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Evaluation of the agronomic performance of 'Syrah' and 'Tempranillo' when grafted on 12 rootstocks

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Summary

Beyond pest resistance, rootstocks significantly influence the performance of grapevine varieties. However, the effect of the rootstock is strongly affected by its interaction with the environment, and it is therefore necessary to evaluate their influence in a particular *terroir*. With the aim of evaluating the influence of 12 rootstocks on the agronomic performance of 'Syrah' and 'Tempranillo', a trial was established in 2011 and 2012 in Miranda de Arga (Navarra, Spain), under the typical environmental conditions of the Ebro Valley. Growth and yield, as well as industrial and phenolic maturity parameters were analysed during four consecutive seasons (2015-2018). Most rootstocks showed a similar performance with both varieties, not always following the trends reported in bibliography, which highlights the relevance of studying rootstocks in different conditions. 3309 C was the rootstock conferring the highest vigour, whereas the lowest were provided by 420 A MGt and 'Fercal'. The implications on grape composition were much more diverse, and were partially conditioned by yield. Results were obtained during the four first harvests of the vineyard, and could therefore change to some extent as the vineyard reaches stability.

Key words: grapevine; vigour; yield; industrial quality; phenolic quality; *Vitis vinifera* L.

Introduction

The use of rootstocks in European viticulture was originally aimed as a control measure for pest resistance due to the phylloxera infection in the second half of the 19th century (Piqueras 2005, Ollat*et al*. 2015, Tandonnet *et al*. 2016), which destroyed nearly all the European vineyards in a few decades (Piqueras 2005). Later on, rootstocks have also been used to combat other pests, primarily nematodes (Anwar *et al*. 2002). Aside from pest resistance, the choice of an adequate rootstock is a key tool to improve the performance of grapevine varieties in different *terroirs*, as rootstocks provide adaptability to soil characteristics such as salinity, acidity, lime content or drought (Pavloušek 2010, Cox 2012, Serra *et al*. 2014). Moreover, they have a significant influence on the growth and vegetative cycle of the plants and, consequently, on yield and grape quality (Main *et al*. 2002, Reynier 2012). Therefore, choosing the right rootstock constitutes a relevant adaptation tool for grape growers in a changing climate (Neethling *et al*. 2017). As a consequence, rootstock election is a key decision when a new vineyard is designed (De Herralde *et al*. 2006), and may have a critical impact on its later performance and profitability (Yuste *et al*. 2017).

However, despite the relatively broad range of rootstocks available, growers in many grapegrowing regions in Europe are very conservative, and reluctant to change the rootstocks they use, not considering many of the factors mentioned above (García 2017). Additionally, despite the fact that there are many publications with this purpose, the performance of a combination scion-rootstock in one environment condition cannot be immediately extrapolated to other situations (Keller *et al*. 2001). Specifically, in the Ebro valley, an area including > 75,000 ha of vineyards, there are only few research works published (Larrea 1950, Hidalgo 1989), so it is important to investigate the influence that different rootstocks have on the agronomical behaviour of different cultivars. The objective of this study was to evaluate the agronomic performance of 'Syrah' and 'Tempranillo' when grafted on twelve different commercial rootstocks in a typical *terroir* in Navarre (Spain).

Material and Methods

Plant material and experimental design: The evaluation of the agronomic performance of 'Syrah' and 'Tempranillo' when grafted on 12 different commercial rootstocks was performed during four consecutive seasons (2015-2018) in an experimental vineyard located in Miranda de Arga (42°27'50.6"N 1°48'10.6"W, 308 m a.s.l.). This field was planted in 2011 ('Tempranillo') and 2012 ('Syrah'), following a completely randomized experimental design, with three replicates of ten vines per rootstock. The

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rootstocks evaluated were: 101-14 Millardet et de Grasset (101-14 MGt), 1103 Paulsen (1103 P), 110 Richter (110 R), 140 Ruggeri (140 Ru), 161-49 Couderc (161-49 C), 3309 Couderc (3309 C), 41 B Millardet et de Grasset (41 B MGt), 420 A Millardet et de Grasset (420 A MGt), 99 Richter (99 R), 'Fercal', 'Gravesac' and Sélection Oppenheim 4 (SO 4), whose pedigree and breeding information is provided in Tab. 1.

The vines were trained to unilateral cordon Royat, pruned to 5 two-shoot spurs per linear meter. Plant spacing was 3 m between rows and 1 m between plants (3,333 vines·ha^{-1}), and the field was drip irrigated to avoid water deficit. During all the seasons, no shoot trimming was performed, and a natural permanent cover was maintained, applying herbicide in the soil just behind the vines.

The climate in this area is Continental-Mediterranean, with an average annual rainfall about 350-400 mm. Climatic conditions were variable among years (Fig. 1). The vineyard is located in a Quaternary sedimentary soil with a sandy loam texture, and 8 % of active lime. The main characteristics of the soil are summarized on Tab. 2 and, accordingly, there is no limiting factor.

Measured variables.

Vegetative growth and yield components: Vegetative growth was quantified in winter by measuring the winter Pruning Weight (PruW) of all the plants of each replicate. Yield (Yld) was determined by weighing all the bunches produced in the 10 vines in each replicate. When harvesting, bunch number per vine (BunNb) was

Table 1

Common name, breeding year of obtention and parentage of the evaluated rootstock

Rootstocks		
Common name*	Breeding year of obtention	Parentage
3309 C	1881	*V. riparia* x *V. rupestris*
101-14 MGt	1882	*V. riparia* x *V. rupestris*
110 R	1902	*V. berlandieri* x *V. rupestris*
1103 P	1896	*V. berlandieri* x *V. rupestris*
140 Ru	1894	*V. berlandieri* x *V. rupestris*
99 R	1902	*V. berlandieri* x *V. rupestris*
161-49 C	1888	*V. riparia* x *V. berlandieri*
41 B MGt	1882	*V. vinifera* x *V. berlandieri*
420 A MGt	1887	*V. berlandieri* x *V. riparia*
SO 4	1896	*V. berlandieri* x *V. riparia*
Fercal	1959	B.C n° 1 B x 31 Richter (complex hybrid)
Gravesac	1962	*V. berlandieri-V. riparia-V. rupestris* (complex hybrid)

* Plant grape. Catalogue of vines grown in France (http://plantgrape.plantnet-project.org/en/porte-greffes).

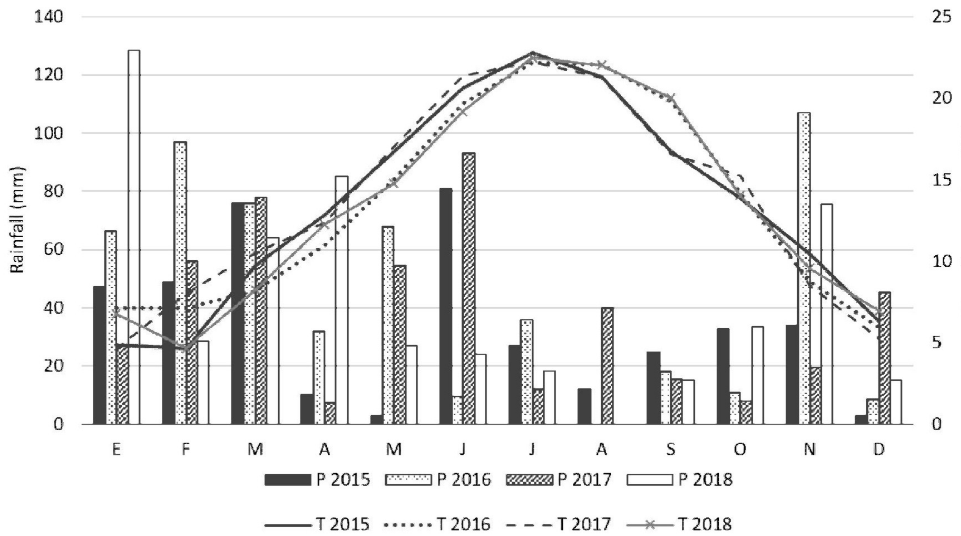

Fig. 1: Monthly rainfall (R) and mean temperature (T) in 2015, 2016, 2017 and 2018.

Table 2

Main characteristics of the vineyard soil

Measurement		Unit	Observation
Water pH	8.6		Slightly alkaline
Organic matter	2.03	$g \cdot 100\ g^{-1}$	High, but for ‚fossilised'
Assimilable P	28.8	$mg \cdot kg^{-1}$	High
Assimilable K	145.2	$mg \cdot kg^{-1}$	Appropriate
Assimilable Mg	61.7	$mg \cdot kg^{-1}$	Correct
Carbonates	40.74	$g \cdot 100\ g^{-1}$	High. Could limit the assimilation of other minerals
Active lime	7.54	$g \cdot 100\ g^{-1}$	Low. No lack of trace elements is expected
E.C.	0.4	$dS \cdot m^{-1}$	No salinity risk

counted, and mean bunch weight (BunW) was calculated as Yld/BunNb. The harvest date was determined each year regarding to grape composition evolution, all rootstocks for each cultivar being harvested the same day.

Berry composition: industrial and phenolic maturity: Grape composition was determined in a 200-berry sample per replicate, picked the day before harvest. The berry samples were formed by 20 berries per vine, picked from four different clusters per vine, five taken from each part in the cluster (shoulder, middle and tip; outside and inside).

Once all the samples were collected, they were weighed immediately to determine mean berry weight (BW, g) and delivered at low temperature to Excell Iberica (Logroño, Spain) laboratories for analysis. Consecutively, samples were homogenized with a blender at full speed, and part of this homogenate (100 g approx.) left macerating for an hour and then it was centrifuged at 10000 rpm. The supernatant was used to measure industrial and phenolic maturity parameters in each sample. Total Soluble Solid content (TSS, °Brix) was measured using a high precision temperature compensating refractometer, and pH was determined by a digital pHmeter, both following the methodology explained in (CEE) N° 2676/90. Total acidity (TA, g tartaric acid$\cdot L^{-1}$) was determined by titration and malic acid (MalA, $g \cdot L^{-1}$) by enzymatic analysis. Total anthocyanin content (Ant, $mg \cdot L^{-1}$) was determined following the method proposed by Ribéreau-Gayon and Stonestreet (1965). Tannins reactivity was evaluated using DMACH index (by reaction with *p*-dimethylamino cinnamaldehyde) proposed by Vivas *et al*. 1994. The rest of the phenolic maturity parameters (Potential Tannins Index, Tan; Tannins maturity Index, TanM, and Organoleptic Potential, OrgP), were calculated following the standardized protocol developed and patented by Excell in France.

Statistical analysis: Two-way ANOVA was conducted for each parameter to detect if there was an interaction between rootstock and year. Principal Component Analysis (PCA) and Clustering was also developed with all the studied parameters in order to group the different rootstocks regarding their similar behaviour. All analysis were performed using R computing environment (R Development Core Team 2016).

Results

Results of the effect of 12 rootstocks on the growth, yield and berry composition parameters of 'Syrah' and 'Tempranillo' are shown in Tabs 3 and 4. The obtained results show that there was a significant effect of rootstock and year on the majority of the parameters related to growth, yield and grape composition. Rootstock x year interaction was shown not to be significant for any of the variables considered.

Therefore, and taking into account the goal of this work, analysis was focused on the rootstock effect. Year effect, though significant for some of the variables, will not be discussed in detail, since the differences found were a consequence of climatic conditions and vineyard age.

Vegetative growth and yield components: Rootstocks had a clear effect on vegetative growth for 'Syrah' and 'Tempranillo', as shown by important differences in terms of PruW. In particular, 3309 C appeared as the most vigorous rootstock for both cultivars, with 0.99 $kg \cdot vine^{-1}$ of winter wood in 'Syrah' and 0.91 $kg \cdot vine^{-1}$ in 'Tempranillo', whereas 420 A MGt and 'Fercal' induced the least vigour (around 0.4 $kg \cdot vine^{-1}$ for both cultivars). The trend observed was similar in both varieties, except for 161-49 C, 'Gravesac' and SO 4, which showed greater PruW values when grafted with 'Syrah'.

With respect to yield components, 'Syrah' was generally less productive, even though it presented more bunches than 'Tempranillo', but smaller. Concerning rootstock effect, 3309 C and SO 4 were the most productive rootstocks. Conversely, there was no consensus with respect to the lowest yielding rootstocks between cultivars, with 110 R, 1103 P, 420 A MGt and 'Fercal' being the lowest producing ones for 'Tempranillo' (Yld < 1.5 $kg \cdot vine^{-1}$, BunNb < 9), and 1103 P, 99 R and 'Fercal' for 'Syrah' (Yld < 1.2 $kg \cdot vine^{-1}$, BunNb < 11).

Berry composition: industrial and phenolic maturity: Regarding industrial maturity, pH, MalA and TSS showed significant differences between rootstocks, but no differences were found for BW and TA in 'Syrah'. With respect to 'Tempranillo', TA and TSS were the parameters mostly affected by the rootstock. TSS in 'Syrah' was significantly higher for 1103 P, 140 Ru, 99 R and 'Gravesac' (avg. 23.9 °Brix) than for 41 B MGt (21.8°Brix), whereas in 'Tempranillo' only 110 R showed

Table 3

Effect of rootstock on growth, yield components and industrial and phenolic maturity parameters of 'Syrah'

	Syrah - growth and yield					Syrah - juice								
	Pruning weight (kg·vine^{-1})	Bunch number	Yield (kg·vine^{-1})	Bunch weight (g)	Berry weight (g)	Total acidity[c]	pH	L-Malic acid (g·L^{-1})	Total soluble solids (°Brix)	Potential tannins index	Antho-cyanins (mg·L^{-1})	Tannins maturity index	Organo-leptic potential	DMACH index
101-14 MGt	0.58[a] bcd	12.83 ab	1.64 ab	126.40 ab	1.37	4.71	3.61 abc	1.28 b	23.60 ab	38.67 ab	529.67 ab	37.00	2.43	106.00
1103 P	0.52 cd	8.72 b	1.03 b	109.05 b	1.48	5.08	3.67 ab	1.45 ab	23.98 a	40.67 a	582.67 ab	34.67	2.47	119.33
110 R	0.53 cd	10.98 ab	1.27 ab	104.31 b	1.48	5.24	3.61 abc	1.56 ab	23.62 ab	35.67 ab	608.00 ab	32.67	2.40	109.00
140 Ru	0.67 abcd	12.82 ab	1.57 ab	120.02 ab	1.50	4.88	3.77 a	1.89 ab	24.05 a	41.00 a	592.00 ab	40.33	2.53	102.67
161-49 C	0.73 abcd	12.94 a	1.96 ab	150.83 ab	1.49	5.46	3.54 bc	1.68 ab	23.11 ab	31.33 b	480.00 ab	30.67	2.27	102.00
3309 C	0.99 a	13.95 a	2.15 ab	148.47 ab	1.47	5.16	3.77 a	2.36 a	23.53 ab	32.33 ab	641.67 a	29.00	2.37	122.67
41 B MGt	0.56 bcd	14.08 a	2.10 ab	146.61 ab	1.48	5.16	3.54 bc	1.64 ab	21.79 b	36.00 ab	434.00 b	33.67	2.33	108.00
420 A MGt	0.42 d	11.25 ab	1.50 ab	120.78 ab	1.29	5.10	3.49 c	1.23 b	22.92 ab	42.33 a	613.67 ab	46.33	2.57	92.33
99 R	0.54 bcd	10.90 ab	1.14 b	98.67 b	1.44	5.04	3.58 bc	1.32 b	23.88 a	32.33 ab	577.33 ab	29.67	2.33	109.33
Fercal	0.44 d	10.72 ab	1.13 b	102.95 b	1.41	4.84	3.53 bc	1.10 b	23.17 ab	32.00 b	572.67 ab	28.33	2.33	112.33
Gravesac	0.91 abc	13.82 a	2.03 ab	145.14 ab	1.45	5.06	3.67 ab	1.77 ab	23.71 a	32.67 ab	599.00 ab	46.33	2.40	78.33
SO 4	0.93 ab	13.45 a	2.33 a	170.91 a	1.55	5.36	3.68 ab	1.94 ab	22.94 ab	36.00 ab	515.33 ab	42.67	2.40	88.00
Significance[b]														
R	*<0.001*	*<0.001*	*<0.001*	*<0.001*	0.302	0.161	*<0.001*	*<0.001*	*<0.001*	*0.003*	*0.022*	0.056	0.068	0.464
Y	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.020*	0.092	*0.004*	0.304
R x Y	1	0.860	0.998	0.999	0.943	0.922	0.474	0.998	0.995	1.000	0.672	0.872	1	0.583

[a] Different letters denote significant differences in ANOVA and Fisher's test. [b] Significance (*p* value) of rootstock (R), year (Y), rootstock and year interaction (R x Y).
[c] Total acidity expressed as gTartaric·L^{-1}.

significantly higher TSS (24.3 °Brix) than 41 B MGt and SO 4 (22.9 and 23.1 °Brix, respectively). In 'Tempranillo', TA values measured in 'Fercal' were significantly lower (3.89 g tartaric acid·L^{-1}), whereas 3309 C presented the highest rate (4.58 g tartaric acid·L^{-1}). For its part, pH tended to be higher in 3309 C and 140 Ru in both cultivars (between 3.7 and 3.8), although the differences for 'Tempranillo' were not significant. 420 A MGt showed the least pH in 'Syrah' (3.48), whereas the rest of rootstocks had rates of pH around 3.5-3.6. Finally, there was also a significant effect of the rootstock on MalA in 'Syrah', reaching the highest values when grafted on 3309 C (2.4 g·L^{-1}) and the lowest on 101-14 MGt, 420 A MGt, 99 R and 'Fercal' (between 1.1 and 1.3 g·L^{-1}), but no significant effect was found for 'Tempranillo'.

With respect to phenolic maturity, significant differences were found in Tan and Ant between some rootstocks for both cultivars (Tabs 3 and 4). 1103 P, 140 Ru and 420 A MGt had higher values of Tan than 161-49 C and 'Fercal' for 'Syrah', whereas there were no significant differences among the others. In 'Tempranillo', only 110 R and 161-49 C reached higher values of Tan than 140 Ru and 41 B MGt. Lastly, Ant tended to be significantly higher only in 3309 C than in 41 B MGt for 'Syrah', and in 140 Ru and 420 A MGt in respect to SO 4 for 'Tempranillo'.

Principal components analysis and clustering: Due to the high number of rootstocks and variables evaluated, multivariate analyses (cluster analysis (CA) and Principal Component Analysis (PCA)) were carried out for each cultivar, in order to ease data interpretation.

According to CA, four groups of rootstocks could be established for both varieties (Figs 2 and 3). For 'Syrah', Group 1 includes 1103 P, 110 R, 99 R and 'Fercal', in which the three first rootstocks are hybrids from *V. berlandieri* x *V. rupestris*, traditionally known as vigorouos and well-adapted to Mediterranean conditions (dry and calcareous soils) (Reynier 2012). Group 2 includes 140 Ru, 420 A MGt and 101-14 MGt which are not related in terms of pedigree. Group 3 comprises 41 B MGt and 161-49 C, both having a *V. berlandieri* parent and commonly known as medium vigorous rootstocks. Finally, Group 4 contains 'Gravesac', SO 4 and 3309 C, which all have a *V. riparia* parent and they usually show medium vigour. Regarding 'Tempranillo', Group 1 includes 1103 P, 110 R, 99 R, 'Fercal', 420 A MGt and 161-49 C, which all are *V. berlandieri* hybrids, and which contains most of the *V. berlandieri* x *V. rupestris* hybrids, with the

Table 4

Effect of rootstock on growth, yield components and industrial and phenolic maturity parameters of 'Tempranillo'

	Tempranillo - growth and yield						Tempranillo - juice							
	Pruning weight (kg·vine⁻¹)	Bunch number	Yield (kg·vine⁻¹)	Bunch weight (g)	Berry weight (g)	Total acidity[c]	pH	L-Malic acid (g·L⁻¹)	Total soluble solids (°Brix)	Potential tannins index	Antho-cyanins (mg·L⁻¹)	Tannins maturity index	Organo-leptic potential	DMACH index
101-14 MGt	0.59[a] abc	10.49 abc	2.06 ab	184.36	1.47	4.20 ab	3.63	1.12	23.71 abc	40.00 ab	683.67 ab	50.33	2.60	79.33
1103 P	0.52 bc	8.12 bc	1.39 b	156.06	1.48	4.15 ab	3.69	1.16	23.82 abc	34.33 ab	827.67 ab	39.67	2.53	86.00
110 R	0.43 bc	7.55 c	1.25 b	145.50	1.54	4.40 ab	3.63	1.24	24.35 a	41.33 a	668.33 ab	39.33	2.53	104.00
140 Ru	0.74 ab	9.62 abc	2.22 ab	211.58	1.69	4.32 ab	3.74	1.62	23.86 abc	32.33 b	864.67 a	44.33	2.53	71.67
161-49 C	0.42 bc	8.53 bc	1.57 b	162.51	1.51	4.38 ab	3.61	1.16	23.33 abc	41.67 a	628.33 ab	37.00	2.53	112.00
3309 C	0.91 a	13.84 a	3.38 a	237.84	1.81	4.58 a	3.71	1.81	24.08 ab	38.67 ab	721.00 ab	53.67	2.60	76.33
41 B MGt	0.49 bc	11.07 ab	2.12 ab	176.85	1.61	4.28 ab	3.62	1.23	22.94 c	32.33 b	740.00 ab	41.00	2.43	79.67
420 A MGt	0.31 c	7.12 c	1.20 b	141.19	1.36	4.03 ab	3.63	1.20	23.42 abc	36.33 ab	869.00 a	37.67	2.57	103.33
99 R	0.65 abc	9.81 abc	1.80 ab	168.50	1.67	4.18 ab	3.64	1.29	23.92 abc	38.33 ab	678.67 ab	39.33	2.50	96.67
Fercal	0.40 bc	6.77 c	1.03 b	150.51	1.33	3.89 b	3.67	0.96	23.31 abc	38.67 ab	599.67 ab	49.00	2.50	77.67
Gravesac	0.71 ab	11.92 ab	2.42 ab	199.41	1.53	4.13 ab	3.69	1.22	23.77 abc	37.67 ab	673.67 ab	49.00	2.57	76.67
SO 4	0.62 abc	11.37 ab	2.43 ab	208.27	1.66	4.47 ab	3.59	1.29	23.11 bc	34.33 ab	559.67 b	39.33	2.37	86.67
Significance[b]														
R	<0.001	<0.001	<0.001	0.018	0.048	0.032	0.041	0.107	<0.001	0.019	0.022	0.060	0.130	0.136
Y	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.175	0.606	0.084	<0.001	<0.001	0.004	<0.001	0.050
R x Y	1	0.669	0.998	0.999	0.999	0.999	0.342	1.000	0.371	0.992	0.218	0.863	1	0.386

[a] Different letters denote significant differences in ANOVA and Fisher's test. [b] Significance (*p* value) of rootstock (R), year (Y), rootstock and year interaction (R x Y).
[c] Total acidity expressed as gTartaric acid·L⁻¹.

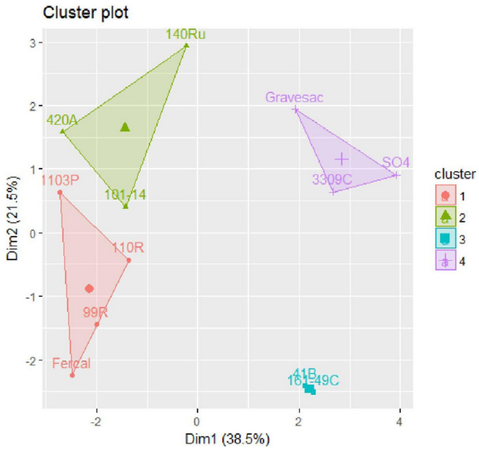

Fig. 2: Results of the cluster analysis for 'Syrah'.

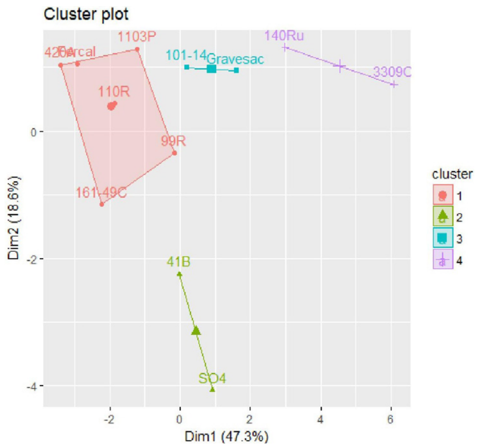

Fig. 3: Results of the cluster analysis for 'Tempranillo'.

exception of 140 Ru. Group 2 contains 41 B MGt and SO 4, which both have a *V. berlandieri* parent, and medium vigour according to bibliography. Group 3 consists of 101-14 MGt and 'Gravesac', which both have a *V. riparia* and a *V. rupestris* parent. Lastly, Group 4 is formed by 3309 C and 140 Ru, which both have a *V. riparia* parent.

The results of the PCA (Figs 4 and 5) showed that the first three components explained 79.1 % of the total variability for 'Syrah', and 80.3 % for 'Tempranillo'. For both varieties, Component 1 (which explained 38.5 % of total variability in 'Syrah' and 47.3 % in 'Tempranillo'), was positively associated to those parameters related to growth and yield, particularly to PruW, BunW and Yld. For both 'Syrah' and 'Tempranillo', MalA, BW and BunNb also influenced the first component, although to a lesser extent. Secondly, Component 2 was positively related to the phenolic maturity parameters (OrgP, TanM, Tan and Ant), and pH and TSS for 'Syrah'; and to OrgP, pH, Ant and TSS for 'Tempranillo'. Finally, Component 3 was influenced primarily by TSS, pH, DMACH and TanM for 'Syrah', and by Tan, DMACH and TSS for 'Tempranillo'. Total Acidity had little effect on any Component for 'Syrah' and the same for TanM for 'Tempranillo'. The combined observation of CA and PCA allows describing the behaviour observed for the four groups established after CA for each cultivar, summarized as follows:

'Syrah':

- Group 1 (1103 P, 110 R, 99 R, 'Fercal'): low vigour and low yield, low MalA and medium-high TSS.
- Group 2 (140 Ru, 420 A MGt and 101-14 MGt): medium to low vigour, medium yield and high values for phenolic maturity parameters.
- Group 3 (41 B MGt and 161-49 C): medium vigour, high yield and low values for TSS and phenolic maturity parameters (Tan, Ant and OrgP).
- Group 4 (3309 C, 'Gravesac' and SO 4): high vigour and yield, high acidity and medium-high Ant.

'Tempranillo':

- Group 1 (1103 P, 110 R, 99 R, 'Fercal', 420 A MGt and 161-49 C): medium to low vigour and low yield, medium-high TSS.
- Group 2 (41 B MGt and SO 4): medium to low vigour, medium yield and low values for TSS and phenolic maturity parameters.
- Group 3 (101-14 MGt and 'Gravesac'): medium vigour and yield and medium values for TSS and phenolic maturity parameters (Tan, Ant) with high OrgP.
- Group 4 (3309 C and 140 Ru): high vigour and medium to high yield, high MalA.

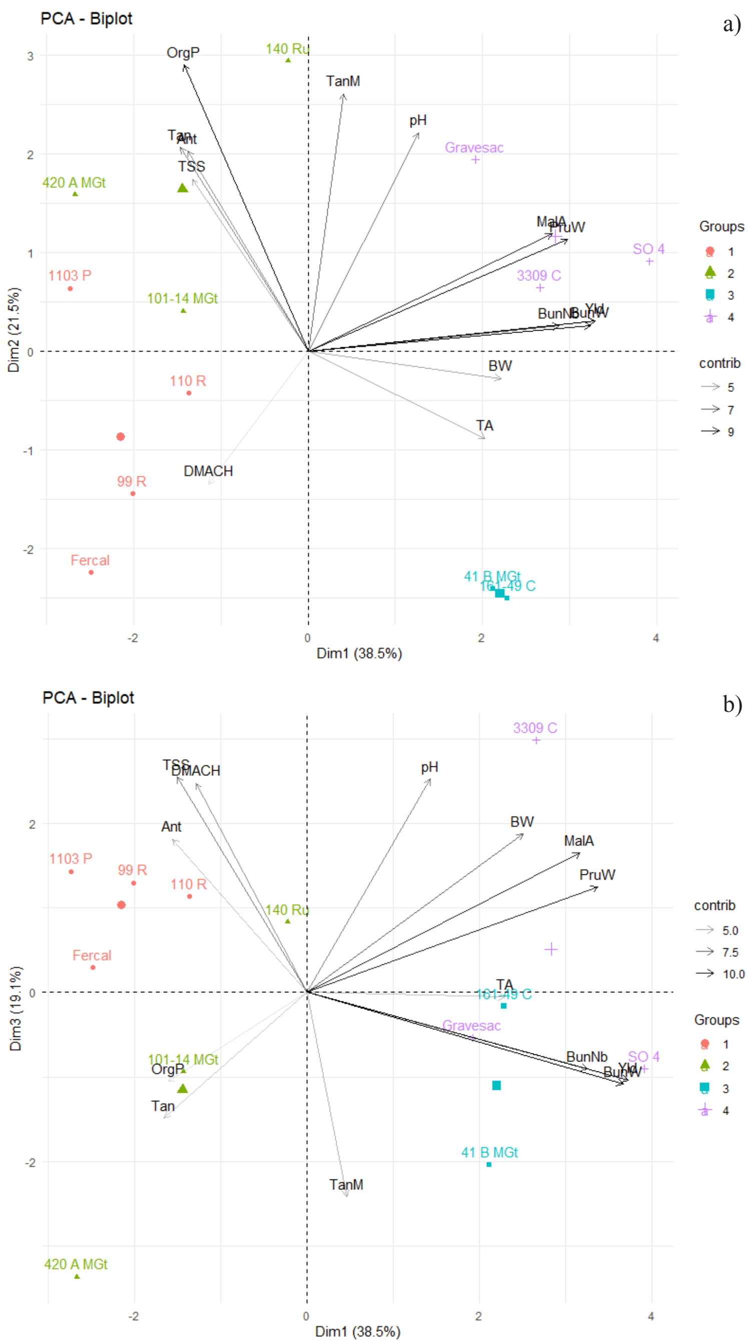

Fig. 4: Principal component analysis with all the measured parameters (growth, yield and industrial and phenolic maturity) for 'Syrah'. Each colour represents a different cluster from the cluster analysis.

Discussion

As expected, the agronomic performance of cvs. 'Syrah' and 'Tempranillo' was heavily influenced by rootstock genotype. Growth and yield parameters were generally the most affected, consequently affecting maturity. In any case, it is necessary to highlight that the results presented correspond to the first 4 harvests of the vineyard, and therefore it is still reaching stability, which can make their behaviour change during the following years. Nevertheless, rootstock evaluation has been exhaustively done during four consecutive seasons and in two different varieties, and a similar behaviour has been observed for the different rootstocks each year, as rootstock x year interaction was not significant.

Comparing the data between the two varieties, most of the rootstocks showed a similar performance in 'Syrah' and 'Tempranillo'. For instance, 3309 C was the most vigorous and one of the most productive rootstock in both varieties. It seems interesting to emphasize that this rootstock did not suffer a decrease in terms of phenolic maturity parameters (except for Tan and TanM in 'Syrah'), despite being the most vigorous one. This behaviour agrees with the results given in several studies (Agut *et al.* 2005, Andrade *et al.* 2005, Wolpert 2005), but not with others that considered 3309 C as a medium vigour rootstock (Cousins 2005, Reynier 2012), or even as low vigour, as reported by Albuquerque *et al.* (2010) in a trial where 'Tempranillo' was grafted on 10 rootstocks in Spain.

'Gravesac' was also one of the most vigorous rootstocks under our study conditions, especially in 'Syrah', and it showed similar behaviour between the two varieties too. It showed medium-high yield with medium-high values for

TSS and phenolic maturity parameters. Similar results were found in Miele and Rizzon (2017). Moreover, Albuquerque *et al*. (2010) and Yuste *et al*. (2017) also found 'Gravesac' conferring medium-high vigour, but with medium to low yield, when grafted with 'Tempranillo' and 'Sauvignon Blanc', respectively.

Rootstocks 1103 P, 110 R and 'Fercal', which also showed similar behaviour between the two varieties, were characterized by low vigour and low yield, with medium to high TSS. Within this group, the *V. rupestris* x *V. berlandieri* rootstocks (1103 P and 110 R) are typically known as vigorous by bibliography (Albuquerque *et al*. 2010, Colldecarrera *et al*. 1997, Jones *et al*. 2009), conversely to our findings. This differential behaviour could be due to the fact that plants received more water than usual in the Ebro valley, since irrigation was routinely performed twice a week. Other rootstocks such as 161-49 C and SO 4 were more vigorous in 'Syrah' than in 'Tempranillo'. 161-49 C was one of the least vigorous for 'Tempranillo', similarly to those results shown by Yuste *et al*. (2017) in a 'Sauvignon blanc' evaluation in Spain. Regarding to yield, 140 Ru and 99 R were more productive in 'Tempranillo'. In the same way, Albuquerque *et al*. (2010) also found in Spain, that 140 Ru had the highest growth and yield values in 'Tempranillo'.

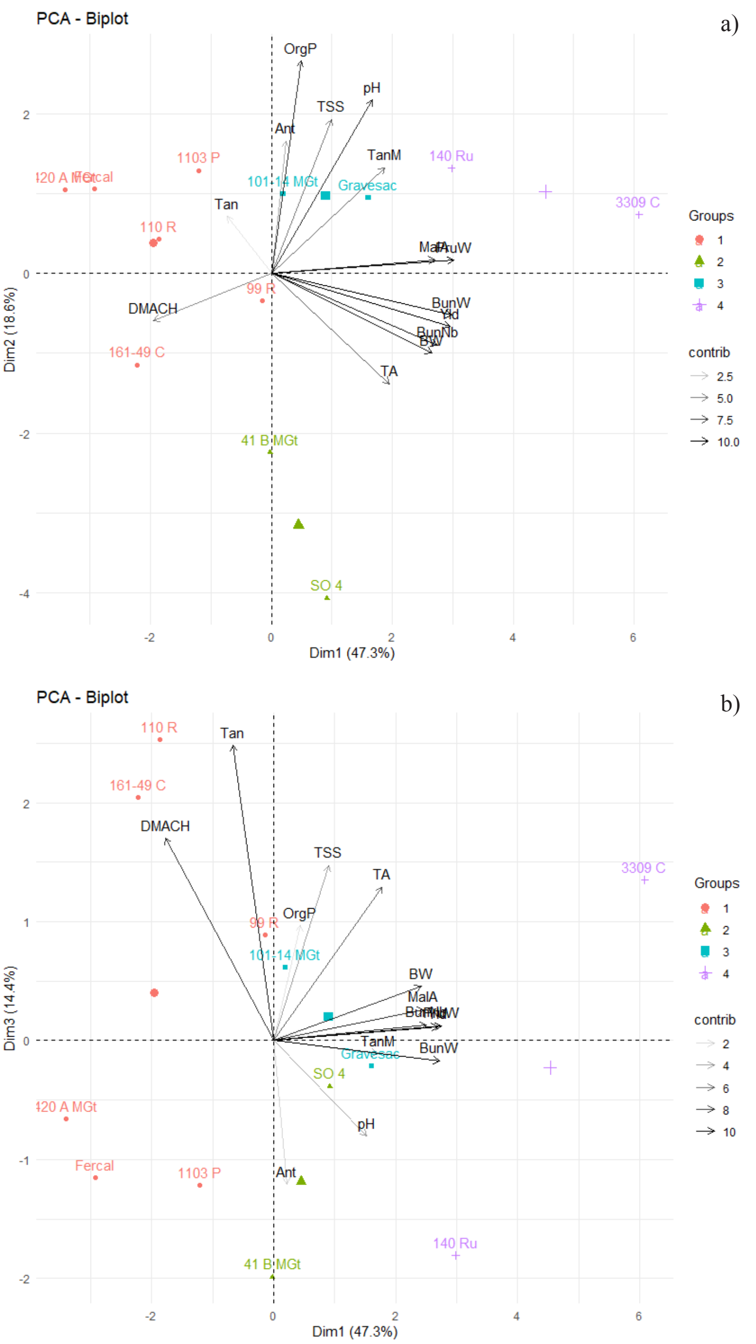

Fig. 5: Principal component analysis with all the measured parameters (growth, yield and industrial and phenolic maturity) for 'Tempranillo'. Each colour represents a different cluster from the cluster analysis.

Conclusions

The results clearly demonstrated the great influence that rootstocks have on vine performance, and emphasized, once again, the relevance of choosing an adequate rootstock before carrying out the establishment of a new vineyard. However, vigour induced by the rootstock to the variety depends not only on the own rootstock vigour but also on its adaptation to soil conditions (Pouget 1987) and, therefore, results are variable between different *terroirs*. For this reason, and regarding the influence that rootstocks may have on vine adaptation to climate change, it is of great interest to know how they may affect the most cultivated varieties in each area. The present work showed that 3309 C rootstock has shown a great vegetative and productive potential, although none has stood out for its high phenolic quality. However, the evaluation was carried out during the first four harvests of the vineyard, and could therefore change to some extent as the vineyard reaches stability.

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