MEASUREMENT OF QUALITY POTENTIAL: INSIGHTS INTO PLANTING CHOICES

MESURE DU POTENTIEL QUALITATIF : NOUVELLES PERSPECTIVES DANS LES CHOIX A LA PLANTATION

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Abstract

Within the current context of climate change, the choice of variety and rootstock for each specific pedo-climatite becomes critical. In order to study the impact of soil, rootstock, and the age of the plot on wine quality, a database was created across a group of 7 chateaux of the Médoc production area (Bordeaux region). The database includes 409 plots representing 289 ha. A quality index was assigned taking in account the type of wine produced (1st, 2sd, 3rd) over 6 years (2008-2013) for each individual plot. The results showed a low diversity of rootstocks and a weak adaptation of rootstock to the soils, highlighting the vulnerability of these vineyards to climate change. Each studied factor had an effect on quality, but none alone explain the type of wine produced. According to variety and vintage, the effect of each parameter on wine quality is different. For instance, on Merlot, the data highlighted a strong effect of age and soil, and a lower effect of rootstock, on the quality index. This study demonstrates the power of working on a larger scale than the individual estate in order to consider a higher variability across the factors studied. The analyses of database produce some surprising results, quite different from what is commonly described as typical for Medoc vineyards.

Keywords: Database, wine quality index, soil-type, rootstock, vine variety

Résumé

Dans le contexte actuel de changement climatique, le choix du cépage et du porte-greffe pour chaque pédo-climat spécifique devient crucial. Afin d'étudier l'impact du sol, du porte-greffe et de l'âge de la parcelle sur la qualité du vin, une base de données a été créée dans un groupe de 7 châteaux médocains (région de Bordeaux). La base de données comprend 409 parcelles représentant 289 ha. Un indice de qualité a été attribué en tenant compte du type de vin produit (1er, 2nd, 3ème) sur une période de 6 ans (2008-2013) pour chacune des parcelles. Les résultats ont montré une faible diversité en porte-greffes et une faible adaptation du porte-greffe aux types de sol, soulignant la vulnérabilité de ces vignobles au changement climatique. Chaque facteur étudié a un impact sur la qualité, mais aucun n'explique seul la qualité du vin produit. Selon la variété et le millésime, l'effet de chaque paramètre sur la qualité du vin est différent. Par exemple, sur Merlot, les données ont mis en évidence un fort effet de l'âge et du sol, et un moindre effet du porte-greffe, sur l'indice de qualité. Cette étude démontre l'intérêt de travailler à plus grande échelle que celle de la propriété afin de considérer une variabilité plus élevée pour tous les facteurs étudiés. Les analyses de cette base de données produisent des résultats surprenants, tout à fait différents de ce qui est couramment décrit comme typique pour les vignobles du Médoc.

Mots-clés: Base de données, indice de qualité du vin, type de sol, porte-greffe, cépage

Introduction

Terroir can be considered as the combination of biological, physical, and human factors (van Leeuwen and Seguin 2006). Thus, many factors affect the productivity of the vine, and the quality and the typicity of the wines, which can be classified as intrinsic or extrinsic relative to the vine. Since the end of the 19th century, vines have been grafted on rootstocks selected or created from American phylloxera-resistant species. The intrinsic factors are both the grape variety with its own morphological and physiological characteristics giving it cultural aptitudes but also the rootstock with also its own characteristics. Significant interactions occur between the rootstock and the scion beyond the phylloxera resistance. The two genotypes associated by grafting determine the metabolic functioning and the physiological characteristics of the whole plant and finally the quality potential of grapes produced (Ollat *et al*., 2015). The influence of the rootstock on the scion has been known for several years, such as the conferred vigor (Ollat *et al*., 2003), but today it is known that the scion also has an impact on rootstock behavior (Tandonnet *et al*., 2010). The quality of the grapes and wines produced will therefore depend on these properties of variety/rootstock association but also its adaptation to environmental conditions, in particular soil and climate. These various extrinsic factors are themselves interacting. The soil will directly influence the water and nitrogen status of the vine (van Leeuwen *et al*., 2009, 2004, Tregoat *et al*., 2002, Choné *et al*., 2001), but effects can be modulated by technical management. Cover crop will influence the water status all the more strongly as the climatic demand will be strong (Morlat and Geoffrion, 2000). The amount of flavonoids and anthocyanins will decrease with nitrogen fertilization (Hadran *et al*., 2016). There are thus many interactions between all of these factors that the winegrower must consider in order to produce the best possible wine on his estate. The present study proposes to examine these interactions between the soil, the grape variety, and the rootstock by vintage on the "micro-regional" scale by studying the data gathered in a seven large estates of this micro-region. Considering the changing climate most vine growers consider choosing a variety/rootstock well-adapted to the terroir is a key factor for sustainable vineyard design.

Materials and methods

A database was created across a group of seven estates located in appellations Saint Julien (3 estates), Pauillac (1), Margaux (1), and Pessac-Léognan (1), all located on the alluvial left bank of the Garonne river. Soil type, grapevine variety, rootstock, and vine age were recorded for all the parcels of these seven estates. Soils are classified according to the French « Référentiel Pédologique » (Baize and Girard, 1995). According to soil maps, the main soil-type was determined for each parcel.

For all of these 7 estates studied, the first quality wine is sold approximately twice as expensive as the second quality wine. Third wines are sold at a price covering just production costs. Based on this postulate, a Quality Index is attributed to each parcel by the following scale: 4 points are given if wine produced in the parcel is blended into the first quality wine; 1.5 point is given if wine produced is blended into the second quality wine; 0 point is attributed if wine is blended into the third quality wine. To take in account the objectives of different estates, the point number (4, 1.5,0) is multiplied by the percentage of second and third wine.

This Quality Index is established for each vintage from 2008 to 2012 and averaged over these years. Yields were recorded for each individual parcel and averaged over the same series of vintages. Hence, a database of approximately 400 plots over 4 years was established, from which it is possible to trace how soil-type, grapevine variety and rootstock, as well as their interactions, affect grape quality potential and yield in these estates.

The mean Quality Index and yields were analysed using a linear model to test effects of soil, grapevine variety, and rootstock (R software; R Development Core Team 2010). When we found a significant effect of soil, rootstock, or yield on the Quality Index, multiple comparisons were conducted to test differences between soils (or rootstock) using Tukey's HSD test.

Plots were classified according to a combination of soil, variety and rootstock characteristics. For example, plots planted in PEYROSOL with Cabernet-Sauvignon on 3309C constitute a group. Groups of plots with at least 4 plots were kept and ranked according to the mean Quality Index.

Results

In the database made up of the selected estates, Cabernet-Sauvignon and Merlot are the most represented varieties with respectively 52% and 39% of the planted surface. The relative percentage of Petit Verdot is 4% and Cabernet franc 4%. Regarding rootstocks, the 101-14 MGt is predominant (33%) followed by 3309 C 14%, 420A MGt 8% and RGM 6%. SO4, 44-53 M, and Gravesac are little used (5%, 3% and 2% respectively). About 28% of plots are planted with a mix of rootstocks. According to the main soil type of each plot, the gravely soils are in the majority (BRUNISOL 26%, PEYROSOL 15%). LUVISOL 12%, PODZOSOL 10%, REDOXISOL 9% are well represented in the database. In the other hand, PLANOSOL 6%, CALCOSOL 5%, COLLUVIOSOL 5%, ARENOSOL 5%, CALCISOL 4% and REDUCTISOL 3% are underrepresented. The planting date of plots spread out from 1940 to 2010. The mean plantation year is 1983+/-1 for Cabernet-Sauvignon versus 1986 +/-1.0 for Merlot.

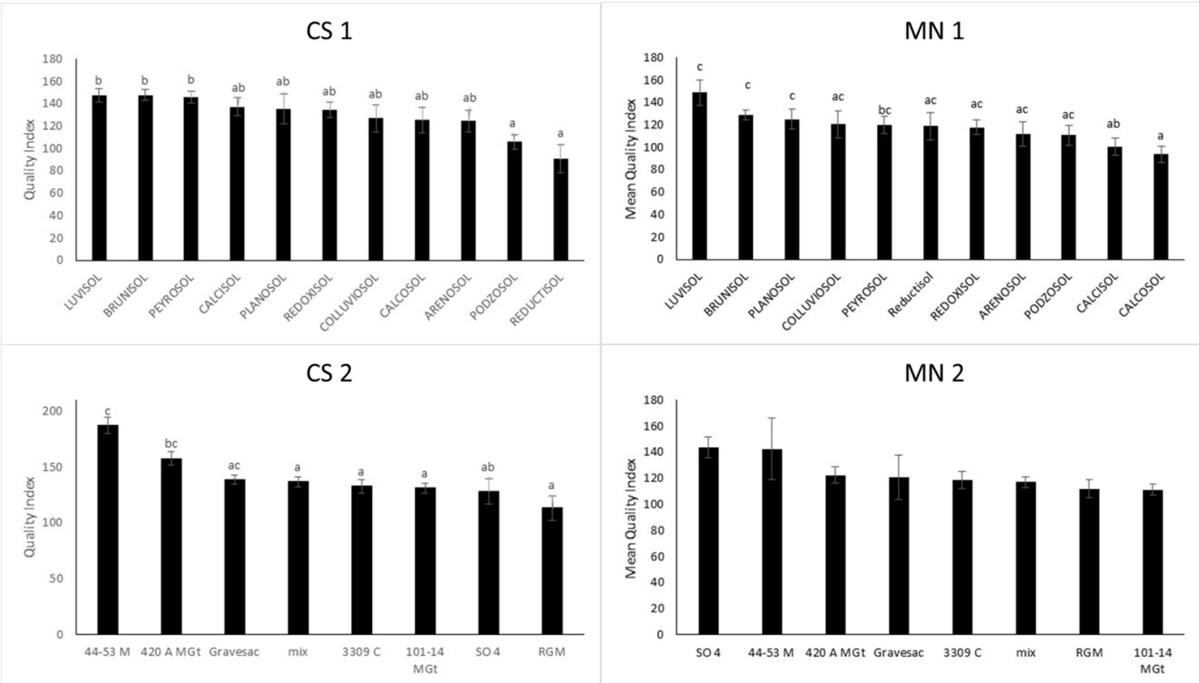

Figure 1 : Mean (±sd) Quality Index per soil type (CS1 and MN1) and per rootstock (CS2 and MN2). Analyses were carried out per variety (Cabernet-Sauvignon: CS1 and CS2; Merlot: MN1 and MN2). Different letters above bars indicate significant differences between soil type or rootstock (at $P < 0.05$).

Effects of soils type, rootstock and age on Cabernet-Sauvignon

Our results showed high and strongly significant effects of soil type ($F=4,69$, $p<0,05$) ; Rootstock $F= 3,2$, $p<0,05$; Age $F=8,9$, $p<0,05$ on mean Quality Index (Figure 1). There is a large part of unexplained variance in the model and our fixed effects explain only 25% of the data variability.

A first group of soil-type which includes vineyards located on PEYROSOL, BRUNISOL, and also on LUVISOL, shows a higher Quality Index and is statistically different from the worst group composed of PODZOSOL and REDUCTISOL. CALCISOL, CALCOSOL, ARENOSOL, COLLUVIOSOL, PLANOSOL, and REDOXISOL present an intermediate Quality Index, not statistically different from the 2 other groups of soil types. Vineyards grafted on 44-53 M and 420A MGt show higher Quality Index than those grafted on the other rootstocks (Figure 1). The older plots are more qualitative than the younger but the age's effect is less clear than what one could imagine.

Yields significantly differ between soil type ($F=3,0$, $p<0.05$) and rootstock ($F=2,8$, $p<0.05$). The model explains 20% of the data variability. ARENOSOL is statistically significant more productive than others soil type. 3309 C and 101-14 MGt have higher yields than RGM and 44-53 M. Others rootstocks are intermediate.

Effects of soils type, rootstock and age on Merlot

Soil types and age are significantly related to the mean Quality Index (soil types $F=2,5$, $p<0,05$; age $F=17,6$ $p<0,05$) and the model explain 23% of the variance ($F=3,46$; 18 df ; $p<0,05$).

LUVISOL, BRUNISOL, PLANOSOL and PEYROSOL show a higher quality index than CALCOSOL (Figure 1). COLLUVIOSOL, REDUCTISOL, REDOXISOL, ARENOSOL, PODZOSOL, and CALCISOL have an intermediate Quality Index (Figure 1).

Soil types also have a significant effect on yields ($F=3.6$, $p<0.05$), but the model explains only 22% of variance. CALCISOL seems to be significantly more productive than BRUNISOL, PLANOSOL, COLLUVIOSOL, ARENOSOL, LUVISOL, PEYROSOL and PODZOSOL. No rootstock effects have been observed on yield.

As could be expected, the Quality Index of Cabernet-Sauvignon is better on gravely soils such as BRUNISOL and PEYROSOL (Figure 1). Renouf *et al*. (2010) also found that grape quality potential for red wine production was highest on these soils. The very good result of Cabernet-Sauvignon planted on LUVISOL is more surprising. Indeed, LUVISOL is often characterized by a non-limiting water and nitrogen supply, which is not conducive to the production of quality red wines (van Leeuwen *et al*., 2009 and 2004). However, in our study LUVISOLS are mainly gravelly LUVISOLS whose behavior will be close to the agronomic behavior of PEYROSOLS. It is also possible that the quality of the wines appreciated in this study is due to the clay being located at depth in this soil type. The worst Quality Index of Cabernet-Sauvignon was obtained on REDUCTISOL which is in accordance with current knowledge.

On Merlot, the best associations are on LUVISOL, BRUNISOL, and PLANOSOL. On other hand, the worst Quality Index has been obtained on calcareous soil such as CALCISOL and CALCOSOL on which this variety is often advised. This result is unexpected because the Merlot acquired its reputation on the limestone soils of Saint-Emilion where it excels. However, this result can be explained by the fact that CALCOSOLS are often less water limiting in the Medoc area and that the typicity of Medoc wines is based on Cabernet-Sauvignon. The classification according to the Quality Index depends on the product’s goal. The question that arises is whether it is an intrinsic difference of Merlot on CALCOSOL or a difference from a different product goal than that sought in Saint-Emilion.
About rootstocks, Cabernet-Sauvignon vines grafted on 420 A MGt or on 44-53 M are better valued (Figure 1). 44-53 M has been abandoned little by little because of susceptibility to magnesium deficiency although it can be an excellent rootstock when fertilization is properly managed. The 420A MGt is a very good rootstock that also has the advantage of being more tolerant to drought than the 101-14 MGt which is an advantage in the current context of climate change. On the other hand, Cabernet-Sauvignon grafted on RGM or 101-14 MGt which are commonly used in association with this variety are less often correlated with the first wine than other rootstocks. These rootstocks are not well valued with MN even if there is not significant statistical difference between rootstock on Merlot. Overall, the Merlot grafted on SO4 and on 44-53 M are very well valued.

The oldest plots are statistically more qualitative than the younger plots. This effect is slightly more pronounced for Merlot (Figure 2). However, it is not possible to generalize this conclusion. Indeed, there are clearly great qualitative differences for the same year of planting as can we see in Figure 2. Furthermore, we could have a very clear age effect since only the best plots remain among the oldest plots because the least qualitative plots have been replaced over time during plot renewal.

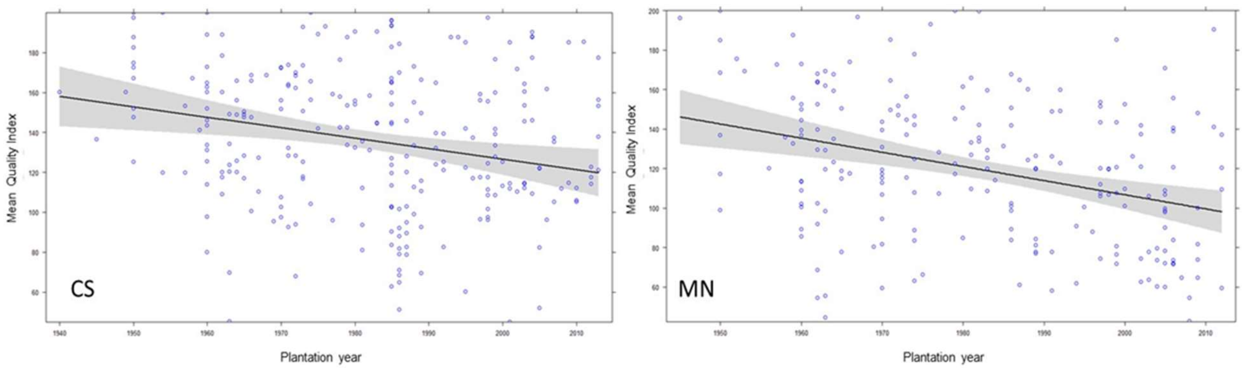

Figure 2: Mean (±sd) Quality Index per plantation year (CS=Cabernet-Sauvignon, MN=Merlot noir)

The best combinations Soil/Variety/Rootstock of the study

Among the ten best Soil type-rootstock-varieties combinations, Cabernet-Sauvignon is in the majority (80%), 420 A MGt and LUVISOL also (40%). However, a great diversity can be observed among rootstocks and soils of these 10 best combinations (5 soils and 5 different rootstocks, Table 1).

Table 1: Characteristics of the ten best combinations on the 35 selected combinations of the group (CS=Cabernet-Sauvignon, MN=Merlot noir)

Varieties	Rootstock	Soil type	Average age	Average yield	Average quality index
CS	44-53 M	LUVISOL	41.6	36.1	186.7
CS	3309 C	PEYROSOL	28.6	44.8	176.5
MN	420A MGt	LUVISOL	44.6	44.1	172.9
CS	420A MGt	LUVISOL	41.4	39.8	172.9
CS	420A MGt	REDOXISOL	42.4	39.1	161.6
CS	420A MGt	BRUNISOL	43.2	55.2	158.3
MN	RGM	PLANOSOL	16.9	43.4	152.7
CS	3309 C	BRUNISOL	32.5	46.0	149.8
CS	101-14 MGt	PEYROSOL	12.6	49.1	143.1
CS	101-14 MGt	LUVISOL	24.6	42.9	142.8

Among the ten best soil type-rootstock-varieties combinations, we can find both old and young plots (Table 1). The fact of systematically considering that wines from old plots give better wines than wines from younger plots is false given the results of this study. The younger vines seem to be better on PEYROSOL but we can also observe a good result with Merlot grafted on RGM and planted on PLANOSOL. All of these ten best combinations allow harvesting more than 39 hl/ha except CS/44-53M on LUVISOL. Therefore the fact that the old plots are less productive is not confirmed. It is always necessary to check both the quality of the wine produced and the yield of each plot before making an objective uprooting decision. However, the best Quality Index combination is Cabernet-Sauvignon on LUVISOL with 44-53 M rootstock but this combination regroup plots with an average age of more 40 years old and with yield under 40hl/ha. The association Cabernet-Sauvignon grafted on 101-14 MGt is represented only twice in the top ten, once on PEYROSOL and once on LUVISOL, and is ranked only in ninth and tenth positions (Figure 3). It is surprising that the couple CS/101-14 MGt, which is highly recommended by consultants and therefore frequently planted but also highly appreciated by winegrowers, is not systematically well noted when tasting the batches before blend (Figure 1 and Table 1). We question, therefore, this recurrent recommendation of 101-14 MGt with the Cabernet-Sauvignon.

More generally, there is a loss of diversity in the plant material used. Yet a greater diversity is an asset to adapt to the different conditions of environment and in particular to variations between vintages. This work shows the interest of carrying out studies on a large scale and it would be interesting to reproduce it in other pedoclimatic contexts throughout the world in order to have an objective vision of the production potential of grape varieties, rootstocks, soils, and their associations. The work could be improved by carrying out blind tastings with the same panel of tasters in order to be truly impartial about the quality of the wines. This approach could allow for an examination of the adaptations of these associations on a global scale in the context of global warming.

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