The interaction of phylloxera infection, rootstock, and irrigation on young Concord grapevine growth

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Summary

Concord roots are moderately resistant to phylloxera, which form nodosities on the fine roots and weaken the root system. Rootstocks and vineyard floor management both have the potential to eliminate or reduce the effect of phylloxera in New York Concord vineyards. Young, container-grown Concord grapevines were used to evaluate the interaction between rootstock (own-rooted, Couderc 3309), irrigation, and phylloxera infection on vine growth. Phylloxera inoculation alone caused a 21 % decrease in vine dry mass and lack of irrigation (mid-day stem water potential: -0.9 to -1.0 MPa) alone caused a 34 % decrease in vine dry mass. The combination of phylloxera stress and water stress was additive and caused a 54 % decrease in vine dry mass. Because C3309 rootstock is resistant to phylloxera, the grafted vines showed a response to irrigation but not phylloxera inoculation. This container study shows the potential benefits of irrigating own-rooted Concord grapevines or the use of rootstocks without irrigation to withstand phylloxera infection.

Key words: irrigation, phylloxera, rootstock, photosynthesis, shoot growth, leaf area.

Introduction

Grape phylloxera, *Daktulosphaera vitifolii* (Fitch), is a major pest of grapes and has had a profound impact on viticultural practices worldwide. *Vitis vinifera* are particularly susceptible to the root-form of phylloxera, theoretically because *V. vinifera* did not co-evolve with the pest (WAPSHERE and HELM 1987). Because phylloxera infection can be lethal to *V. vinifera*, it is generally necessary to grow these varieties on resistant rootstock where phylloxera has become established (HUSMANN 1930; DELAS 1992). The importance of phylloxera-resistant rootstocks has prompted rootstock research in many grape-growing regions of the world (WOLPERT *et al.* 1992). Thus, the mandatory use of phylloxera-resistant rootstocks for *V. vinifera* in phylloxera-infected soil and the success of rootstock research has deterred both the use and research of other cultural practices to combat the pest. The situation is different for Concord (*Vitis labrusca*, Baily) production in the northeast U. S., where the majority of Concord vineyards are own-rooted and unirrigated. Concord grapevines have phylloxera-resistant leaves and moderately resistant roots (WAPSHERE and HELM 1987). Although phylloxera infection does not kill Concord grapevines, their roots support large populations of phylloxera in the northeast U. S. (STEVENSON 1964; TASCHENBERG 1965). Phylloxera nodosities weaken the root system and potentially decrease the water and nutrient absorbing capacity of Concord. Roots moderately resistant to phylloxera have been shown to perform as poorly as *V. vinifera* roots in the field. In Fredonia, N. Y., White Riesling grafted to Elvira rootstock (*V. labrusca*-derived) had the same cane pruning weight and yield as own-rooted vines; however, White Riesling grafted to phylloxera resistant rootstocks showed increased productivity (POOL *et al.* 1992).

The lack of adequate vegetative growth (vine size) is a major limitation to Concord production in New York (SHAULIS 1956; KIMBAL and SHAULIS 1958). In 1969, SHAULIS showed that optimum Concord vine size for commercial production could be achieved at the Cornell Vineyard Laboratory in Fredonia, N. Y. by fertilization, weed management, and crop control despite root phylloxera infection (SHAULIS and STEEL 1969). Alternatively, similar vine size and production could be achieved by grafting Concord onto phylloxera-resistant rootstock (Couderc 3309) in combination with less intensive management practices. Intensive management and phylloxera-resistant rootstocks together produced vines that were too large for the allotted trellis space, which eventually led to internal canopy shading and decreased fruit quality (LIDER and SHAULIS 1974). Since the majority of the New York Concord industry remains own-rooted, research in New York continues to focus on intensive vineyard management, such as row-middle techniques and irrigation to increase water and nutrient availability for optimum growth and productivity (POOL *et al.* 1990; LAKSO *et al.* 1998).

Soil temperature, the quantity and quality of roots, and the presence of grape phylloxera in the soil influence phylloxera feeding (OMER *et al.* 1997). Phylloxera infection produces entry points in grape roots for fungi, which can have secondary negative effects by increasing root necrosis (OMER *et al.* 1995). However, organic management techniques may help suppress the interacting effect of phylloxera and fungal infection (LOTTER *et al.* 1999). Therefore, in the cool climate of the northeast U. S., the pattern of Concord fine root growth, row-middle management, and soil nutrient and water availability may all influence the degree and impact of phylloxera infection on Concord productivity.

The purpose of this research was to evaluate the interaction of rootstock, phylloxera infection, and irrigation on the vegetative growth of young Concord grapevines.

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Material and Methods

Twenty-four own-rooted Concord, and 24 Concord grafted to Couderc 3309 rootstock one-year-old field-grown grapevines (Double A Vineyards, Fredonia, N.Y.), matched for size, were dipped in a hot water bath for approximately 4 min to remove phylloxera that may have colonized roots (Flaherty *et al.* 1992). The phylloxera-clean vines were planted in 94.6 l (25 gal.) plastic pots (MacKenzie Nursery Supply, Inc., Perry, Ohio) containing a 50:50 mixture of phylloxera-free topsoil and sterile potting soil mix and placed outdoors at the Vineyard Laboratory in Fredonia, N. Y. Each of the rootstock treatments were split for irrigation and then split again for phylloxera inoculation. Therefore, the experiment consisted of two rootstocks x two irrigation levels x two phylloxera levels x 6 replicates = 48 pots. Drip irrigation was used to keep the irrigated pots well watered throughout the experiment. Tensiometers (Forestry Suppliers, Inc. Jackson, Miss.) were used to monitor relative soil moisture and leaf gas exchange (Ciras-1, PP Systems, Hitchin, UK) was measured to monitor leaf photosynthetic rate and leaf stomatal conductance. To keep the un-irrigated vines from defoliating, the un-irrigated pots were watered when tensiometer readings and leaf gas exchange indicated vine water stress: Mid-day stem water potential: -0.9 to -1.0 MPa, corresponding to a decline of leaf photosynthesis from 20 to 10 $\mu mol \cdot m^{-2} \cdot s^{-1}$. For phylloxera infection, about 100 phylloxera eggs were placed at the root crown and covered with soil at planting time.

All vines were pruned back to two shoots after the last threat of spring frost and flower clusters were removed. Leaf area development was measured twice during the growing season by measuring the mid-rib length of every leaf on every vine and using a regression equation to calculate leaf area (modified from Elsner and Jubb 1988). In the fall, the pots were destructively harvested. Root fresh mass, shoot fresh mass, and number of phylloxera nodosities per root system were measured at harvest. Vine tissues were dried at 60 °C and root and shoot dry mass were measured.

Results and Discussion

For own-rooted vines, the addition of phylloxera to the pots increased the nodosity density on the roots (Tab. 1, Figure). Irrigated vines had greater nodosity density than non-irrigated vines and vines not inoculated with phylloxera remained fairly clean except for some roots growing near the drain holes in the pots, where phylloxera presumably entered the system. All grafted vines remained phylloxera nodosity free.

In own-rooted/irrigated vines, phylloxera caused a 21 % reduction in vine dry mass and inhibited root growth more

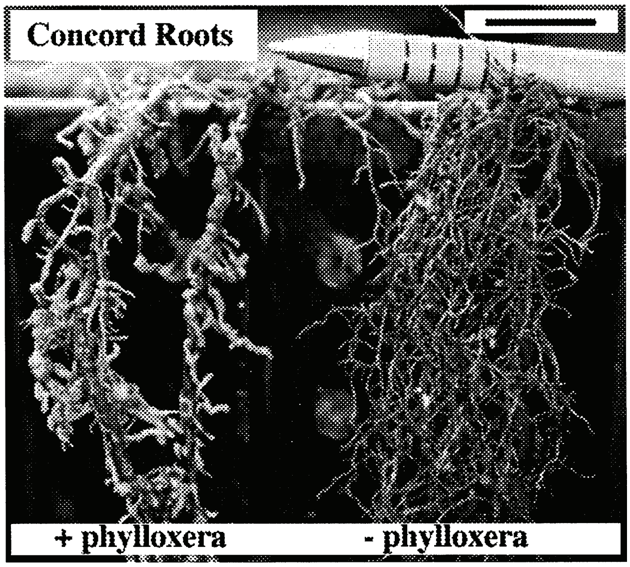

Figure: Concord roots with and without phylloxera infection showing the decrease in fine root surface area caused by phylloxera nodosities (bar = 2 cm.).

Table 1

Effect of irrigation, phylloxera, and rootstock on the vegetative production of young, container-grown Concord grapevines

Treatment I	P	R	Phylloxera density (nodosities per g root dry mass)		Root dry mass ($g \cdot vine^{-1}$)		Shoot dry mass ($g \cdot vine^{-1}$)		Vine dry mass ($g \cdot vine^{-1}$)		Number of ripe nodes per vine	
-	+	own	8.7	b	106.0	a	61.5	a	167.5	a	22.8	a
-	-	own	1.5	a	157.4	bc	83.9	b	241.3	bc	27.5	a
+	+	own	12.3	c	173.9	cd	113.5	c	287.4	c	60.4	bc
+	-	own	0.8	a	244.2	e	119.1	c	363.3	e	64.2	c
-	+	graft	0.0	a	126.8	ab	78.2	ab	205.0	ab	29.2	a
-	-	graft	0.0	a	136.4	abc	77.0	ab	213.4	ab	29.2	a
+	+	graft	0.0	a	173.1	cd	120.8	c	293.9	cd	54.4	b
+	-	graft	0.0	a	210.6	de	131.5	c	342.1	de	61.4	bc

I = (+/-) irrigation
P = (+/-) phylloxera inoculation
R = rootstock, own = Concord/own-rooted, graft = Concord/C3309
Mean separation by Duncan's Multiple Range Test at 5% level.

than shoot growth (Tab. 1). In own-rooted/non-irrigated vines, phylloxera caused a 31 % reduction in vine dry mass, through reductions in both the roots and the shoots (Tab. 1). Phylloxera inoculation did not have an effect on grafted vines. In own-rooted/phylloxera-clean vines, water stress caused a 34 % reduction in vine dry mass. In own-rooted/ phylloxerated vines, water stress caused a 42 % reduction in vine dry mass. Grafted vines showed a similar response to irrigation with a 30-40 % reduction in vine dry mass in non-irrigated vines.

Designating own-rooted/irrigated/phylloxera-clean vines as the least stressed or control vines, the additive effect of phylloxera stress and water stress can be illustrated. As stated, phylloxera inoculation alone caused a 21 % decrease in vine dry mass from the control and lack of irrigation alone caused a 34 % decrease in vine dry mass from the control. The combination of phylloxera stress and water stress was additive and caused a 54 % decrease in vine dry mass from the check. Because the C3309 rootstock is resistant to phylloxera, the grafted vines showed a response to irrigation but not phylloxera inoculation. Total biomass production in grapes is dependent on the amount of exposed leaf area (sunlight interception) and leaf area function (photosynthetic rate). Both leaf area development and leaf function are dependent on the capacity of the roots to supply water and nutrients. When all of the pots were well watered by rain and/or irrigation, leaf photosynthesis was equally high in all vines (Tab. 2). During a drying cycle (7 d without rainfall and 3 d without irrigation), all non-irrigated vines, despite rootstock or phylloxera treatment, were water-stressed and had equally low leaf photosynthesis. All irrigated vines continued to have relatively high leaf photosynthesis; however, the own-rooted/phylloxerated vines began showing signs of water stress and had slightly lower leaf photosynthesis at the same leaf area. Therefore, under situations of continuous high water availability, phylloxera had little effect on leaf photosynthesis in Concord grapevines. However, the majority of Concord vineyards in New York are not irrigated and drying cycles occur during the growing season. As soil water availability decreased during a drying cycle, phylloxera-infected vines were the first vines to decrease leaf photosynthesis. Under drought conditions, all non-irrigated treatment vines were water-stressed and any additional effect of phylloxera infection on already low leaf photosynthesis could not be measured. The effect of the treatments on the combination of total leaf area and leaf photosynthesis was reflected in total dry matter production (*i.e.* vines that grew the most leaf area and maintained high leaf function had the greatest dry matter production).

Contrary to the perception in New York that phylloxera does not affect Concord production, this research illustrates that Concord root systems are weakened by phylloxera infection, which has the potential of inhibiting vine productivity. In own-rooted Concord vineyards, irrigation and other soil water management practices can help overcome negative phylloxera effects and maintain adequate productivity. Intensive soil, pest, and crop management to increase and maintain vine size is the current norm for the New York Concord industry. Alternatively, the use of phylloxera-resistant rootstocks with new Concord plantings should result in increased productivity, and should be more cost effective in the long run than own-rooted vines with cultural manipulations to combat phylloxera.

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Table 2

Effect of irrigation, phylloxera, and rootstock on the leaf photosynthesis and leaf area of young, container-grown Concord grapevines

Treatment I	P	R	Leaf A (wet) (μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)		Leaf A (dry)		Leaf area (T1)		Leaf area (T2) ($cm^2 \cdot vine^{-1}$)		Δ Leaf area	
-	+	own	15.1	a	4.8	ab	3200	ab	5020	a	1820	a
-	-	own	14.7	a	3.9	ab	3720	abc	6113	ab	2393	a
+	+	own	15.9	a	8.0	bc	5110	c	10673	d	5563	b
+	-	own	15.1	a	10.4	cd	4623	bc	10351	d	5728	b
-	+	graft	16.5	a	3.2	ab	3205	ab	5955	ab	2750	a
-	-	graft	15.7	a	2.2	a	2795	a	5643	a	2848	a
+	+	graft	14.6	a	14.5	d	2953	a	7779	bc	4826	b
+	-	graft	14.1	a	11.8	cd	4307	abc	9444	cd	5137	b

I, P, R: see Tab. 1
A = Photosynthetic rate
Mean separation by Duncan's Multiple Range Test at 5% level.

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