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Effect of dehydration during storage on viability of dormant grafted grape

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Additional index words: plant survival, transplant, rootstock

Abstract

This study quantifies the effect of dehydration during storage of bare root grape vines delivered from the nursery and planted in winter. In that period, plants are at risk of dehydration, but it has not been well studied.. One-year-old dormant bench grafts of *Vitis vinifera* cv. 'Redglobe' on Freedom or Harmony rootstocks were exposed to a range of dehydration treatments to observe survival and growth of the vines after planting. Field-finished plants were harvested from nursery soil, and the roots of 25 plants were exposed to air for 0, 4, 8, 22, 32, 70, 96, 128, 192 or 262 h to simulate variable environmental conditions that plants suffer before planting. For each rootstock-time combination, the hydration status was determined gravimetrically on 5 plants and the remaining 20 were individually planted in containers for weekly evaluation of bud break and growth. Plant organs exhibited different dehydration kinetics. Roots and trunk (two-year-old wood) were the most appropriate organs to determine plant hydration status and later planting success, whereas one-year-old wood was highly variable. Hydration status of root and trunk during dormancy were significantly related to growth potential. Dormant plants grafted on Harmony tolerated dehydration better than plants grafted on Freedom.

The plant propagation method choice for different species depends on a series of factors, including feasibility and plant establishment success; the later highly related to dehydration avoidance (Scianna *et al*., 2004). Traditionally, grapevines are propagated by cuttings, which can be rooted in containers or directly in the soil. As grape rootstocks in Chile become more popular, cuttings are normally bench grafted, field-finished (growth in the field for one year before selling) and sold during the following winter. For deciduous plants, the most tolerant stage for transplant and dehydration is dormancy, with some species and cultivar considerations (Murakani *et al*., 1990; Englert *et al*., 1993). Harvesting plants at the nursery should be done on cool, cloudy and still days, and with cultural practices that help to avoid dehydration of the roots, maintaining the rootball with its substrate and moisture (Englert *et al.,* 1993; Hartmann *et al*., 2002). Later, plants are selected based on size and root quality and put in cold storage or are "*heeled-in*" with saw dust, sand or both covering the roots (Hartmann and Kester*,* 1988; Englert *et al.*, 1993; Hartmann *et al*., 2002; Schuch *et al.*, 2007). Dehydration during nursery handling of plants has been associated on other species like red oak (*Quercus rubra* L.), Norway maple (*Acer platanoides* L.) and Washington hawthorn (*Crataegus phaenopyrum* Medic.) with poor regrowth and regressive death after transplant (Englert *et al.*, 1993; Murakami *et al.*, 1990). Therefore, a special consideration for nurseries is to avoid dehydration, but no specific information on grapevines has been developed.

Until recently small nurseries produced plants for local growers (McKay, 1996), but nowadays the industry has transitioned to large-scale nurseries distant from the plant-

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ing site, increasing the time and risks associated to plant dehydration. For table grapes in Chile the situation is even worse, since nurseries are located in the central region with relatively mild and humid winters, but vineyards are spread all over and many plants are intended for the north region, more than 800 km away and with a warm and dry climate that increases dehydration potential. Plant shipping is done in truck containers with controlled temperature and humidity and roots maintained in moist sawdust, but often there are problems during or after transport

Grapevines are generally considered tolerant to water stress (Keller, 2010), but there are no specific studies regarding dehydration behavior during harvest, storage, transport or planting of propagating material. New vineyards may develop problems with plant survival associated with dehydration, which is hard to evaluate since grapevines do not have leaves at that time (Chen *et al.,* 1991).

For this research we obtained objective and quantitative data to evaluate vineyard establishment success of one-year-old grafted plants with varying hydration status.

Materials and Methods

The study was conducted between July (winter) and Dec. (end of spring) 2009, in a commercial grapevine nursery located in Malloa, Región del Libertador Bernardo O`Higgins, Chile (34º 24´56´S; 70º 55´27´W)

Previously (winter 2008), a large number (commercial nursery operation) of one-bud 'Redglobe' scions were grafted onto Freedom or Harmony cuttings and rooted in the field for one season. These one-year-old dormant grafts were harvested on July 3rd and graded by trunk diameter, length, and size of root system, choosing the #1 size (1.5 cm diameter, 40 cm trunk length and 40-60 cm root system). After harvest, dormant bench grafts were mounded in 100% sawdust trenches for five days and irrigated daily, a common nursery practice. Plants were rehydrated for 20 h by full immersion in water. Then, plants were put on pallets and dehydrated under uncontrolled conditions, with their roots exposed to air; simulating field conditions at planting. During air exposure time (AET) the average temperature was 7.4 ± 3.9 ºC; with maximum 22.5 ºC and minimum -1.5º C; and average relative humidity was 82 ± 16.7%

The AET was 0, 4, 8, 22, 32, 70, 96, 128, 192 or 262 h. Plants were randomly assigned to each AET/ rootstock combination. Roots, trunk and one-year-old wood of five plants were used to determine water content by the gravimetric method (Eq. 1) using the dry weight.

$$\mathrm{Wc} = \frac{\mathrm{Fw} - \mathrm{Dw}}{\mathrm{Dw}} \qquad \text{Eq. 1}$$

Where:
Wc: water content (g)
Dw: Dry weight (g) after 72 h at 62ºC oven
Fw: Fresh weight (g) immediately after AET

Cumulative vapor pressure deficit (VPD) was then calculated using the equation suggested by Murray (1967) and reported as VPD per second for each AET period.

The remaining 20 plants were individually planted in 3 L-polyethylene containers filled with composted pine bark. Roots were lightly pruned to allow proper root distribution in the container and NPK was added according to nursery standards. Containers were irrigated to saturation when control containers had lost 20% of their weight (approximately every 3-4 days) and put in a polyethylene greenhouse for 3 weeks between 12º (night) and 28ºC (day), then moved to a plastic-covered growth area, where containers could be irrigated. One week after bud break the three shoots (corresponding to the three buds left after cutting back the plants) were retained on each plant and new lateral shoots were periodically removed. Every seven days, from Aug. 7 to Nov. 28, bud break (stage 04 of the modified Eichhorn-Lorenz system, Pearce and Coombe, 2004) and length of the longest shoot were recorded.

Bud break value (BbV) and bud break peak period (BbP) were calculated, relating to the number of days for bud break, by Eq. 2 and 3, modified from the seed germination analysis (Hartmann *et al*., 2002). The mean days for bud break (DBb) were obtained from the sum of the number of plants beginning bud break on each evaluation day by the corresponding number of days (N1 plants x days for bud break 1 + N2 plants x days for bud break 2 +…… Nn plants x days for bud break n).

$$\mathrm{BbV} = \mathrm{BbP} \times \mathrm{DBb} \qquad \text{Eq. 2}$$

Where:

BbV: Bud break value
BbP: Bud break peak period
DBb: Mean days for bud break

$$\mathrm{BbV} = \frac{\mathrm{MBb}/100}{\mathrm{DMBb}} \times \frac{\mathrm{FBb}/100}{\mathrm{DFBb}} \qquad \text{Eq. 3}$$

Where:

MBb: Maximum bud break (%) (when bud break rate begins to slow down)
DMBb: Days for maximum bud break (days)
FBb: Final bud break (%)
DFBb: Days for final bud break (days)
Bud break rate was calculated by Eq. 4.

$$\mathrm{BbR} = \frac{1}{\mathrm{DBb}/(\mathrm{DFBb} - \mathrm{DIBb})} \qquad \text{Eq. 4}$$

Where:

BbR: Bud break rate
DBb: Mean days for bud break
DFBb: Days for final bud break
DIBb: Days for initial bud break

Statistical Analysis

The experiment was a two x 10 factorial, with 2 rootstocks and 10 levels of AET and there were 25 replicates per treatment combination in a completely randomized design. Data were analyzed graphically according to data position and scattering. The data for plant survival did not fit lineal models; therefore non-lineal regressions were used (*Curve Expert Professional v1.3.0*). Regression models were evaluated with *Infostat* (Di Rienzo *et al*., 2008) and Akaike Information criterion (AIC) and Baysian Information criterion (BIC) were used to select the best model among the set of candidate models to predict plant survival.

The main selection criterion was AIC, choosing models based on maximum likelihood, with the smaller AIC (Balzarini *et al.,* 2008; Gómez *et al.* 2012). To choose a model representing both rootstocks and also plant parts, models for DFBb, BbR, BbV and shoot dry matter and maximum shoot length were ranked according to AIC. Lineal models were adjusted using dummy variables.

Results

In general, based on visual observations in July (winter time) Harmony plants had thicker roots, a lighter root color and 3 to 5 main roots; whereas Freedom plants had fascicular brown-reddish roots and a shorter root system.

Fresh weight of dormant plants declined when exposed to increasing VPD (Fig. 1) and this supports the results of Allen *et al.*(2006). Roots had the highest rate of water loss (Fig. 1D), followed by the whole plant (Fig. 1A). Dehydration kinetics of dormant bench grafts is stronger for the roots and weaker for the one-year-old wood. Standard errors were smallest for whole plants and trunk. Therefore, taking into account the rate of water content change and the standard deviation, the best organs to determine water content loss are trunks and roots.

Plant survival decreased with increasing AET and plants on Harmony tolerated dehydration better than plants on Freedom (Table 1.) Plants grafted onto Freedom had 90% sur-

Table 1. The number of hours of exposure (AET) of bare-root grapevines on two rootstocks required for several plant survival rates.

Survival probability	AET*	
	Freedom	Harmony
%	----- h -----	
95	0.0 – 1.9	0.0 – 31.1
90	9.3 – 11.9	51.8 – 53.1
50	59.2 – 65.0	95.7 – 99.4

*For local ambient conditions of the study

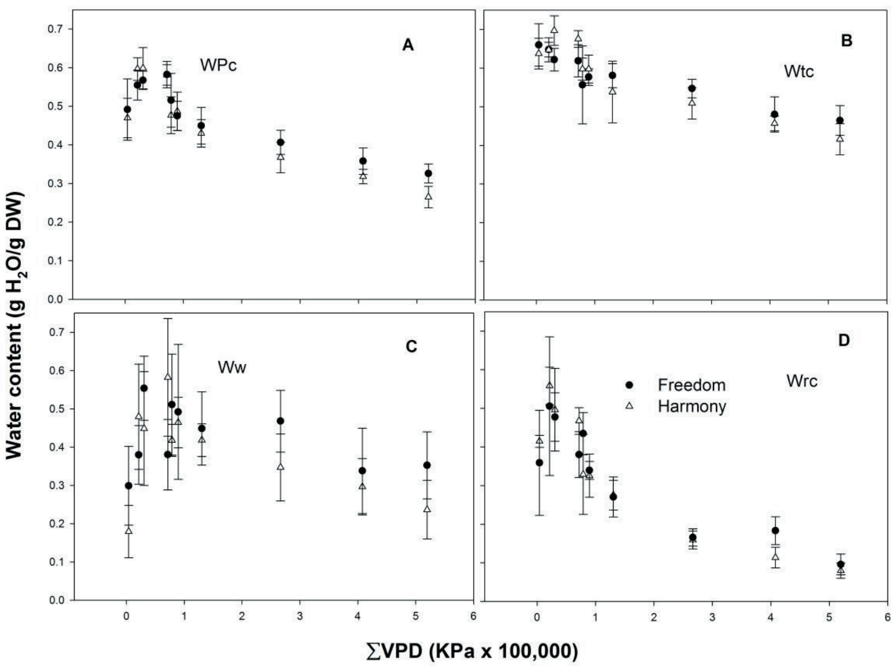

Fig. 1. The relationship between gravimetric water content (Wc) and accumulated VPD during the AET period for one-year-old dormant 'Redglobe' grapevines on two rootstocks: (A) Whole plant, WPc; (B) trunk, Wtc ; (C) one-year-old wood, Wwc; and (D) roots, Wrc. Bars represent standard errors of the means.

vival after only 9-11 h of AET, whereas plants on Harmony had the same survival probability after 51-53 h, corresponding to 20.0 to 23.1 and 102.0 to 106.0 KPa of cumulative VPD respectively (data not shown). Plants exposed to air for 192 or 262 h did no survive.

The relationship between plant survival and water content was evaluated for whole plant, trunk, one-year-old wood and roots, and the best predictive model was obtained when the model contained both trunk and roots (Wc t+r). Plants on Harmony and Freedom with values of Wc t+r from 0.46 to 0.52 g H_2O/g DW, respectively had 95% survival rates (Fig. 2).

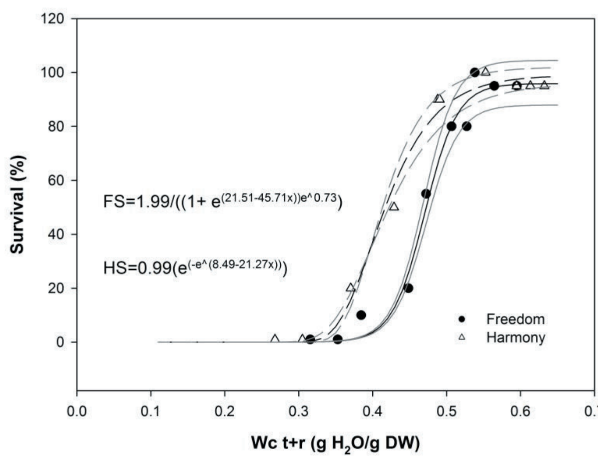

Fig. 2. Survival of one-year-old dormant grape 'Redglobe' plants grafted on two rootstocks as affected by water content of trunk and roots (Wc t+r) on a dry weight base (DW). FS: Freedom survival; HS Harmony survival.

Table 2. Dehyrdation effect on time needed for bud break (DBb) of one-year-old dormant Redglobe grafted grapevines.

Rootstock	Air exposure time (AET) h	Plants n^z	Days for bud break (DBb) (Number of days)	
Harmony	0	20	61.4	A[y]
	4	19	66.1	A B
	8	19	69.6	A B C
	22	19	71.5	A B C D
	32	18	82.7	B C D E
	70	18	82.8	B C D E
	96	10	91.1	E F
	128	4	113.0	G
Freedom	0	20	70.3	A B C
	4	19	75.6	A B C D E
	8	19	84.1	B C D E
	22	16	86.3	C D E
	32	16	89.4	D E F
	70	2	91.5	E F
	96	11	105.3	F G
	128	2	113.0	G

[z] Different n are due to varying plant survival following treatment, with maximum of 20 plants.
[y] Means followed by common letters do not difference, by, Tukey (p<=0.05).

Cumulative bud break was negatively related to the duration of AET and plants on Harmony broke bud earlier than on Freedom (Table 2). For control plants 50% bud break occurred at 50 and 65 days after planting when grafted on Harmony and Freedom, respectively. For plants exposed to air for 32 hours, 70 and 85 days were required for 50% budbreak and no plants had 50% bud break when exposed to air for 96 or 128 hours.

Days for bud break were negatively and linearly correlated with Wc t+r (Fig. 4A), and bud break was delayed on plants exposed to dehydration. Bud break rate and bud break value were positively and linearly related to water content (Fig. 4 B& C). Rootstocks did not differ significantly for all three response variables. Shoot dry matter and maximum shoot length increased linearly with increasing water content, but rootstocks were not different (Fig. 5).

Low values for Wc t+r were associated with short shoots with low dry matter in shoots (Fig. 5), with no differences between rootstocks (data not shown).

Discussion

One of the main causes for poor growth sprouting and establishment of bare root deciduous plants is dehydration stress during harvest and postharvest of plants in the nursery, and dehydration can occur at other times before planting (Remmick, 1995; Englert *et al.*, 1993; Guehl *et al.*, 1993; Chen *et al.,* 1991).

Plants on Harmony tolerated dehydration stress better than plants on Freedom, with higher survival at similar Wc t+r or at similar AET and environmental conditions. Our data support reports for other species such as maple (*Acer platanoides* L.), and hawthorn (*Crataegus phaenopyrum* Med.), where roots dehydrated faster than one-year-old wood (Murakami *et al.*, 1990), possibly due

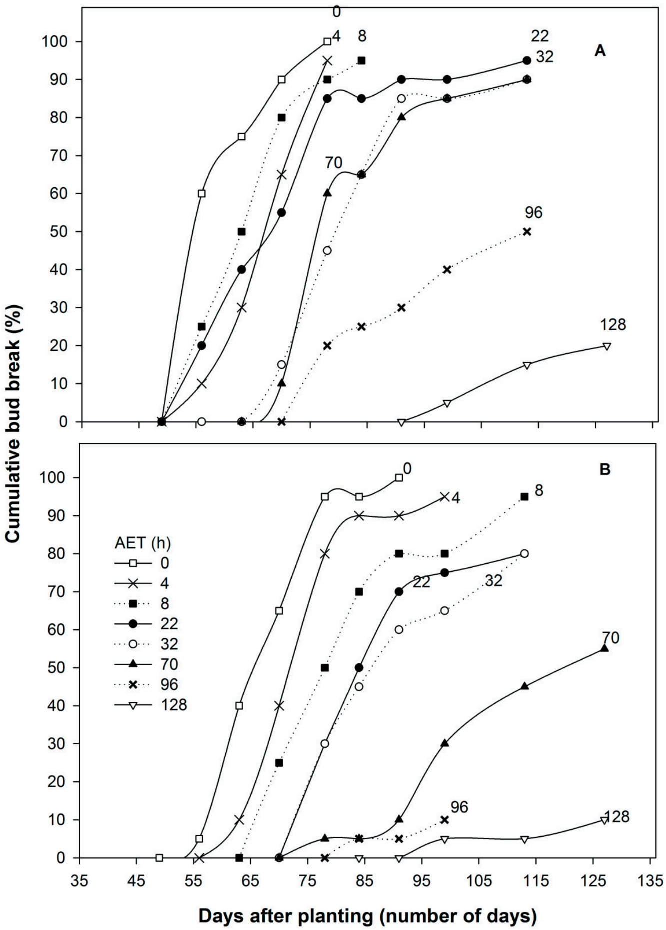

Fig. 3. Cumulative bud break after planting for one-year-old dormant 'Redglobe' grapevines grafted on (A) Harmony and (B) Freedom rootstocks for different AET.

to greater exposed surface area and thinner cuticles for roots (Schuch *et al.*, 2007). Similarly, Chen *et al.* (1991) found differences in dehydration tolerance between apple rootstocks, with MM.111 being more tolerant than MM.106 or M.7. Differences among rootstocks could be in part explained by root morphology. Dehydration tolerance is related to root size, for example the exposed area; species with smaller area/volume (thicker roots) were more resistant to dehydration (Englert *et al.*, 1993). Harmony and Freedom are rootstocks with similar parentage (1613 (*V. solonis* x Othello (*V. vinifera x (V. labrusca x V. riparia)))* x Dogridge (*V. champinii*)) and are very similar. However, plants grafted onto Freedom are often more vigorous than plants grafted on Harmony (UC-ANR, 2003), a characteristic that could be related to differences in root systems. We found that Harmony root systems had 3 or 4 thick main roots and few thinner roots, whereas Freedom plants had many main roots and more thin roots, and these differences could explain the better dehydration tolerance of Harmony (Fig. 6).

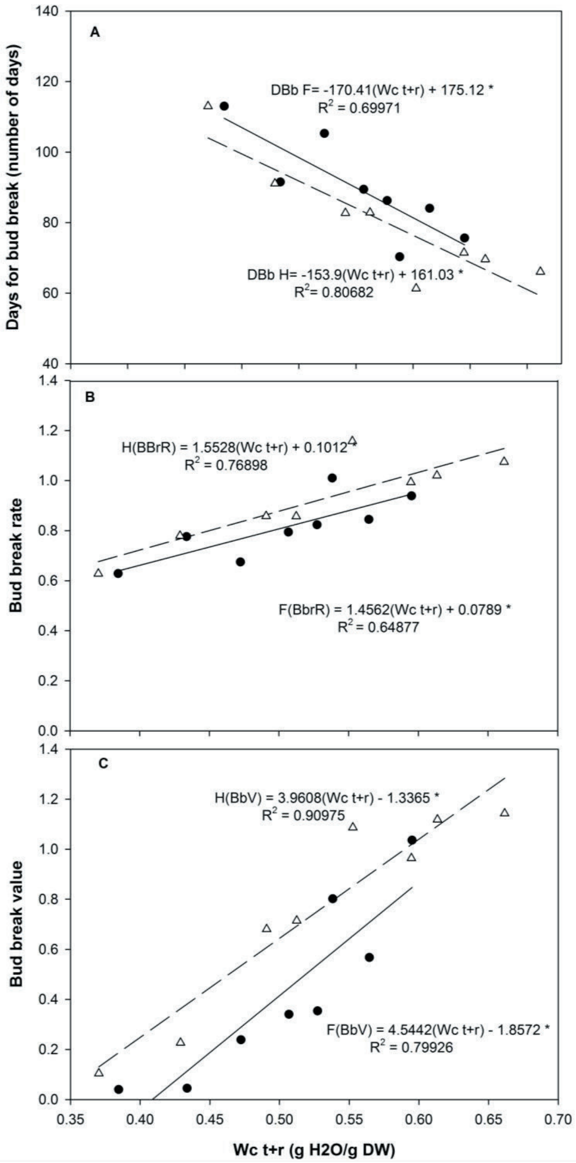

Fig. 4. The relationship between water content of trunk and roots (Wc t+r) and (A) Days for budbreak, DBb; (B) bud break rate, BbR and (C) bud break value, BbV for one-year-old dormant 'Redglobe' grapevines grafted on two rootstocks.

Slopes are significantly different from zero, but slopes were not affected by rootstock..

Bates and Niemiera (1994) used root water content as a plant water status indicator during transplant of bare-root trees and confirmed its usefulness to predict establishment success. Dehydration stress or the lower water content of different tissues increased DBb and reduced BbR and BbV, and maximum shoot growth and dry matter accumulation, similar to the results reported by McKay (1996) and Shuch *et al*. (2007) on trees and roses showing delayed sprouting and reduced shoot growth.

The results of this study point out the need for quality evaluation of dormant plants including plant water content, to determine the establishment success of new vineyards. Results from this research are restricted to our conditions and the two rootstocks chosen, but they represent a first phase for future work toward developing guidelines for proper handling of dormant plants.

The Wc t+r expressed as g H_2O/g dry weight represents an objective quantitative tool to estimate survival of 'Redglobe' grapevines grafted on Freedom or Harmony. The Wc t+r threshold for 95% survival for both Harmony and Freedom plants was 0.52 g H_2O/g dry weight, though Harmony had higher survival. Low water content prolonged dormancy, increased dormancy level, delayed bud break, and reduced uniformity of plant growth in the field.

Threshold values for other rootstocks should be determined, and should include quick and objective measurements of hydration status, like root xylem water potential that according to other authors would relate to survival and

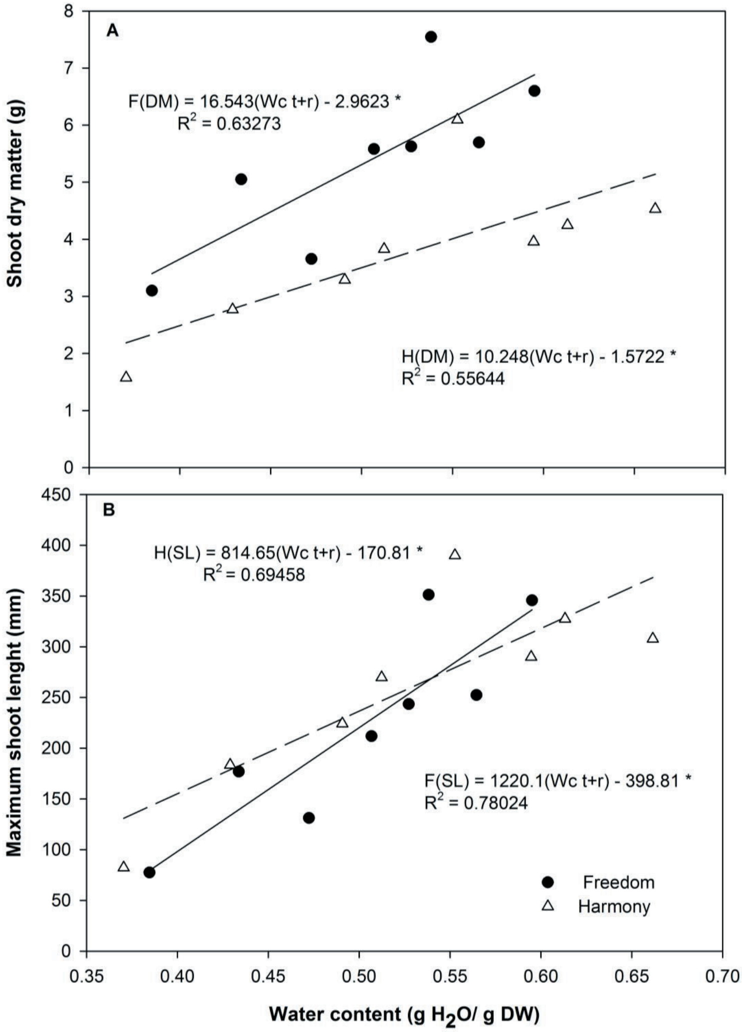

Fig. 5. Effect of trunk and root water content on (A) shoot dry matter; and (B) maximum shoot length for one-year-old dormant 'Redglobe' grapevines grafted on two rootstocks. All slopes were significantly different than zero ($P = 0.05$), but slopes were not affected by rootstock.

dormancy stage (Bates and Niemiera 1994; Chen *et al*., 1991; McKay, 1996). Likewise, practices to rehydrate plant material should also be evaluated.

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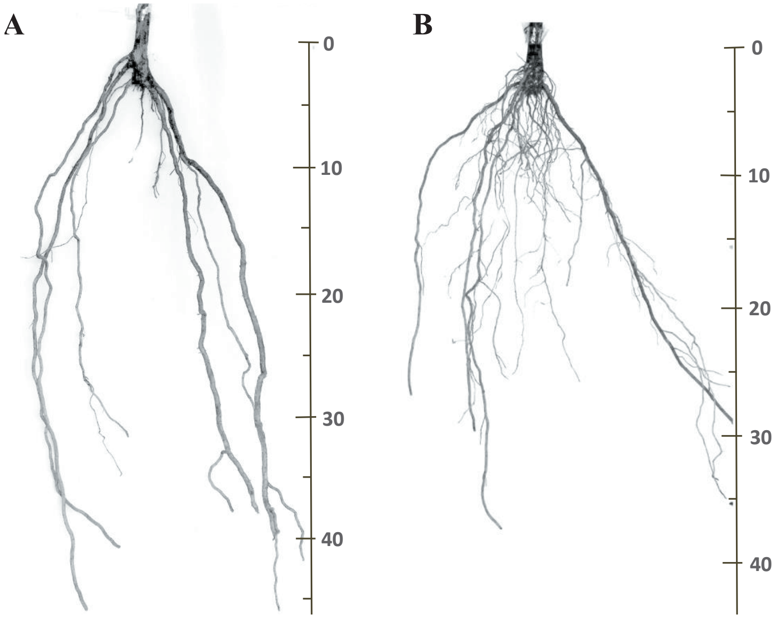

Fig. 6. Typical root systems for (A) Harmony and (B) Freedom (b) grape rootstocks. Image taken July 15th (winter time).

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