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ORIGINAL RESEARCH ARTICLE

Influence of the rootstock on the behavior of Pi-not noir under the conditions of the central Valais

Jean-Laurent Spring[1*], Vivian Zufferey[1], Thibaut Verdenal[1], Olivier Viret[2]

[*1] *Agroscope, 1009 Pully, Switzerland. E-mail: jean-laurent.spring@agroscope.admin.ch*

[2] *Agroscope, 1260 Nyon, Switzerland.*

ABSTRACT

The agronomic and oenological behavior of the Pinot noir grape variety was studied in relation to different rootstocks on the Agroscope estate in Leytron (VS): 3309 C, 5 BB, Fercal, 41 BMGt, Riparia Gloire, 420 AMGt, 101-14 MGt and 161-49 C. Rootstock primarily influenced vigor, speed of vine establishment, and mineral nutrition of the graft. Riparia Gloire, 41 BMGt, 420 AMGt and 161-49 C rootstocks were less vigorous and, for the last three, induced a lower nitrogen and potassium supply leading to the production of slightly more acidic wines. The less vigorous rootstocks and 101-14 MGt were slightly more sensitive to water stress.

Keywords: Grapevine; Pinot Noir; Rootstock; Mineral Nutrition; Water Stress; Wine Quality

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1. Introduction

Pinot noir is the most cultivated grape variety in Switzerland (4,261 hm^2), occupying half of the area devoted to red grape varieties or a third of all vineyards. In Valais, this area amounts to 1,597 hm^2, or slightly more than half of the red grape varieties in the canton[1]. Recognized worldwide for the quality of its wines, its cultivation is however delicate. Of medium to strong vigor, Pinot noir provides its best results in temperate zones on well-drained soils with low fertility and moderate water reserves, where vigor and production levels are limited (**Figure 1**). Given its low adaptive plasticity and high susceptibility to gray mold (Botrytis cinerea), the choice of plant material (clone, rootstock) and cultural techniques (soil maintenance, fertilization, irrigation, load regulation, etc.) plays an important role in its successful cultivation.

Figure 1. The behavior of Pinot noir, the most cultivated grape variety in Switzerland, is strongly influenced by the rootstock (photo Carole Parodi, Agroscope).

Agroscope's research on Pinot noir touches on aspects as diverse as safeguarding the biodiversity of this grape variety, providing qualitative clones adapted to Swiss vineyard conditions[3–5], the control of yield and sensitivity to Botrytis cinerea[6], the influence of water and nitrogen supply on agronomic behavior and wine quality[7,8], and the study of its adaptation to different terroirs[9,10]. The present publication reports on a trial conducted from 1995 to 2012 at the Agroscope experimental field in Leytron on agronomic behavior and wine quality in relation to the choice of rootstock.

2. Material and methods

2.1 Experimental site, soil and climate

The experimental site in Leytron (VS) is located on a soil composed of recent alluvium (alluvial cone), its blue, deep and very stony (5% clay, 15% silt and 80% sand). Soil (0–20 cm) and subsoil (30–50 cm) analyses show an alkaline composition (pH 8.1–8.3), very calcareous (44–45% total limestone) and a satisfactory organic matter content (1.4–1.7%). Soil nutrient content determined by extraction with water (ratio 1:10) and ammonium acetate EDTA (ratio 1:10) shows a normal fertility level for P and K and normal to high for Mg. During the whole test period, only an annual potassium maintenance fertilizer (75 kg K_2O/hm^2) was applied from the fourth year of vegetation.

In Leytron, the multi-year average temperature during the growing season (April 15–October 15) is 15.5 °C and the average annual precipitation is 636 mm.

2.2 Experimental device

The trial is organized in randomized blocks with four replications of 13 vines per variant. The vines planted in 1995 are trained in simple Guyot (140 × 90 cm). The Pinot noir used is the RAC 12 clone from Agroscope.

The following eight rootstocks were tested:

V. riparia x V. rupestris group

3309 Couderc: used in Valais in soils not prone to iron chlorosis.

101-14 Millardet and de Grasset: little or not represented in the region. Known to be more sensitive to iron chlorosis than 3309 C, it was selected for its lower vigor level than 3309 C and for the generally positive effect it is attributed on quality aspects[11].

V. riparia group x V. berlandieri

5 BB Kober: its good behavior in calcareous soils makes it the most frequently used rootstock in the region, considered, with 3309 C, as the reference rootstock in this trial.

161-49 Couderc: traditionally little represented in the region, it has been tested in the context of studies for the reconstitution of the vineyard[12,13] and recommended for stony, permeable and deep soils. It was not very popular because of its vigor, which was considered too weak at the time, but it has recently been revived.

420 A Millardet et de Grasset: tested in the region at the beginning of the reconstitution of the vineyard[12,13], it did not develop significantly. It was retained in this trial because of its relatively low vigor.

Selection of V. riparia

Riparia Gloire de Montpellier: much used at the beginning of the reconstitution[12,13], its sometimes abusive use in situations too chloosant or too dry led to many disappointments, then its abandonment. It has been included in this study because of its low vigor and the positive influence on quality aspects that is generally attributed to it.

V. vinifera x V. berlandieri group

B Millardet et de Grasset: studied at length during the reconstitution of the vineyard[12,13] and recommended for very calcareous and permeable soils, it is not very widespread in the region because of its very long initial development.

V. vinifera x V. berlandieri x V. longii

Fercal: obtained from INRA, this fairly recent rootstock is used for very chlorotic soils. Its vegetative behavior and its influence on grape maturity are still poorly described in Swiss vineyards.

2.3 Controls performed

2.3.1 Vigor

Measured by unit weighing of prunings from 1996 to 2012 and fresh weights of trimmings from 2007 to 2010.

2.3.2 Performance components

Bud fertility (control of ten vines per replication), berry weight (50 berries per replication), cluster weight (calculated from harvest weight and number of clusters per vine) from 1999 to 2012 and rendering from 1997, to take into account disparities in production entry related to rootstock.

In order not to jeopardize the development of the stock, some rootstocks were lightly degrafted during the installation period (until 2003). Afterwards, the vines were managed without yield limitation.

2.3.3 Maturation follow-up

Grape ripening was monitored from 2007 to 2011 (except in 2009).

2.3.4 Mineral feed

Foliar diagnosis: determination of N, P, K and Mg content of main leaves (leaf blade and petiole) in the cluster area, at veraison from 1999 to 2012.

Determination of potassium content in musts and yeast-available nitrogen content from 2007 to 2011 according to the method of Aerny.

2.3.5 Water supply

Determination of baseline foliage water potential during the summer period of 2007 to 2010, using a PMS Instrument and Co. pressure chamber, model 1002[14].

Vine water supply was also estimated by the carbon isotope discrimination method (ΔC^{13}, $^{13}C/^{12}C$ ratio) in musts at ven dange[15]. The ΔC^{13} indicates the level of water stress experienced by the vine from veraison to harvest.

2.3.6 Sensitivity to botrytis

Observation of rot attack from 1999 to 2012 on a sample of 50 clusters per replication, estimating the proportion affected on each cluster using the following classes: 0, 1/10, 1/4, 1/2, 3/4, 9/10, 10/10.

2.3.7 Must analysis

Determination of the sugar content, pH, acidity to tale (expressed in tartaric acid), tartaric acid, malic acid and in assimilable nitrogen at the crushing.

2.5 Vinification and sensory analysis

From 2007 to 2011, the different variants were vinified according to a standard protocol. The musts were neither corrected for assimilable nitrogen nor deacidified. The standard analyses of wine and must were performed according to the Swiss Food Manual. In addition, the total phenol index (OD 280), color intensity and anthocyanin content were measured according to Ribéreau Gayon *et al.* The dyeing intensity and anthocyanin content were determined according to Ribereau Gayon *et al.*[16].

The wines were tasted by Agroscope's internal panel, a few weeks after bottling, and evaluated on 22 criteria according to a scale of 1 (low, bad) to 7 (high, excellent).

3. Results and discussion

3.1 Influence of rootstock on vigor

Figure 2 shows the evolution of pruning wood weights from 1996 to 2012. A clear distinction can be made between the installation phase, from five to seven years depending on the rootstock, during which vigor progresses steadily, and the adult phase, during which internal variations are mainly related to the effects of climate. The Riparia G., 420 AMGt and 41 BMGt rootstocks took two years longer to reach their adult phase. Agronomic parameters were analyzed over the adult phase from 2001 to 2012. The average vigor level shows that the rootstock effect is very important. Statistically, five groups can be distinguished. The first group of rootstocks shows rapid establishment and high vigor (3309 C, 5 BB, 101-14 MGt and Fercal). Various sources[11,17] generally attribute lower vigor to 101-14 MGt than to the other three, which was not demonstrated in this trial. 16149 C, despite a relatively rapid establishment, stabilizes at a much lower level of vigor, close to Riparia G and 420 AMGt. The 41 BMGt has the lowest level of vigor, contrary to what is generally accepted in the literature for this rootstock[11,17]. This must be seen as a specific interaction between the behavior of this rootstock and the particular soil and climatic conditions of the central Valais, as already observed by Spring *et al.*[18] on Pinot noir in a network of plots located in the region of Sierre and Salgesch, as well as in a trial on Cornalin du Valais conducted on the experimental mental estate of Leytron[19].

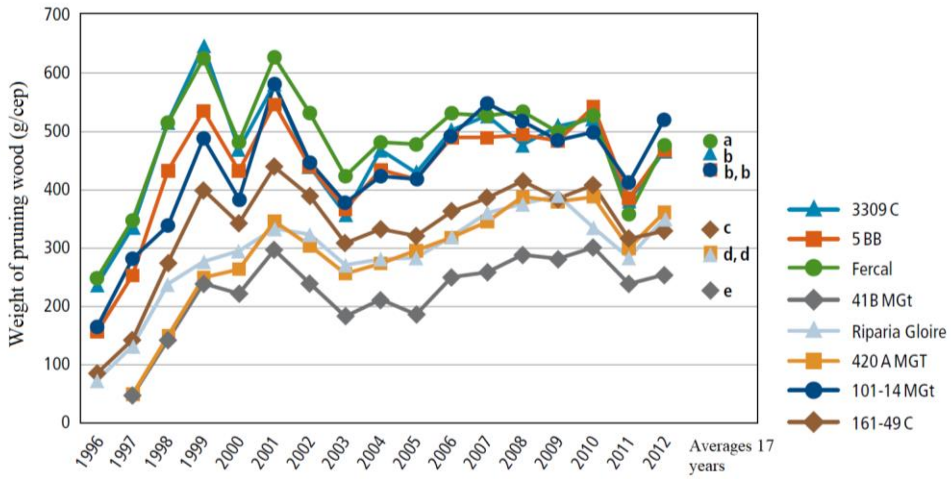


Figure 2. Rootstock trial on Pinot noir in Leytron. Weight of pruned wood, 1996–2012. Data with a common letter are not significantly different ($p = 0.05$).

The analysis of total trimming weights (**Figure 3**) confirms the conclusions drawn from the weights of pruning wood. Two groups are formed with, on the one hand, vigorous rootstocks (3309 C, 5 BB, Fercal and 101-14 MGt), whose average trimming weights exceed 400 g/cep and, on the other hand, weaker rootstocks (161-49 C, 420 AMGt, Riparia G. and 41 BMGt), whose average trimming weight does not exceed 240 g/cep.

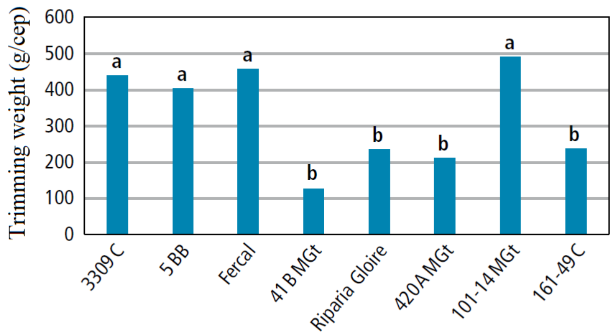


Figure 3. Rootstock trial on Pinot noir in Leytron. Total fresh weight of trimmings, averages 2007–2010. Means with a common letter did not differ significantly ($p = 0.05$).

3.2 Performance components, production

The main results are collected in **Table 1**. Averages were calculated over the period 2001–2012, when all strains were in production and considered mature. Although the differences are quite small, trends can be noted. The 5 BB generates the highest yields, due to the larger berry and cluster size. On the other hand, Cal Iron is the least productive in the adult phase, with fewer berries per cluster (slight tendency to coulure). **Figure 4** shows the evolution of the cumulative yields since the beginning of production of each of the rootstocks. Generally speaking, the vigorous rootstocks, with a faster entry into production, have the highest cumulative yields. The weaker rootstocks (Riparia G, 41 BMGt and 420 AMGt) are slightly behind, mainly due to their slightly delayed entry into production. The 41 BMGt rootstock tends to "catch up" with time, despite its particularly weak vigor. Overall, it can be noted that significant differences in vigor do not lead to a proportional reduction in yield potential.

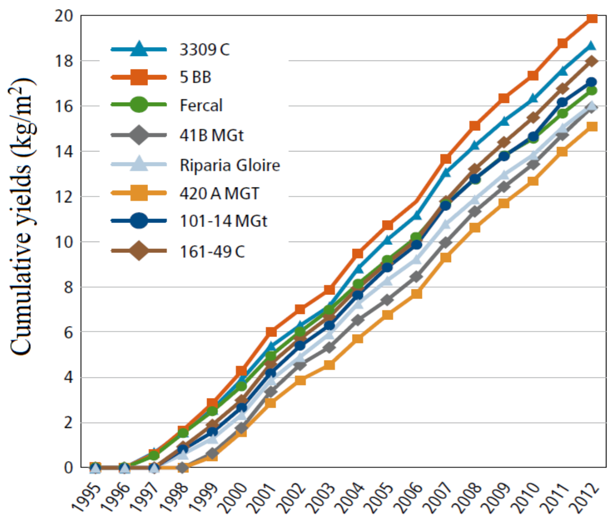


Figure 4. Rootstock trial on Pinot noir in Leytron. Cumulative yields, 1997–2012.

3.3 Monitoring of the maturation process

Monitoring of ripening highlighted the superior precocity conferred by Riparia G. (**Table 2**). This rootstock shows in fact, at an equivalent content of sugars in the musts (75° Oe), an advance of about two and a half days compared to the reference 3309 C. On the other hand, 41 BMGt is slightly later, in accordance with the literature[11,17]. However, these differences are not very significant.

Table 1. Rootstock trial on Pinot noir. Yield components. Leytron, averages 2001–2012

Rootstock	Bud fertility (bunches/wood)	Berry weight (g)	Cluster weight (g)	Yield (kg/m^2)
3309 C	1.73 a	1.36 ab	177 ab	1.23 ab
5 BB	1.68 ab	1.40 a	187 a	1.30 a
Fercal	1.62 ab	1.36 ab	160 b	1.09 c
41 B MGt	1.64 ab	1.20 c	164 ab	1.18 abc
Riparia G	1.63 ab	1.36 ab	165 ab	1.14 bc
420 A MGt	1.57 b	1.16 bc	162 ab	1.13 bc
101-14 MGt	1.62 ab	1.28 bc	172 ab	1.20 abc
161-49 C	1.65 ab	1.34 ab	176 ab	1.25 ab

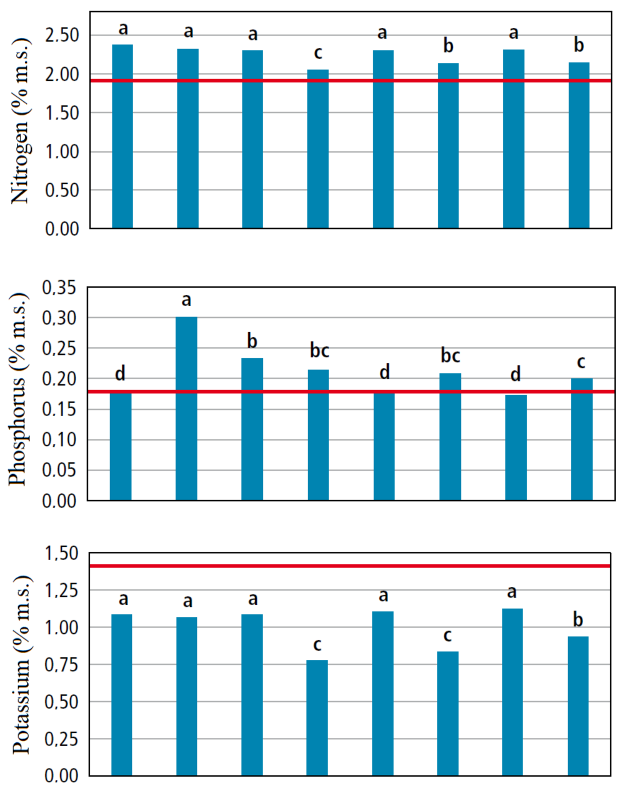
Means with a common letter did not differ significantly (p = 0.05).

Table 2. Rootstock trial on Pinot noir. Phenological offset (in days) from 3309 C (dates defined according to the evolution of the sugar content in the musts with 75 °Oe as the comparison value of the rootstocks). Leytron, averages 2007–2011

Rootstock	2007	2008	2010	2011	Average
3309 C	0	0	0	0	0
5 BB	+0.6	-1.1	+1.0	+0.9	+0.35
Fercal	-3.0	-1.7	+0.9	-0.7	-0.98
41 B MGt	+0.6	+1.4	+0.6	+1.8	+1.18
Riparia G	-3.7	-3.3	-1.4	-1.3	-2.43
420 A MGt	-1.5	-0.2	+0.9	+0.1	-0.18
101-14 MGt	+0.3	-0.6	+0.4	+0.1	+0.05
161-49 C	-1.5	-1.8	+1.2	0	-0.78

3.4 Mineral feed

The results of the leaf diagnosis are shown in **Figure 5**. The red line represents the "very low" feeding threshold below which symptoms of carence could occur[20].



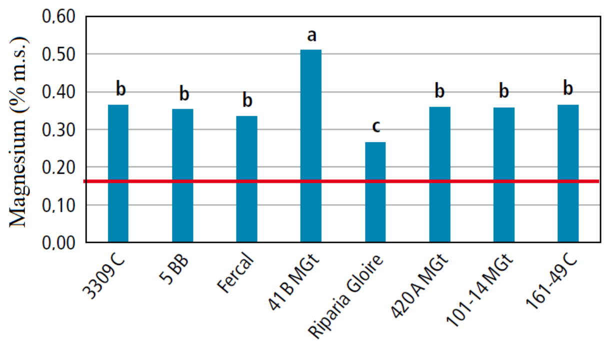


Figure 5. Rootstock trial on Pinot noir in Leytron. Mineral element contents of leaves at veraison, averages 1999–2012. The base line corresponds to the limit value below which the content is considered "very low".
Data with a common letter did not differ significantly (p = 0.05).

The less vigorous rootstocks, with the exception of Riparia G, induced a lower nitrogen (N) supply, without falling below the critical values. For phosphorus (P), the high uptake capacity of 5 BB and Fercal contrasts with the much lower values recorded for 3309 C, 101-14 MGt and Riparia G, in agreement with other authors[11]. Potassium (K) levels are all very low, despite normal potassium richness in the soil. This certainly indicates a specific influence of the Leytron terroir (very stony soils characterized by a very deep rooting). However, differences appear between rootstocks, with particularly low values for 41 BMGt and 420 AMGt and to a lesser extent for 161-49 C, as indicated by other sources[11,17]. Despite these very low values, no symptoms of potassium deficiency were detected on the foliage. For magnesium (Mg), all values can be described as high to very high, which is consistent with the very low values for potassium (K/Mg antagonism)[21,22]. The highest values were recorded for 41 BMGt and the lowest for Riparia G.

The respective ability of the rootstocks to absorb mineral elements is also reflected in the concentrations determined in the musts for nitrogen and potassium (**Table 3**). For these two elements, the values of 41 BMGt, 420 AMGt and 161-49 C are significantly lower than those of the other rootstocks.

Table 3. Rootstock trial on Pinot noir. Analysis of musts during crushing. Leytron, averages 2001-2012. Means with a common letter do not differ significantly (p = 0.05)

Rootstock	Refractometry, sugars (°Oe)	Total acidity[1] (g/l)	Tartaric acid (g/l)	Malic acid (g/l)	pH	Assimilable nitrogen (mg/l)	Potassium (mg/l)[2]
3309 C	98.5 ab	7.8 a	6.4 b	3.5 a	3.20 a	224 a	1955 a
5 BB	97.9 ab	8.1 a	6.5 ab	3.5 a	3.16 a	195 a	1924 a
Fercal	97.8 ab	8.0 a	6.6 ab	3.3 ab	3.17 a	195 a	2039 a
41 B MGt	93.9 b	7.8 a	7.2 a	2.4 b	3.12 a	132 b	1615 b
Riparia G	99.3 a	7.7 a	6.2 b	3.3 ab	3.20 a	204 a	1870 a
420 A MGt	97.7 ab	7.7 a	6.8 ab	2.7 b	3.16 a	160 b	1715 b
101-14 MGt	98.1 ab	7.6 a	6.2 b	3.2 ab	3.21 a	211 a	1971 a
161-49 C	97.0 ab	8.0 a	6.9 ab	2.8 b	3.13 a	153 b	1701 b

[1]Expressed as tartaric acid. [2]Average, 2007–2011.

3.5 Water supply

Figure 6 shows the evolution of the basic water potential during the 2007 to 2010 seasons. The 2007 vintage, with humid summer conditions, did not cause any water stress for the vines. On the contrary, measurements taken in 2009, a hot and dry year, show moderate water stress from mid July onwards, with values between -3 and -5 bars, which are within the thresholds established by Riou and Payan[23]. This constraint even became strong for some rootstocks such as 41 BMGt, 420 AMGt, Riparia G and 101-14 MGt in the last decade of August. On the other hand, Fercal and 5 BB had the lowest water stress. The increased sensitivity to water stress of 420 AMGt, Riparia G and 101-14 MGt is confirmed by other sources[11,17]. The 2008 and 2010 vintages occupy a more classical position, with dry periods alternating with wetter sequences and a water supply to the vine evolving between low and moderate stress.

C13 values in musts for the years 2007 to 2011 are plotted in **Figure 7**. This measure reflects the water stress experienced during grape maturation. Van Leeuwen *et al.*[24] propose the following thresholds for the interpretation of this measure:

No water stress: <-26
Low water stress: -24.5 to -26
Moderate water stress: -23 to -24.5
Moderate to high water stress: -21.5 to -23
High water stress: > -21.5.

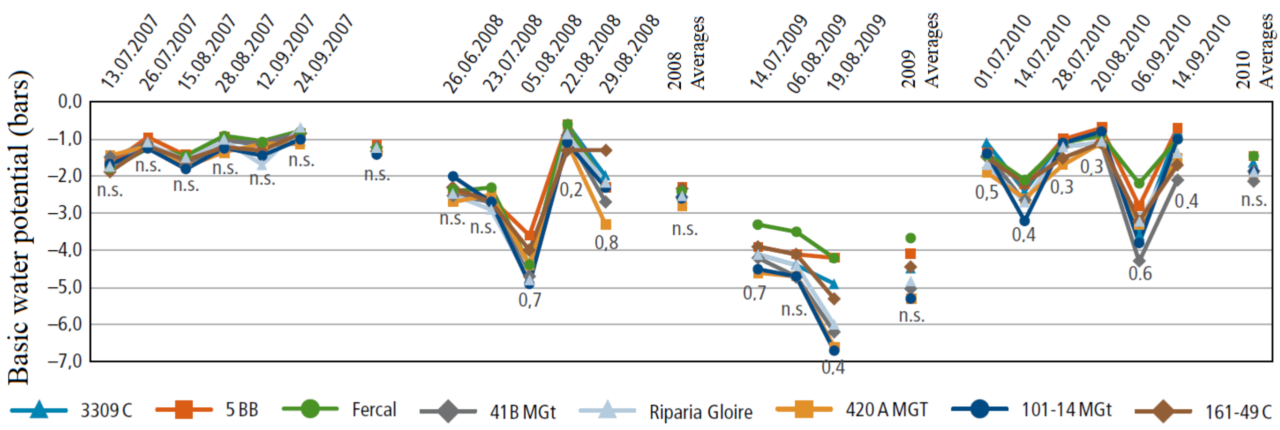


Figure 6. Rootstock trial on Pinot noir in Leytron. Changes in baseline water potential during the season, 2007-2010. Numbers indicate the value of ppds (p = 0.05).

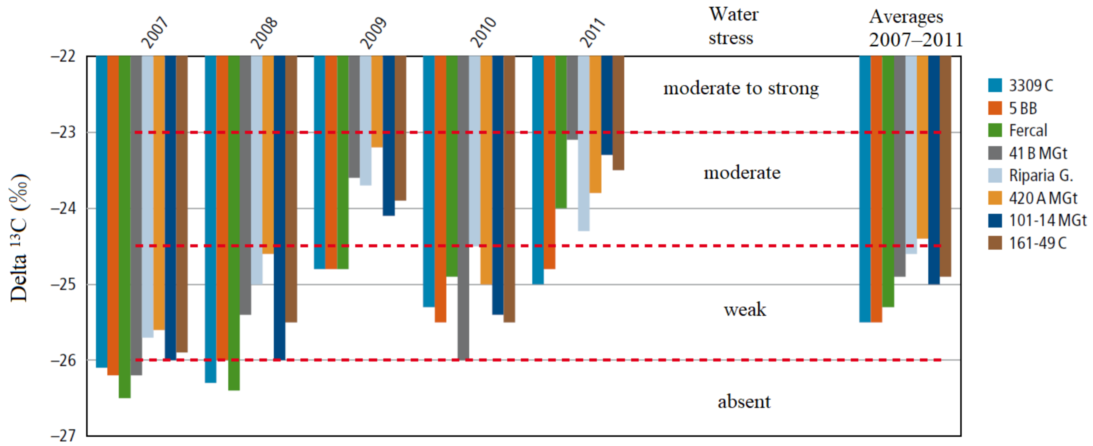


Figure 7. Rootstock trial on Pinot noir in Leytron. C13 values of the must at the Leytron harvest, 2007–2011.

For the driest vintages (2009 and 2011), only a few rootstocks show a moderate level of water stress, the other values indicating little or no water stress. Overall, under dry conditions, the weakest group of rootstocks has the highest level of water stress. Among the vigorous rootstocks, 101-14 MGt seems to be the most sensitive to water stress, which confirms the observations made with the basic potential.

3.6 Sensitivity to grey mould

Bunch rot was observed in seven of the fourteen years. Only Riparia G was slightly more sensitive, with an attack rate of 6.7%, which did not exceed 3 to 4% with the other rootstocks. This trend is certainly related to the slightly earlier maturation induced by Riparia G.

3.7 Composition of the musts (Table 3)

The sugar content was close for all the rootstocks, except for 41B MGt, which provided slightly less sweet musts, in connection with the phenological delay observed in the latter. Rootstocks with lower nitrogen and potassium uptake (41 BMGt, 420 AMGt and 161-49 C) showed a tendency to slightly more tartaric acid and slightly less malic acid in the musts.

3.8 Wine analysis (Table 4)

Table 4. Rootstock trial on Pinot noir. Analysis of wines. Leytron, averages 2007–2011. Means with a common letter do not differ significantly ($p = 0.05$)

Rootstock	Alcohol (% vol)	pH	Total acidity (g/l)[1]	Tartaric acid (g/l)	Total phenol index	Antocyanins (mg/l)	Color intensity index
3309 C	13.5 a	3.90 a	3.7 c	1.0 a	29 a	302 a	3.4 a
5 BB	13.6 a	3.81 ab	4.0 c	1.1 a	31 a	279 a	3.7 a
Fercal	13.5 a	3.82 ab	4.0 c	1.0 a	30 a	289 a	3.6 a
41 B MGt	13.5 a	3.59 c	4.9 a	1.4 a	33 a	273 a	4.7 a
Riparia G	14.0 a	3.83 ab	4.0 c	1.1 a	31 a	298 a	3.9 a
420 A MGt	13.6 a	3.71 abc	4.3 bc	1.2 a	33 a	280 a	4.2 a
101-14 MGt	13.4 a	3.89 a	3.8 c	0.9 a	32 a	315 a	3.8 a
161-49 C	13.6 a	3.64 bc	4.7 ab	1.3 a	32 a	302 a	4.5 a

[1]Expressed as tartaric acid.

The analysis of the wines shows mainly differences in pH and acidity. Rootstocks with poor potassium assi liance (41 BMGt, 420 AMGt, 161-49 C) have slightly lower pH and slightly higher acidity. **Figure 8** shows the close correlation between wine pH and must potassium content, which indeed influences the acidity balance of wines[2,25,26]. The precipitation of potassium tartrate during winemaking is inversely proportional to the potassium content of the must.

3.9 Sensory analysis

Of the 22 criteria studied, the sensory analysis revealed very few significant differences (results not presented here). Some trends can be noted: slightly more acidic and colored wines with 41 BMGt and 161-49 C, a slightly lower tannic intensity with 5 BB, tannins judged more tender and coated with 3309 C and a little drier and rougher with 161-49 C. In conclusion, it would seem that the fairly marked differences noted on the agronomic and analytical levels had little influence on the quality of the wines in this trial.

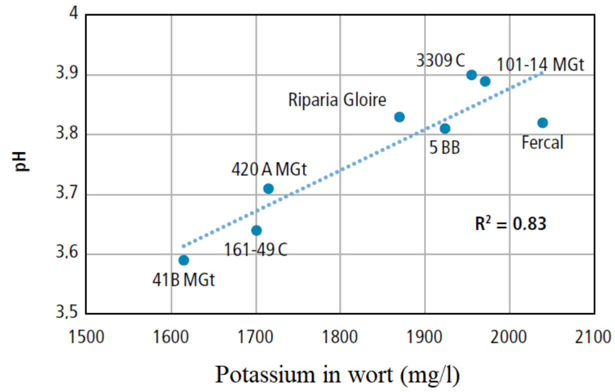


Figure 8. Rootstock trial on Pinot noir in Leytron. Correlation between wine pH and must potassium levels, 2007–2011.

3.10 Synthesis

To characterize the main axes of the action of the rootstock on the behavior of Pinot noir, a principal component analysis (PCA) was applied to the different variables observed during the period when the harvest was vinified (2007–2011). The results are presented in **Figure 9**. The analysis shows, on the one hand, a segregation according to an axis related to vigor and, on the other hand, an axis more related to qualitative aspects. Among the less vigorous rootstocks, a first cluster is made up of 41 BMGt, 420 AMGt and 161-49 C, associated with lower nitrogen and potassium nutrition, lower pH and more colored wines but with harder tannins. Ripa ria G is distinguished from this group by its proximity to criteria more related to wine quality (higher structure, higher pH, higher nitrogen and potassium supply, soft and coated tannins) and is therefore similar to the behavior of some vigorous rootstocks (3309 C, 101-14 MGt).

4. General conclusions

Sixteen years of experimentation including five vintages of a trial of the behaviour of eight rootstocks (3309 C, 5 BB, Fercal, 41 BMGt, Riparia Gloire, 420 AMGt, 101-14 MGt, 161-49 C) on the Pinot noir grape variety at the Agroscope experimental estate in Leytron (VS) allow us to draw the following conclusions:

The rootstock has strongly influenced the speed of vine establishment. The establishment and the beginning of production of the vines grafted on Riparia G. ,420 AMGt and 41 BMGt took two years longer than with the other rootstocks.

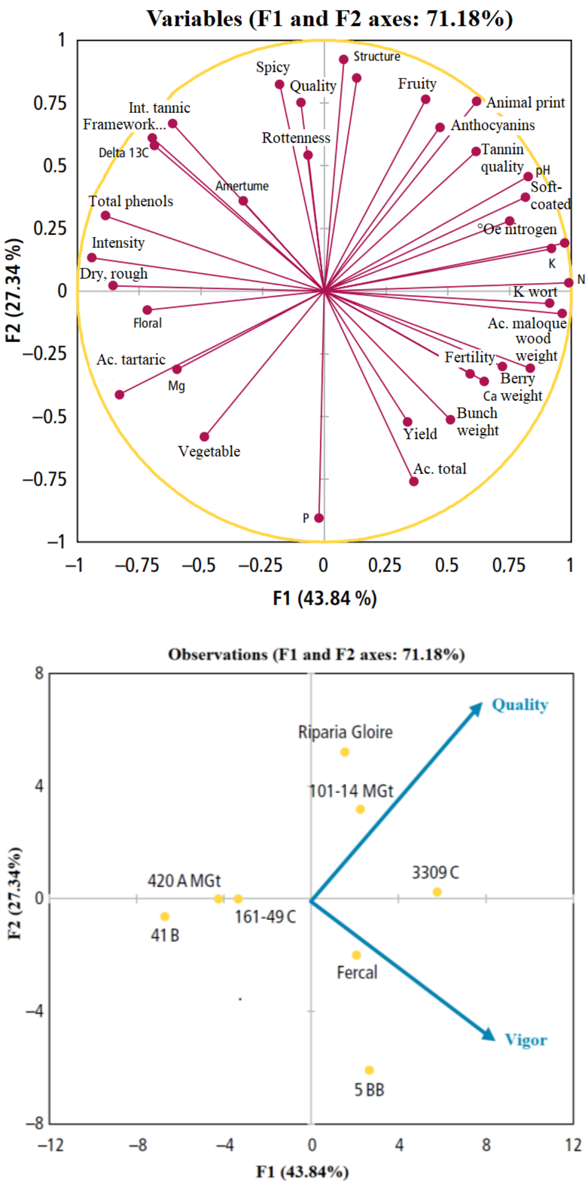


Figure 9. Rootstock trial on Pinot noir in Leytron, 2007–2011. Results of the principal component analysis (PCA). The left figure represents the observed variables; vectors pointing in the same direction are highly correlated with each other. The figure on the right represents the rootstocks studied; nearby rootstocks have a similar behavior.

In adult grapevines, 3309 C, 5 BB, Fercal and 101-14 MGt conferred high graft vigor, while 161-49 C, Riparia G., 420 AMGt and especially 41 BMGt determined significantly lower vigor.

The differences in cumulative production at the end of the experiment are mainly due to the speed of installation and entry into production of the different rootstocks and much less to their level of productivity in the adult phase, which is very close.

Mineral nutrition was strongly influenced by rootstock. 161-49 C, 420 AMGt and especially 41 BMGt had significantly lower nitrogen and potassium uptake. The lower potassium levels in the musts from these rootstocks resulted in the maintenance of higher acidity in the wines.

In the driest vintages, the less vigorous rootstocks (Riparia G., 41 BMGt, 420 AMGt and 161-49 C) as well as 101-14 MGt were slightly more sensitive to water stress.

The significant influences of rootstock detected agronomically and analytically, resulted in only limited differences in wine quality. Practical conclusions for the different rootstocks studied.

5. Practical conclusions for the different rootstocks studied

3309 C: its level of vigor and productivity is close to that of 5 BB, but it has a lower phosphorus content and a slightly better magnesium content. It adapts to many vineyard situations as long as the soils are deep, permeable, well drained and the active limestone content does not exceed 11%.

5 BB: reference rootstock in Valais, characterized by a high vigor and production (except in too fertile situations, likely to cause coulure by excess of vigor). It absorbs phosphorus and potassium very well, a little less magnesium, which can be detrimental in soils rich in potassium (increased risk of stalk dryness).

Fercal: it induces a high vigor which can, in very fertile conditions, cause coulure by excess of vigor. It absorbs phosphorus and potassium well, a little less magnesium, which can be detrimental in soils rich in potassium (increased risk of stalk desiccation). It is particularly interesting in areas with high chlorosis where other rootstocks are not satisfactory.

41 B MGt: its weak vigor induces a slow installation which requires attentive care the first years. On the other hand, its productivity in adult vines is satisfactory. It absorbs magnesium very well, much less nitrogen and potassium (more acidic wines) and can be quite sensitive to water stress. It resists well to limestone but behaves well only in permeable, sufficiently deep and perfectly drained soils. The success rates in nurseries are quite low, which penalizes its multiplication.

Riparia Gloire: with a low vigor, it is quite sensitive to water stress. It hastens the ripening of the grapes by a few days, absorbs nitrogen and potassium well and magnesium a little less. Its effect is generally positive on the qualitative aspects, but its area of adaptation is limited (sufficiently fertile, deep, draining soils, not too dry and with an active limestone content not exceeding 6%).

420 A MGt: of weak vigor, it induces a rather slow installation and is rather sensitive to the hydric stress, absorbs poorly the nitrogen and the potassium (more acid wines). It resists well to limestone (like 5 BB) provided that the soils are permeable, healthy and deep.

101-14 MGt: it induces a high vigor and a fast establishment in the conditions of Leytron, absorbs well nitrogen and potassium but rather badly phosphorus. It is rather sensitive to water stress and adapts only in sufficiently deep and permeable soils with an active limestone content not exceeding 9%, which limits its range of adaptation.

161-49 C: it induces a relatively weak vigor, absorbs poorly nitrogen and potassium (more acidic wines). It has a good resistance to limestone (like 5 BB) but adapts only to deep, permeable and perfectly drained soils. It is subject, during the first years, to the formation of thylls in the conductive vessels, which sometimes causes problems of mortality of the young plants and limits its recommendation without reserve.

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Conflict of interest

The authors declare that they have no conflict of interest.

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