectoring, irrigation can be carried out using less water
- because the laterals are secured to the vine trellis, they do not interfere with any tillage operations
- low operating pressure reduces energy costs for pumping
- it is possible to "fertigate," i.e. distribute nutrients carried by water, with great precision and at a low cost, immediately and without waste.

To benefit from all these positive aspects, it is imperative to have a carefully designed and accurately installed drip irrigation system. For this purpose, the resolution of certain problems is crucial to the performance of the system and the efficiency of irrigation. The first problem stems from the reduced water path size inside emitters, making it necessary to preventively remove all water-borne causes of clogging or occlusion. A correct filtration is thus essential, with the installation of filtering stations of adequate size in relation to the type and concentration of the suspended particles found in the water used for irrigation. To ensure a continuously efficient filtration, the filtering stations are usually equipped with automatic flushing systems, which remove particles trapped in the filters every time there is a pressure loss that goes beyond a set threshold.
Mean flow rate and position of emitters along the laterals should be defined according to soil type. In general, on permeable soil types such as those found on the Castello Banfi estate, due to the consistent skeletal structure, the point source emitters should be close together and emitters with low flow rate should be adopted. On clay soils, the point source emitters can be spaced farther apart and, if the terrain is mostly flat, it may be preferable to use emitters with a higher discharge. In sloping situations, the

discharge of the emitters must be limited to avoid excessive water run-off toward the valley, due to soil's low infiltration rate. The next step is to choose the type of emitter to adopt, whether a "common" non-compensating one, or an automatic pressure compensating type. Non-compensating emitters will have a change of discharge rate in response to a change of operating pressures and are best suited for flat or small slope situations. Therefore it is necessary to limit the length of the lines to keep the rate variations within the desired limits. Pressure-compensating emitters have a discharge rate that remains unvaried even with changes of operating pressures within a certain interval, called the self regulating range. These emitters, though requiring a higher initial investment and usually higher energy costs for pumping, can irrigate sloped terrains, and with the same diameter, use longer laterals. Pressure compensating laterals and emitters are used to maintain uniform discharges in spite of pressure changes caused by slope or high friction losses due to excessively long laterals.

Irrigation systems can use online or inline drip emitters. Online emitters are typically attached to the outside of the supply tubing, while inline emitters are housed inside the tubing and are an integral part of it. Online emitters can easily be replaced when they malfunction due to clogging or damage, but require more labor for installation and are more liable to accidental damage during field operations. The inline emitters currently on the market offer an ample choice of emitter spacing, appearing as whole tubes without protrusions; thus, they are more easily installed and not subject to damage during field operations. The latter were adopted as the technical solution for the Castello Banfi estate.

After having defined average flow rate, emitter spacing, type of drippers and laterals, the next step was to identify the model of the drippers and integrated dripper laterals to employ, keeping in mind the quality of material and, above all, irrigation uniformity attainable with their use. Uniformity is of vital importance in drip irrigation of vineyards, as each plant is very dependent on the water furnished by the single emitter. If the emitter supplies higher water quantities than those preset, the plant suffers, causing inevitable repercussions on production. It is therefore fundamental to choose the lateral model prudently, after verifying on paper the attainable uniformity with different models under specific conditions of use. To properly check this, it is necessary to have the technical functioning characteristics of the different laterals, which consist of:

- the law that defines how the discharge rate varies in relation to the pressure on the line
- the coefficient of technological variation, which indicates the possible swings between the discharge rates at a set pressure caused by inevitable small differences in construction due to manufacturing technology
- the law of complex pressure loss, uniformly distributed and localized at the laterals, as a function of the number of laterals per line

Recently, emergencies have arisen again, highlighting the need for optimizing water and energy use to minimize waste. These goals can easily be reached, even by laymen, thanks to specific data processing tools, such as the software program Ve.Pro.L.G., recently released by L.N.I. for ARSIA- Tuscan Regional Government Agency for Agriculture. The software, of which several screens are shown below, is aimed specifically at saving water and energy and its main functions are the following:

- it verifies the functioning of the laterals in systems already in operation and identifies eventual modifications to improve efficiency
- while the project is being developed, it establishes the dimension of the laterals to obtain the required degree of efficiency

Ve.Pro.L.G. not only reconstructs the hydraulic functioning of the laterals, but is also able to furnish a great amount of supplementary information, evaluating for each lot:

- wasted water volume and useful water volume for the crop
- energy consumption and cost of irrigation management
- annual incidence of the initial cost of the laterals

A database is associated with the program. The topographic, cultivation, and irrigation system characteristics of each plot can be stored in the database and used for successive checks, variations of the irrigation techniques or adaptations of the systems. The database can be very useful for governmental bodies, territorial organizations or big farming organizations for analyzing and programming the uses of water resources.

Once the type of lateral has been chosen, the area covered by the system is subdivided into irrigated sectors, or portions of an area that will be irrigated successively. Taking into account the intensity of water application, or more specifically the relationship between the average discharge rate of the emitter and the surface covered by it, a number of sectors are established in relation to the water rates and to the programmed time between irrigations during the peak seasonal periods. When planning, it is a good rule to ensure that the system will work for less than 24 hours daily, even in peak irrigating periods, to allow for recovery in case of breakdown or an exceptional climatic situation.

Once the number of sectors has been established, it is necessary to define the surface and the location on a detailed map. This should take into account the manifolds and main lines, the choice and position both of the sector valves and of the regulation and control devices, and selection of the pump.

WEED CONTROL

S. Miele, M. MarMugi, S. Benvenuti, C. Cuscito, e. Bargiacchi

Many kinds of weeds from a range of different botanical families can infest vineyards. Those most harmful for the vine are the ones that compete strongly for water (and secondly for nutrients), especially during periods of water scarcity or when the vine requires a lot of water, as well as weeds with great aerial development that form a mat of stalks and roots that hamper water and gas exchanges of the soil.
The volume of water withdrawn is always high. Bermuda grass-type weeds (Cynodon Dactylon), for example, use about 1 to 1.5 liters to form a gram of dry matter, while the grapevine, which has a lower water-absorbing capacity, needs around 0.3 l g^{-1}.
Weeds have many negative effects on the vine:

- they can greatly reduce development (Agropyrum repens, for example, reduces development of the vine shoots by 28%, Calystegia sepium by 41%)
- they favor water stagnation, enhancing development of blue mold, Oidium and berry rotting
- they can secrete substances with allelopathic effects that compromise the vine's normal activity
- they can be a haven for parasites and phytophages, not to mention being attractive to nematodes (as does the ombrelliferic Amni majus)

Weeds that have underground organs pose particular problems, especially if they are deep and able to send out additional shoots: among these are the grasses (Cynodon Dactylon, Agropyrum Repens, and sometimes Sorghum Balepense), Canada thistle (Cirsium Arvense), the common horsetail (Equisetum Arvense), etc.
The technical charts to follow will take into consideration the weeds most commonly found in the vineyards of the Castello Banfi estate, including in particular the following:

- Agropyrum repens
- Amaranthus retroflexus
- Calystegia sepium
- Chenopodium album
- Cirsium arvense
- Conyza canadensis
- Cynodon dactylon
- Digitaria sanguinalis
- Echinochloa crus-galli
- Equisetum arvense
- Inula viscosa
- Lolium multiflorum
- Rumex acetosella
- Rumex crispus
- Setaria glauca
- Setaria viridis
- Solanum nigrum
- Sonchus oleraceus

It should be noted that among the weeds found at Castello Banfi, there is a rare species; the *Equisetum variegatum Schleicher*, a species of circumboreal origin that is typically found in sandy, gravelly, relatively humid soil. This filiform weed tends to grow near drip emitters and is difficult to control since it is characterized by a *habitus* and tissue that reduces the foliar absorption of the active ingredients.

Agronomic, mechanical and physical means of weed control

Planting vines on lands previously planted for forage crops, such as alfalfa and sulla, offers the advantage of reducing the soil seed bank from the start. In this environment, a few shallow operations are sufficient to keep the plots relatively free from weeds before planting the new vineyard. Mulching the rows with plastic polyethelyne black film and/or manual and mechanical hoeing (between the rows) are common means of controlling weeds in new vineyards. Recently, these techniques have been compared to the use of a residual herbicide (isoxaben) to evaluate the efficiency of chemical control. Nonetheless, mulching with plastic film offers a series of advantages, including its function of maintaining soil humidity, which can be rewarding in a dry environment such as that of the Castello Banfi estate.

Mulching with straw has also been studied in young vineyards before the poles are laid, in the established vineyards with rows 3 meters (9.8 feet) wide, and in the main ditches more exposed to erosion. For this purpose a straw-spreading unit, originally designed for zoo-technical use, was specifically modified so it could spread as much as 0.5-1kg m^{-2} (1.3-2.6 pounds per square yard) of long- stemmed straw. Along with these tests, together with the Department of Agronomy and Agro-ecosystem Management (DAGA) of the University of Pisa, complementary treatments to extend straw persistence on the soil have also been studied. Mechanical operations and manual hoeing, however, remain the most widely used means of weed control, particularly on an annual basis, given that the only way to control any species with agamic multiplication organs (rhizomes, bulbs, etc.) is chemical weed control. Normally, the operations consist of disking or harrowing 2-3 times a year, at the end of winter/ beginning of spring, in alternating rows where there is controlled turfing. In this way, the water stress caused by turf competition is reduced. In an environment characterized by low summer rainfall, microirrigation affects the germination of the most warm-season weeds, which tend to grow mostly along the rows, causing many challenges to mechanical and manual hoeing. Even mulching modifies weed distribution: it is common for weeds to sprout from the same hole from which the vine cutting or the young vine grows, and this causes obvious difficulties during uprooting.

Controlled turfing

This technique offers numerous advantages in the vineyard: it reduces soil loss due to erosion, especially on sloping plots; it improves water infiltration during the rainy season; and it allows equipment to work more easily in the vineyard. On the other hand, it requires the correct choice of the species, variety, and mix to sow and correctly manage (overseeding, clippings, topdressing) over time. While doing this, one must keep in mind the potential risk of water stress that turfing may cause the vine.

As shown by the tests carried out at the Castello Banfi estate over several years, good results, in terms of persistence and low levels of competition with the vines for water, have been obtained first with a mixture of *Lolium perenne* (40%), *Poa pratensis* (38%), *Festuca rubra* (20%) and *Agrostis stolonifera* (2%); then with a combination, based on the previous grasses with different percentages of *Trifolium subterraneum* and, more recently, with a third one, made from a variety of *Festuca rubra* with a particularly deep rooting, ideal for reducing erosive phenomena on sloping field surfaces. Grass species are sowed using a sowing machine for sod-seeding, custom designed for Banfi by one of the main national manufacturers of *no-till* machines. Usually the turf is sown after a weed control treatment.

Chemical weed control

The chemical management of the vineyard weeds, initially proposed on the whole area, is now done only on the rows, both to reduce environmental impact and costs, and also to maintain controlled turfing in some lanes. The advantages of this technique include low-cost, speed, and the absence of damage to the plant's collar and superficial roots.
On-the-spot treatments are carried out only in the vineyards where there are particular types of weeds that typically grow in patches (*Equisetum, Rumex, Inula*) using active ingredients that are specific to these weeds (MCPA). The main products used are the following:

- Systemic products with foliar action, such as glyphosate and trimesium glyphosate, absorbed by the plant's green parts and then transported to its various organs, including the roots. They are generally applied mixed with ammonium sulphate (3-5 kg per hl / 32-54 ounces per gallon of water). To prevent the active ingredient from accidentally being absorbed by the vine itself, it is distributed during winter dormancy using shielded equipment or a dripping bar.
- Contact products with foliar action, such as ammonium gluphosinate; the effect lasts for a shorter period because it simply desiccates the tissues that it touches.

The Castello Banfi estate does not regularly use residual products with anti-germination action, as the estate has long since agreed to the directives of low-input cultivation. As previously indicated, tests are being carried out on the new vineyards to compare mulching with plastic film and an initial treatment with isoxaben. Weed management operations (combined use of tillage, turf clipping and foliar herbicide application) are timed according to the weed germination pattern and any consequent need to control them. This is actually determined by a careful *scouting* of the vineyards. Rainfall and temperature trends, the presence of certain kinds of strongly competitive weeds and the combined effects of other operations (topdressing, suckering, irrigation, etc.) may greatly modify both the type and the number of weed control operations. In the past, Banfi would apply a single treatment with glyphosate or similar products, though now following the Region of Tuscany's directives on low-input cultivation, as a rule, Banfi has started applying 2-3 treatments using much lower doses of active ingredients than the original single treatment. This is possible because low volumes are used and treatments are targeted where there is an evident problem, using drip bars or impulse sprayers.
Based on germination dynamics, there are three main phases of operation: autumn-winter, when the annual cool season weeds grow (*Veronica, Stellaria, Senecio, etc.*); spring, during which the perennial species prevail (*Cirsium, Cynodon, Convolvulus*); and summer, when grass and annual dicots (*Amaranthus, Solanum nigrum, Digitaria, etc.*) emerge if water is available.

BANFI

Dedicated to a finer wine world

IN-DEPTH NOTE

Vineyard Turfing

Turfing is a soil management technique that introduces a spontaneous turf plant, or one that has purposely been sown, to cover the vineyard. This covering can be permanent or it can be performed only in some periods of the year, and it can cover all the vineyard surface or just single strips on the rows or between them. Turfing is a valid solution when tillage is difficult because of poor access in the vineyard and it is necessary to reduce soil erosion and compaction. Its positive effect, that balances all the physical, chemical and biological processes involving the soil-plant system, makes it a viable option under most agronomic conditions. First of all, equipment can travel more easily through the vineyard in all weather conditions. The physical structure and porosity of the soil improves, due to the higher input of organic matter, the protective effect of the grass cover and the screening effect of the clay- humic aggregates. This makes it possible to limit damage caused by springtime rainfall, and to reduce chlorosis potential and root asphyxia. Normalization of the water balance also indirectly affects mineral absorption, which increases, and reduces thermal excursion both between night and day and between the seasons. All these effects result in less damage caused by physiological disorders and plant diseases such as root desiccation and Botrytis. In terms of fertilization, it reduces the amount of leached Nitrogen, optimizing the availability of this element throughout the year. Furthermore, even if Phosphorus and Potassium are top dressed, they are transferred and redistributed better throughout the entire soil penetrated by roots. Even the soil's biological activity is intensified as a result of the enrichment of organic matter. Moreover, penetration of rainwater in the soil is made easier, with a consequent improvement of subsoil drainage. Spontaneous weeds are not eliminated but simply kept under control, and this allows the development, within the vineyard, of a useful population of insects.

As for the inconveniences of turfing, the most important one is certainly connected to the fact that the grass sod competes with the vine for water and nutrients, especially during the vineyard's first years. Moreover, the presence of tall grass in spring makes the threat of frost more serious, while, in some cases, the non-tillage of the soil may favor the presence of some pests and diseases.

The choice of which species (Graminaceae and/or Leguminosae) to sow, and which type of turfing to perform (natural, artificial, temporary or permanent), obviously depends on the physical, chemical, and climatic characteristics of the area in which the vineyard is located. Grass species, such as Lolium Perenne, Poa Pratensis, Festuca Rubra, Festuca Ovina, have rustic traits: they are quick to establish, resistant to trampling, strongly competitive against weeds and, at the same time, moderately competitive against the vine for water and nutrients (especially if sown in alternate rows and kept cut low). By introducing one or two legume species with a modest development in a mix (Trifolium Repens or Lotus Corniculatus) one can obtain a sod that is almost self-sufficient in terms of nitrogen needs and similar to spontaneous mixtures, but less beneficial in terms of wear, water competition and carrying capacity. Many ready-made mixtures are available on the market; however, knowing the main characteristics of each species and mixture helps to choose those which can solve different problems. In the cooler, more fertile soils of the plains, in order to solve soil carrying capacity problems and vine vigor control, the most suitable is Festuca Arundinacea, by itself or mixed with Bromus Inermis or Lolium Perenne. To avoid risks of water and nutrient competition, it is best to choose Festuca Ovina, Festuca Rubra, Agrostis Tenuis and Poa Pratensis, which have fewer needs, are rustic and do not need frequent clipping. When short establishment periods are required Bromus Inermis is the choice.

Among the annual self-seeding legumes, to obtain an artificial sod, one should keep in mind two groups: the subterranean clovers (Trifolium Subterraneum, T. Yanninicum and T. Brachycalicinum) and the annual alfalfa (Medicago Litoralis, M. Murex, M. Polimorfa, M. Rotata, M. Rugosa, M. Scutellata, M. Tornata and M. Truncatula).

In short, a good mixture must have the following characteristics: quick establishment, good competitiveness against weeds, resistance to trampling, and low maintenance requirements.

Graminaceous

Festuca Ovina
Very similar in behavior to the red Festuca but more adapted to dry climates and lean soils. It is resistant to trampling because of its structure, but is not very competitive and therefore recommended as a component in mixtures.

Festuca Arundinacea
A rustic species, adaptable to a range of climates with the exception of overly shallow soils; it has a deep reaching root structure which gives it high resistance to drought. It is characterized by good longevity and resistance to trampling, but its vigor often makes it unsuitable for vineyard turfing (for excessive competitiveness and the need for frequent mowing). It is slow to germinate and then establishes a thick shell which reduces the development of spontaneous flowering. It does not adapt itself well to low mowing, given the desired height of the fully grown plant (recommended minimum height 30 mm / 1.2 inches). The leaf structure is broader than that of Lolium, but intense genetic selection over recent years has brought it into the category of "dwarf" grasses with more fine leaf structure.

Festuca Rubra
This species has thin rhizomes; it has a good germinating speed (10-15 days) and establishes itself quickly. Its peculiar resistance to low clipping and to low nutrient input allows this plant's use in poorly maintained areas. It has an excellent resistance to high temperatures, drought and shade. On the other hand, it has a modest resistance to trampling; the minimal advised clipping height is 10 mm / .4 inches.

Agrostis Tenuis
This perennial species germinates in spring and blooms in summer. It has short stolons of the stolonifera type, and, compared to others of this type, a less dense sod. It prefers poor soils, scarcely tilled (it is a pioneer species in the very poor soils), and even the cold. In mixes, it is frequently preferred to other species, due to its low competitiveness and adaptability to modest levels of nutrition and maintenance.

Lolium Perenne

It is a perennial plant, with rhizomes and side buds that emit roots. It prefers fertile soils, rich in nitrogen, compact and also clay-silty. The varieties chosen to be used in turfing have a more contained development and higher ability to adapt to frequent clippings compared to those used for forage. They also have a good resistance to trampling, establish quickly and with little effort, but do not last long, especially in high temperatures and with scarce rainfall.

Legumes

Trifolium Repens

It is a permanent species, due to its capacity to spread asexually. It has a high adaptability even under extreme conditions (temperature, skeleton in the soil). However, it prefers warmth and sun, rather loose soils, which help the penetration of its roots, and even those rich in nitrogen. The adult plant reaches a height of 8-10 cm / 3-4 inches, and a length of 45-80 cm / 18-31 inches. It is not particularly competitive; therefore it is preferably used in mixtures together with grasses.

Trifolium Subterraneum,

T. Brachycalycinum and T. Yanninicum Subterranean clover is the common name for the three clover species: Subterraneum, Brachycalycinum and Yanninicum. All three prefer soils that range from fine-sandy to clayey, with a pH ranging from

5.5 to 7; the species Brachycalycinum also adapts to soils with a pH higher than 7.0 but is less resistant to cold conditions.

The adult plant does not grow over 10cm / 4 inches and has a stoloniferous bearing.

The Medica Genus

The Medicago genus includes annual or perennial grass species, rarely shrubs, that have a long-lasting blooming period (from May to September) and their yield depends on the cuttings that are periodically performed. For turfing, it is used both before planting the vine, to "influence" the soil positively (Medicago Sativa) and together with appropriate mixtures (other species of the family later described).

Alfalfa is a plant that adapts to different climates and soils; it withstands both high and low temperatures and grows well both in humid and dry climates. It prefers temperate and cool climates and loamy soils, which are rich in lime and nutrients. It grows only with difficulty in shallower, less permeable, acid soils. Thanks to its deep root system, it does not impoverish the topsoil, but rather enriches it with organic matter from the crop's residues and with the nitrogen fixated by the bacteria in the root nodules. Generally the infection occurs naturally as the nitrogen-fixing bacteria are present in the soil. Should the infection not occur, one can resort to spreading a ton of soil from a good alfalfa field on the new one.