The Early Selection of Grapevine Rootstocks for Resistance to Drought Conditions

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The resistance to severe drought conditions of 20 classical grapevine rootstocks and seven new rootstock genotypes was determined using an early selection test. One-year-old vines were grown under a restricted water regime (1/9 maximum evapotranspiration) in small containers inside a greenhouse. For each plant, the parameter F/rs (F = total active leaf area; 1/rs = stomatal conductance of active leaves) were determined. The results specify the pedoclimatic adaptation of the rootstocks and indicate that the water absorbing activity of the rootlets were the likely primary mechanisms of adaptation to drought.

The literature on the pedoclimatic adaptation of grapevine rootstocks is very precise concerning iron chlorosis (9,10). Presently in the Bordeaux area, further studies involve the general problem of mineral nutrition (11). In this context, it is useful to enhance nutrition experiments by determination of rootstock resistance to drought, since this phenomenon generally interacts with nutrient level availability (14). This technique will allow the new rootstock genotypes developed by the Viticultural Research Station (INRA, Bordeaux) to be compared with classical rootstocks.

The aim of this technique is not to analyze the mechanisms involved in the adaptation to water stress, but rather to define the general growing conditions which can simulate the physiological effects of water stress occurring under field conditions, using the relative behavior of reference rootstocks as a base.

Materials and Methods

The general principle of the rootstock selection test used under greenhouse conditions for drought resistance was previously presented (2).

In this study, the plants were one-year-old grafts of Cabernet Sauvignon, with relatively high stomatal conductance (2), grafted onto different rootstocks (20 classical, 7 new, Table 1).

The young grafts were grown in five-liter containers filled with coarse sand (that provided possible water storage in the bottom) inside a greenhouse which was heated during spring and cooled during summer. They were given an optimal water and mineral supply during the month following budburst. The plants were then selected for uniformity of growth and summer-pruned to three nodes. Two months later, two shoots per plant were selected, the laterals removed, and summer-pruned to above the ninth leaf. Four plants were chosen for each rootstock and each water regime.

Different water regimes were progressively applied over one month. Trickle irrigation was provided four times per day (5 h, 8 h, 14 h, 17 h solar time) from a 2S nutrient solution reservoir (12). Three irrigation levels were maintained. The first corresponded to maximum evapotranspiration (MET) under these greenhouse conditions. The other two were proportional to the previous control (MET/3 and MET/9). MET was measured for each container by computing the difference between the known over-water supply provided by trickle irrigation and the drainage in the bottom of the container. The two other irrigation levels were computed for each rootstock from the mean previous data and did not induce any drainage. In practice, the MET/9 regime corresponded to an equal distribution of nutrient solution for each rootstock. Figure 1 shows the influence of the MET/9 regime on young grafts. It is important to note that the drought conditions should be progressively established during the season and during the day. If not, wilting symptoms would quickly appear on the foliage and would not represent natural drought conditions in the field.

Table 1. *Vitis* rootstock genotypes studied.

Riparia
Riparia Gloire (de Montpellier)
Rupestris
Rupestris du Lot
Berlandieri
7383: open pollinated of Vidal 107 (*V. berlandieri* hybrid)
7405: open pollinated of Berlandieri d'Angeac
Rotundifolia
Yuga
Riparia × Rupestris
Millardet and de Grasset 101-14
Couderc 3309
Riparia × Berlandieri
Millardet and de Grasset 420A
S04 (Selection Oppenheim No. 4)
Kober 5BB
Couderc 161-49
RSB1 (Rességuier Selection Birolleau No. 1)
Riparia × Labrusca
Vialla: seedling of (*Labrusca × Riparia*)
Riparia × Vinifera
7542: open pollinated of Geisenheim 26 (*vinifera × Riparia*)
Rupestris × Berlandieri
Richter R 99
Richter R 110
Ruggeri R 140
Paulsen P 1447
Paulsen P 1103
Vinifera × Berlandieri
Millardet and de Grasset 41 B
Ecole de Montepellier EM 333
Fercal : (*Berlandieri* × Colombard No. 1) × EM 333
(Riparia × Berlandieri) × (Riparia × Rupestris)
7903: 161−49 × 3309
(Vinifera × Rupestris) × (Riparia)
Castel 196-17
(Cordifolia × Ruperstris) × (Riparia)
Malègue 44-53
(Riparia × Berlandieri) × [(Vinifera × Rupestris) × Riparia]
7921 and 7924: 161−49 × 196−17

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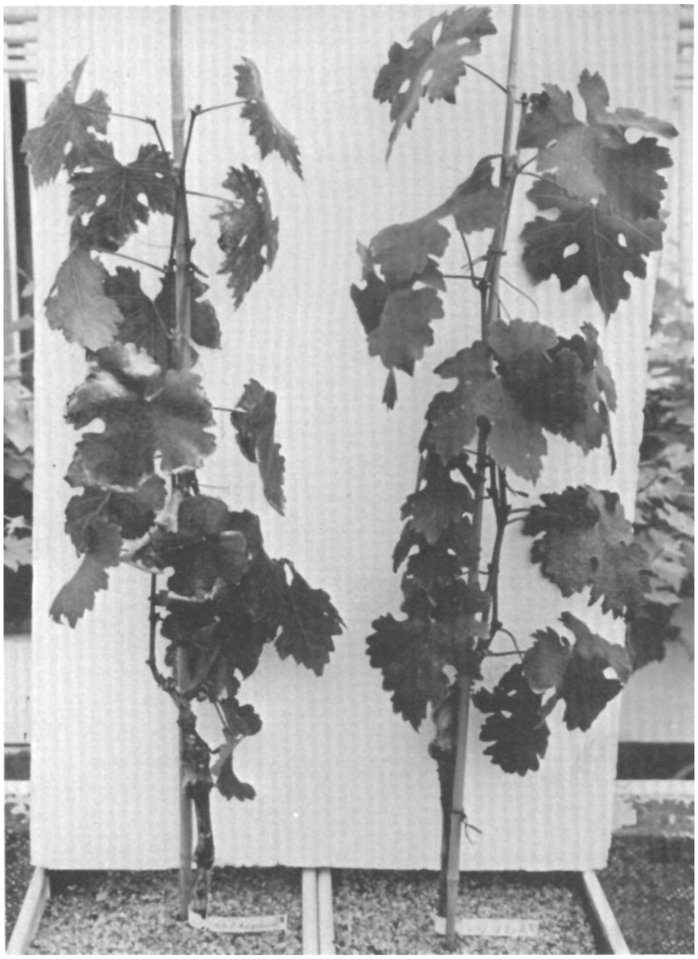

Fig. 1 View of the young grafts of Cabernet Sauvignon on Riparia Gloire (left) and on R 110 (right) for MET/9 experimental conditions in August 1983. Notice the evidence of leaf dessication symptoms for Riparia Gloire and not for R 110.

At the end of one month, two parameters were measured.

Total active leaf area of the plant (F cm^2): For each leaf, a relationship between the dimensions of the first two lateral veins and the leaf area established for Cabernet Sauvignon were used (2); necrotic portions of the leaves were excluded.

Stomatal conductance, 1/rs (cm s^{-1}): Conductance of active leaves was measured around 12 hours (solar time), under warm (32°C) and sunny (1500 $\mu Em^{-2}s^{-1}$) conditions which corresponded to maximum transpiration rates (2). All these measurements were done for each rootstock within two hours and four hours after the last irrigation. Stomatal conductance was measured by a ventilated diffusion porometer with regular calibrations (model Cayuga Development - Cornell).

An average of 40 measurements of F and rs were recorded for each rootstock and each water regime in July and August 1981, 1982, and 1983. The ratio F/rs (cm^3 s^{-1}) (transpiration index) was computed for each plant and expressed in percent of the reference rootstock R 110. Statistical analysis was based on the Kruskal Wallis test, and statistical groups (multiple comparisons) at the 5% level were established relative to three reference rootstocks: R 110, SO4, Riparia Gloire.

Results and Discussion

Methodological results: Under these experimental conditions, the ratio F/rs (cm^3 s^{-1}) appeared to be in excellent linear relationship with the daily nutrient solution supply. This was computed from all the data for the three water regimes and for each rootstock. For R 110, the regression equation was: $y = 5.92x - 39.63$, where y = F/rs (cm^3 s^{-1}) and x = daily nutrient solution supply (cm^3); the correlation coefficient was 0.978 (significant at the 1% level).

The results were not as good using F or 1/rs independently. Among the elementary components of transpiration, F/rs appeared to be much more representative of the nutrient solution supply than of leaf water potential (measured around mid-day) or of any simple relationship including leaf water potential or leaf water content (2), as used in similar experiments (4).

In this study, based on growing vines in containers with free soil surface, variation of the transpiration index well represented variations of transpiration or of water consumption. For a given nutrient solution supply, significant difference in transpiration index among rootstocks revealed a different ability to extract water from the soil (the excess being evaporated).

The main problem is the significance of a high value of the transpiration index under drought conditions (MET/9). We consider drought resistance induced by the rootstock to be the ability of the root system to extract maximum water from the soil. This is an agronomical approach, which requires sufficient photosynthesis allowing for good crop production under stress, rather than an ecological one, which deals with survival of xerophytes and water saving in very limiting situations.

Our experiment indicated that only the MET/9 level was discriminating enough to simulate a normal ranking among stocks. The MET/3 regime, which is often used (7,8), was less discriminating. For example, R 110 and R 140 are considered very drought resistant, and P 1103 , P 1447, 196-17, R 99 resistant or very resistant; Rupestris du Lot, 101-14, and Riparia Gloire are considered susceptible, and Vialla, very susceptible (1,2,5,6).

Therefore, only the rootstock results relative to the MET/9 level are presented, although this irrigation level was so low that the observation of growth recovery post-stress was unable to give consistent results within the short time generally observed (13). However, this water regime insured maximal discrimination among genotypes according to F/rs, and appeared precise enough and reliable enough for selecting rootstocks at an early stage of development.

Physiological results: Table 2 gives the absolute values for R 110 for the three irrigation regimes. Table 3 illustrates the transpiration index results obtained from the MET/9 regime by the 27 rootstock genotypes relative to the R 110 values, and shows the presence of five statistical groups related to three reference rootstocks R

Table 2. Mean absolute values related to R 110 and concerning the total plant leaf area (F), the mean leaf stomatal conductance (1/rs), the mean plant transpiration index (F/rs) and the mean daily nutrient solution supply (NSS),for the 3 irrigation regimes proportional to maximum evapotranspiration (MET).

	MET	MET/3	MET/9
F (cm^2)	4 176	3 042	1 404
1/rs ($cm\ s^{-1}$)	0.43	0.21	0.06
F/rs ($cm^3\ s^{-1}$)	1 815.7	633.8	85.6
NSS (cm^3)	315	105	35

110, SO4, and Riparia Gloire.

Class 1: These are highly resistant rootstocks (*i.e.* equal to R 110 and superior to SO4 and Riparia Gloire), and are in the decreasing drought resistance ranking: R 110, R 140, 44-53. These results correspond well to numerous observations under field conditions. Thus, 44-53 is considered highly resistant without any notable interference of its susceptibility to magnesium deficiency.

Class 2: These resistant rootstocks (*i.e.* equal to SO4, superior to Riparia Gloire, and inferior to R 110) are in a decreasing drought resistance ranking: P 1103, 196-17, P 1447, SO4, R 99, 7383. This group corresponds well to rootstocks which are normally considered as resistant, but less so than the previous group. SO4 is sometimes considered as drought susceptible (4,6), but not according to this experiment. The new genotype 7383 is notably drought resistant.

Class 3: These less resistant rootstocks (*i.e.* equal to SO4 and Riparia Gloire, and inferior to R 110) are in a decreasing drought resistance ranking: 3309, 7405, 7903, 420 A, Fercal, RSB1, 7921, 5 BB, 161-49, 41 B, Rupestris du Lot, 101-14 (the last two rootstocks being at the limit of significant difference relative to SO4). These results are in accord with most of the general observations, and it is interesting to note the position of the new genotypes 7405, 7903, Fercal and 7921.

Class 4: These susceptible rootstocks (*i.e.* equal to Riparia Gloire, and inferior to R 110 and SO4) are in a decreasing drought resistance ranking: Riparia Gloire, EM 333, 7924, Rotundifolia Yuga. Such conclusions fit well the practical observations for the classical rootstocks. Rupestris du Lot and 101-14 belong to this group or to the previous one as well. New data indicate resistance of 7924 and Rotundifolia Yuga. But for Rotundifolia Yuga, some prudence is needed because it is necessary to use a green grafting technique in propagation.

Class 5: These highly susceptible rootstocks (*i.e.* inferior to R 110, SO_4 and Riparia Gloire) are in a decreasing drought resistance ranking: 7542, Vialla. These results confirm the high susceptibility of Vialla and the new genotype 7542.

Conclusions

This early screening test of rootstock drought resistance corresponds to most of the practical observations on adaptation to severe drought conditions of classical grapevine rootstocks. It also reveals characteristics of some classical genotypes for which new field experiments are needed (for instance, SO4), and allows the classification of new genotypes (for instance, Fercal).

Table 3. Results and statistical groups for the 27 genotypes based on F/rs measurements expressed in % of R 110 values, and for MET/9 regime. The reference rootstocks are italicized.

	Highly resistant (≃ R 110)	Resistant (≃ S04 < R 110)	Less resistant (≃ S04, Riparia Gloire < R 110)	Susceptible (≃ Riparia Gloire < R 110, S04)	Highly susceptible (< R 110, S04, Riparia-Gloire
R 110	100				
R 140	99				
44-53	98				
P 1103		78			
196-17		77			
P 1447		74			
S04		73			
R 99		72			
7383		72			
3309			69		
7405			67		
7903			66		
420 A			64		
Fercel			63		
RSB1			63		
7921			63		
5 BB			62		
161-49			62		
41 B			62		
Rupestris du Lot			60	60	
101-14			60	60	
Riparia Gloire				58	
EM 333				54	
7924				54	
Yuga				54	
7542					47
Vialla					36

The results also suggest that this methodology is well adapted as a first approach to the complex problem of drought resistance. On a broad physiological basis and based on the conclusions of this experiment (in which all the root systems had the same volume of soil), it is now possible to assume that the drought resistance mechanism is more directly related to water extracting activity, and perhaps to water distribution, than to the ability of a root system to explore large volumes of soil (1). This phenomenon could be well a consequence of the water absorbancy activity of the rootlets.

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