The Influence of Rootstock on Leaf Water Potential, Yield, and Berry Composition of Ruby Seedless Grapevines

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An experiment was conducted to determine the effect of eight different rootstocks [99 Richter (99R), 110 Richter (110R), Rupestris du Lot (du Lot), 140 Ruggeri (140Ru), SO4, 41B, 101-14, and 1103 Paulsen (1103P)] on the productivity of non-irrigated Ruby Seedless grapevines grown in Morocco. Measurements taken over a three-year period included fruit growth and maturity indices, yield, and pruning weights. Leaf water potential (ψ_L) was measured at various times during the second year of the study. Results indicated that midday ψ_L declined throughout the season for all rootstocks, averaging -0.9 MPa at fruitset and -1.3 MPa at fruit maturity. The diurnal time course of ψ_L averaged across all rootstocks was approximately -0.4 MPa before sunrise, -1.2 MPa around solar noon, followed by a recovery to -0.6 MPa shortly after sunset. An analysis of seasonal, midday ψ_L indicated two extreme groups of rootstocks: du Lot and 110R had more negative leaf water potentials than 41B and 1103P. The difference between the two rootstocks with the greatest and the least negative average ψ_L, du Lot and 1103P, respectively, approached 0.2 MPa. Berry weight was greatest for vines on SO4, 99R, and 41B, and lowest for 101-14 and du Lot. At maturity, the lowest fruit soluble solids concentration was obtained on 99R and 41B while the lowest fruit coloration was obtained on 110R, du Lot, 140Ru, and 41B rootstocks. These results demonstrated that rootstock had a significant effect on Ruby Seedless fruit characteristics under non-irrigated conditions.

KEY WORDS: berry weight, soluble solids concentration, fruit coloration, table grapes, drought tolerance

Numerous factors should be considered when selecting a rootstock-scion combination for a specific site (13). The rootstock St. George has been reported to be vigorous, resulting in low bud fruitfulness per unit of growth (3) and fewer number of berries per cluster (23). In one study, St. George and SO4 were classified as vigorous stocks, while 110R was classified the least vigorous (11). However, in another study, 110R, SO4, and 101-14 were classified as higher yielding rootstocks with high cluster number and weight, and berry weight (10). Fruit quality and maturity also were reported to be affected by the rootstock. Fruit from vines on St. George had high potassium and pH, and low acidity (23). The rootstocks SO4 and 110R were reported to delay maturity based upon soluble solids concentration (7,10) with fruit on 110R having low pH (7).

Rootstocks also have been classified with regard to their drought tolerance (5,8,16,17). Galet (8) classified the performance of hybrids of *Vitis berlandieri* × *V. rupestris* as the most satisfactory in very dry soils. The species *V. riparia* and *V. rupestris* are thought to be sensitive to soil-water deficits (16). It should be pointed out that the drought resistance classification of rootstocks may vary from country to country (5,17).

Water is a limiting factor to grapevine productivity in Morocco. Most rainfall occurs during the dormant portion of the growing season, and the water holding capacity of the soils (such as that used in this study) is low. Average rainfall is approximately 175 to 225 mm per year. The objectives of this study were: *(1)* determine the influence of eight rootstocks on vine water status and vegetative growth; and *(2)* determine the effect of rootstocks on yield and fruit quality of Ruby Seedless table grapes.

Materials and Methods

Vitis vinifera L. (cultivar Ruby Seedless) vines used in this study were grafted onto eight different rootstocks and planted in 1985. The vineyard was located near Meknes (approximately 33° N, 6° W), one of the major grape production regions in Morocco. The vineyard was operated by the Societe de Developement Agricole (S.O.D.E.A), Production Unit number 1101, located in Agourai. The soil was composed of 74.0% sand, 14.3% silt, and 11.7% clay. The vineyard was flat and not irrigated. Vine and row spacings were 1.5 and 3.0 m, respectively. The vines were head trained and pruned to two canes of six to 10 buds each. The two-wire trellis used was composed of a cane wire and foliage wire located 0.7 and 1.0 m above the soil, respectively. The eight rootstocks used in this study were: 99 Richter (99R), 110 Richter (110R), Rupestris du Lot [syn, St. George] (du Lot), 140 Ruggeri (140Ru), SO4 (syn. Selection Oppenheim 4), 41B Millardet et de Grasset (41B), 101-14 Mgt (101-14), and 1103 Paulsen (1103P). Data were not collected in 1990.

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Midday leaf water potential (ψ_L) was measured biweekly throughout the 1991 season and diurnally on 2 August 1991. The ψ_L was measured with a pressure chamber (PMS Instrument Co., Corvallis, OR) on six to eight of the most recent, fully expanded leaves on sun-exposed shoots per treatment. To avoid evaporative loss, leaves were enclosed in a plastic bag just prior to cutting the petiole and left covered throughout pressurization.

At harvest in 1989, 1991, and 1992, crop yield and cluster number per vine were recorded, and samples of 100 berries per replicate were randomly collected, then analyzed for berry weight, soluble solids, titratable acidity (determined by titration with 0.133 *N* NaOH using phenolphthalein as indicator), and pH. Fruit coloration was determined according to Kliewer and Weaver (12), on 7-mm diameter discs of berry skin taken from the apical region of 20 berries from each sample. The absorbance of the skin extracts were read at 520 nm with a spectrophotometer (Perkin-Elmer, Lambda 2). The fruit pH and color and pruning weights were recorded for each plot in 1989 and 1991.

The experimental design was a randomized complete block with each block replicated three times. Each individual plot (rootstock) consisted of three vines. The data were analyzed using analysis of variance and linear regression. Mean separations were determined using Duncan's multiple-range test. Means were averaged across years.

Results

Midday ψ_L declined throughout the season (Fig 1). On the first measurement date, ψ_L averaged -0.85 MPa and ranged from -0.9 for 99R to -0.8 MPa for 110R. On the last measurement date, ψ_L averaged -1.3 MPa and ranged from -1.4 for 140Ru and 110R to -1.1 MPa for vines on 1103P. The relative positions of an individual rootstock's ψ_L were established early in the season and remained such thereafter (Fig. 1). The overall seasonal mean ψ_L indicated three groups corresponding to their average midday ψ_L (Fig. 2). The first group (consisting of du Lot and 110R) had significantly lower ψ_Ls than a second group (consisting of 1103P and 41B). The remaining four rootstocks had ψ_Ls intermediate to the extremes.

The diurnal ψ_L pattern of Ruby Seedless grapevines on all the rootstocks is illustrated in Figure 3. Before sunrise, ψ_L averaged -0.4 MPa and ranged from -0.35 to -0.45 MPa. By 0900 hours, ψ_L had decreased to an average of -1.2 MPa across all rootstock/scion combinations. The mean ψ_L of all rootstocks continued to decline up to solar noon. The difference between 1103P and du Lot was 0.3 and 0.25 Mpa at 0900 hours and

Table 1. The average effect over three years (1989, 1991, and 1992) of rootstock on yield components (collected at harvest, corresponding to 6, 1, and 11 September for 1989, 1991, and 1992, respectively), and pruning weights of Ruby Seedless grapevines measured in 1989 and 1991.

Rootstock	Yield (kg/vine)	Clusters per vine (number)	Berry wt (g)	Pruning wt (kg/vine)
du Lot	3.7 bc[y]	29 ab	2.86[z]	1.14 c
140Ru	4.5 abc	27 abc	2.97	1.22 bc
101-14	4.4 bc	27 abc	2.84	1.86 a
110R	5.1 ab	32 ab	2.89	1.33 bc
41B	6.3 a	35 a	3.02	1.14 c
99R	4.3 bc	25 bc	3.03	1.45 b
SO4	4.1 bc	27 abc	3.10	1.36 bc
1103P	2.8 c	19 c	2.95	1.17 c

[y]Means followed by a different letter within a column are significantly different at the 5% level using Duncan's multiple range test.
[z]Means were not significantly different in this column.

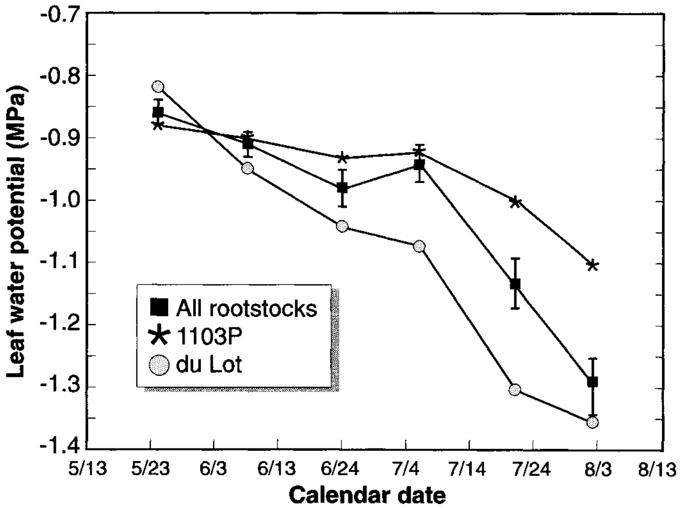

Fig. 1. Midday leaf water potential of Ruby Seedless grapevines grafted onto 1103P, du Lot, and the mean of all eight rootstocks from berry set to harvest. Each data point represents the mean of 6 to 8 individual leaf measurements for the single rootstocks. The solid squares are the means of all rootstocks ± one SE on each date.

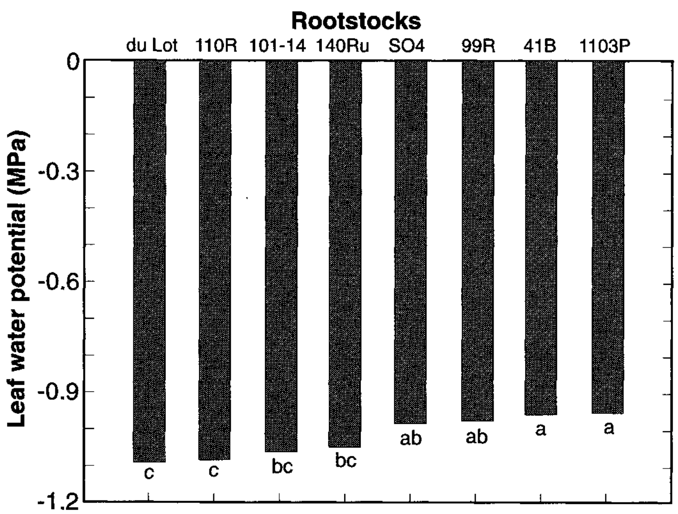

Fig. 2. The average midday leaf water potential of Ruby Seedless grapevines grafted onto eight different rootstocks. Measurements were taken every two weeks from 23 May to 31 August 1991. Mean separation by Duncan's multiple range test at the 5% level.

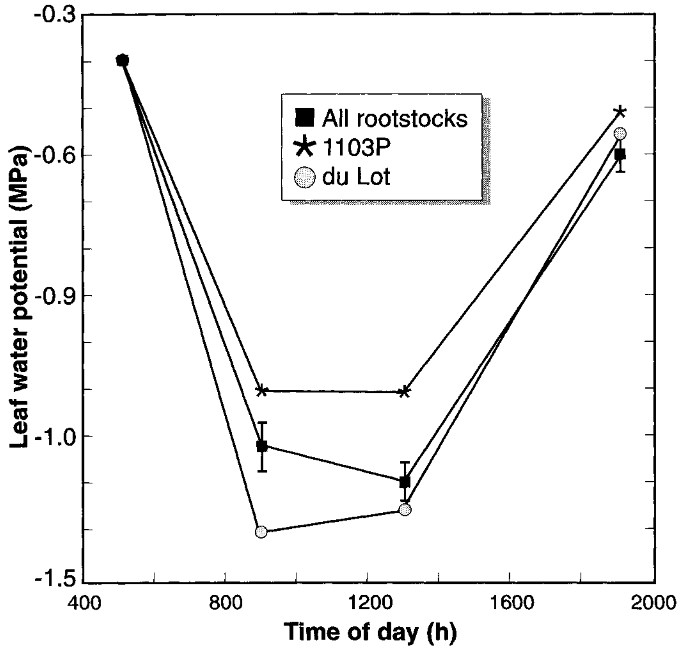

Fig. 3. The diurnal time-course of leaf water potential for Ruby Seedless grapevines grown in Morocco. Data were collected on 2 August 1991. Other information as found in Figure 1.

solar noon, respectively. Leaf water potential averaged across all rootstocks was -0.6 MPa at 1900 hours.

There were significant differences in yield and cluster number per vine among rootstocks (Table 1). Ruby Seedless grafted onto 41B had the highest yields (an average of 6.3 kg/vine) while those on 1103P had the lowest yield (2.8 kg/vine). The number of clusters per vine was lowest for 1103P (19 clusters/vine), but highest for 41B (35 clusters/vines).

Berry weight did not differ significantly among rootstocks (Table 1), while there were significant differences in soluble solids concentration at fruit harvest (Table 2). The lowest soluble solids concentration was measured on the fruit of 99R and greatest measured on the fruit of 101-14 and 1103P. There was a difference of 2° Brix between the highest (101-14) and lowest (99R) rootstocks. Titratable acidity was lowest in fruit on du Lot but highest in fruit from scions on 99R. The pH was lowest in fruit on 41B but highest in fruit on 101-14 rootstock. Color absorbance ranged from 0.67 to 1.32. Fruit on du Lot, 140Ru, 110R, and 41B had significantly lower color than fruit from 101-14.

There were significant differences among treatments with regard to pruning weights (Table 1). The rootstock 101-14 had significantly greater pruning weights than the rootstocks du Lot, 41B, and 1103P. Pruning weights ranged from 1.14 for du Lot and 41B to 1.86 kg/vine for 101-14.

Table 2. The average effect over three years (1989, 1991, and 1992) of rootstock on Ruby Seedless berry composition at harvest (fruit pH and color were not recorded on 1992).

Rootstock	°Brix	TA (g/100 mL)	pH	Color ($A_{520\ nm}$)
du Lot	18.5 bc[z]	0.47 e	3.77 ab	0.67 b
140Ru	18.7 bc	0.54 cd	3.75 ab	0.77 b
101-14	20.2 a	0.54 cd	3.82 a	1.32 a
110R	18.8 bc	0.51 de	3.73 ab	0.83 b
41B	18.5 bc	0.58 bc	3.70 b	0.84 b
99R	18.2 c	0.64 a	3.72 ab	1.03 ab
SO4	19.4 ab	0.62 ab	3.75 ab	1.08 ab
1103P	19.9 a	0.57 bc	3.72 ab	0.92 ab

[z]Means followed by a different letter within a column are significantly different at the 5% level using Duncan's multiple range test.

Discussion

Averaged across all rootstocks, there was a seasonal decline in ψ_L for Ruby Seedless grapevines grown at this location. The decrease of ψ_L early in the season will occur regardless of whether vines are maintained well watered with irrigations daily or weekly (21). However, ψ_L should remain relatively stable after veraison if the vine is given the amount of water needed to meet vineyard evapotranspiration (ET) demands (9). Therefore, a decline in ψ_L after this growth stage would be associated with decreases in soil water content or increased evaporative demand. Osmotic adjustment by the leaves may also take place during drought with a resultant decrease in ψ_L (6). Daily, minor fluctuations in ψ_L as the soil water content declines would be expected due to changes in environmental conditions. The seasonal decrease in midday ψ_L found in this study would reflect in part the fact that they were not irrigated. Therefore, water availability in the soil became less as the season progressed. This has been demonstrated for deficit irrigated Thompson Seedless grapevines in California (9). However, in that study, midday ψ_L of vines irrigated at full ET never became more negative than -1.0 MPa.

Both seasonal and diurnal patterns of ψ_L measured in this study indicated differences among rootstocks. Previously, a comparison of Cabernet Sauvignon grafted onto three different rootstocks (5C, St. George, and AXR#1) indicated that rootstock had no effect on ψ_L (22). However, measurements in that study were made only on a single date. Research reported here extended over a two and one-half month period and the relative position of an individual rootstock with respect to the others was generally maintained throughout that time. The greatest change in ψ_L from the first measurement date to the last was 0.6 MPa for du Lot and 140Ru while the least was 0.2 MPa for 1103P.

The midday ψ_L averaged across all measurement dates indicated that there were two extreme groups of rootstocks. Ruby Seedless vines on du Lot and 110R had more negative ψ_Ls than those on 41B and 1103P. In a study with one-year-old, potted Cabernet Sauvignon vines, drought tolerance of rootstocks was determined based upon leaf area development and stomatal conductance measurements (2). The rootstocks 101-14, du Lot, and 41B were classified less drought tolerant than SO4 and 99R. The rootstocks 110R, 140Ru, and 1103P were classified as highly drought tolerant in that study. The relative rankings of rootstocks for drought tolerance using potted vines (2) had several similarities to the results obtained here using field-grown vines and ψ_L as a measure of vine water status. For example, du Lot and 1103P had the greatest and least values of ψ_L, respectively, in this study and 1103P was classified as highly drought-tolerant by Carbonneau (2), while du Lot was one of the least. SO4 and 99R had intermediate values of ψ_L in this study and were classified as intermediate in drought tolerance in the previously mentioned study. However, other rootstock comparisons were less clear between the two studies. This may be due to the fact that one measure of vine water status (stomatal conductance) and another (ψ_L) may not themselves be related to one another. Stomatal conductance of grape has been shown to be more highly correlated to soil water content than to leaf water potential (19). This may indicate that stomata respond to signals from roots as the soil drys out (4,18) and not to some measure of leaf water status.

In this study the highest yield was measured on vines grafted onto 41B. This was one of the rootstocks found to have the least negative seasonal ψ_L. A linear relationship between vine productivity and midday ψ_L has previously been measured on Thompson Seedless (9). However, averaged across all rootstocks there was no significant correlation between ψ_L and yield per vine in this study. The major factors determining vine productivity in this study were cluster number per vine and to a lesser extent berries per cluster. There was a significant linear correlation ($r^2 = 0.67$) between yield and cluster number per vine. 110R has previously been classified as a high yielding rootstock (10,17) under diverse soil and environmental conditions, and its increased yield was associated with increased cluster number per vine (10). The high yields of 110R and 41B in this study also were associated with greater cluster number per vine. Vines grafted onto du Lot had a high cluster number per vine but also had the lowest calculated number of berries per cluster. The 41B rootstock had the highest number of clusters per vine and highest number of berries per cluster. Berry set, cluster differentiation, and continued maintenance of the cluster primordia are sensitive to vine water stress (15). Therefore, vine water stress may explain the differences in cluster number per vine and berries per cluster found among the eight rootstocks used in this study.

Ruby Seedless grafted onto SO4, 99R, and 41B had the heaviest berries and least negative midday ψ_L, compared to vines on du Lot and 101-14 which had the smallest berries and most negative ψ_L. This would indicate that vine water status in part affected berry growth and supports other work demonstrating the negative effect water deficits have on berry expansive growth (21). The 101-14 rootstock had the highest soluble solids concentration and fruit color, but moderate yield. du Lot had low °Brix, and lowest titratable acidity and berry color among all rootstocks compared. This may have been due to the fact that this rootstock also had the most negative ψ_L throughout the growing season. While water stress generally is associated with an increase in sugar accumulation (21), severe water deficits actually may delay maturity (20).

There was a positive linear correlation ($r^2 = 0.59$) between titratable acidity and ψ_L in this study (1991 data only). A moderate decrease in titratable acidity has always been observed when measured water status of the vine has indicated stress (1,21). In this study, rootstocks with more negative ψ_L (du Lot, 110R, 101-14, and 140Ru) had less titratable acidity. Of the two major acids found in grape berries, malic acid is the one generally affected by water deficits in grapevines. The timing of vine water stress, whether occurring before or after veraison also will affect malic acid concentration (14).

Conclusions

This is one of the few studies investigating the effects of rootstocks on vine water status and productivity in a field situation. Therefore, this research provides both basic knowledge about rootstocks and applied information useful to viticulturists. This study also was important because in Morocco a majority of the vineyards are either dry-land farmed or the availability of water for irrigation is minimal.

The results indicate that the eight rootstocks used in this study could be classified into different groups based upon their seasonal, midday ψ_L measurements. This classification, based upon one measure of vine water status, was similar in several respects to another study in which a different measure of vine water status was used to make a classification for drought tolerance. However, the ψ_L data indicates that the effect of a rootstock upon the scion's water status was not the sole factor determining the productivity of a vine under dryland farming conditions. Based upon yield data, du Lot should not be considered as a rootstock for use in Morocco under dry-land conditions. Yield data obtained from the rootstock 110R in this and other studies has been classified as highly drought tolerant (5,27), would indicate that it could be used in non-irrigated vineyards in Morocco and perform relatively well.

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