# Rootstocks Impact Vine Performance and Fruit Composition of Grapes in British Columbia

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**Additional index words.** *Vitis*, yield, *Vitis vinifera*, French–American hybrids

**Summary**. Nine wine grape cultivars ['Chardonnay', 'Gewurztraminer', 'Ortega', 'Riesling', 'De Chaunac', 'Marechal Foch', 'Okanagan Riesling', 'Seyval blanc', and Verdelet'], own rooted or grafted to four rootstocks ['Couderc 3309' (*Vitis riparia* x *V. rupestris*); 'Kober 5BB' (5BB), 'Teleki 5C', and 'Selektion Oppenheim 4' (SO4) (*V. riparia* x *V. berlandieri*)] were planted into a randomized complete block experiment in 1985. Data were collected on yield components, weight of cane prunings (vine size), and fruit composition between 1989 and 1996. Yield per vine, clusters per vine, cluster weight, and berry weight were not affected by rootstock, but SO4 tended to produce lowest berries per cluster. Lowest vine size was associated with 5BB and own-rooted vines were usually largest; 5BB was also associated with highest crop load (yield to vine size ratio). Own-rooted vines tended to produce berries with lowest percentage soluble solids (%SS) while 5BB led to highest %SS. Titratable acidity was not strongly affected and pH differences between rootstocks were very small. These data suggest that rootstocks may not provide significant advantage over own-rooted vines under conditions found in the arid regions of the Pacific northwestern U.S. and British Columbia.

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The necessity of using rootstocks is a question frequently being asked by grape growers in the Pacific northwestern U.S. and British Columbia. Vinifera grapevines are customarily grafted to prevent injury from biotic problems such as grape phylloxera (*Dactylosphaera vitifolii*) or nematodes (Pongracz, 1983). Numerous studies (Howell, 1987; Reynolds and Pool, 1980; Shaulis and Steele, 1969; Striegler and Howell, 1991) have demonstrated the advantage of using stocks such as Couderc 3309 (3309), Selektion Oppenheim 4 (SO4), Kober 5BB (5BB), and Teleki 5C (5C) to improve yields and fruit composition. Most of these responses, however, have been attributed to secondary effects of rootstocks mediated through increases in vine vigor, usually as a consequence of phylloxera resistance. Few studies have concentrated on the benefits of rootstocks in overcoming abiotic problems such as salinity (Downton, 1977; 1988), nutrient uptake (Downton, 1977; Ruhl et al., 1988), chlorosis (Valat et al., 1988), and drought (Pongracz, 1983), and fewer still (Reynolds and Wardle, 1995) have been conducted in the absence of confounding biotic factors.

In order of importance, rootstocks are selected based upon seven major criteria: 1) phylloxera resistance; 2) nematode resistance; 3) adaptability to high pH soils (lime); 4) adaptability to saline soils; 5) adaptability to low pH soils; 6) adaptability to wet or poorly drained soils; and 7) adaptability to drought. In areas such as the Pacific northwest, there are little or no biotic problems with which to contend. Moreover, most of the soils being used for viticulture are well-drained, coarse-textured, and free of major physical and chemical problems such as salinity, waterlogging, and extremes in pH. Therefore, the question of whether rootstocks should be used is frequently posed.

Use of rootstocks in nonphylloxerated areas may be justified if a specific rootstock can improve vine performance and winegrape quality by 1) lowering vine size due to minor water stress; 2) controlling uptake of specific nutrients; 3) improving winter hardiness independent of vine size effect; and 4) shorten the vegetative cycle to allow more veraison-to-harvest heat units.

For instance, Couderc 3309 and other *V. riparia* x *V. rupestris* rootstocks have limited tolerance to water stress (Pongracz, 1983). The use of moderately drought-sensitive rootstocks to control growth and improve wine quality in irrigated areas is not a well-researched subject. Excessive nitrogen uptake may lead to large vine size, hence canopy shade, reduced winter hardiness, excessive potassium ($K^{+}$) uptake, and low wine quality (Smart, 1991). Rootstocks 5C and SO4 reduced cluster rachis ammonium ($NH_4$) and nitrate ($NO_3$) concentration in 'Riesling' but not 'Chardonnay' or 'Gewurztraminer' (Reynolds, unpublished). Ruhl et al. (1988) demonstrated the effect of rootstock on potassium accumulation in 'Muscat Gordo Blanco' petioles and lamina and on 'Chardonnay' musts. The conclusions drawn from these studies were that petioles of some scion cultivars, under the influence of specific rootstocks, may act as reservoirs for some ions, to prevent toxicities and undesirable whole-plant responses.

Rootstocks have also been shown to have indirect effects on scion hardiness that are mediated by and through vine vigor. Hence a vigorous vine (e.g., one grafted to 5BB) may have a higher percentage of shootless nodes following a cold winter than a smaller, ungrafted vine. Striegler and Howell (1991), however, found that hardiness of 'Seyval blanc' vines was substantially improved through grafting onto its own roots, and increased further when 3309 rootstock was used. Also, rootstocks such as 'Millardet et de Grasset 101-14' (101-14) allegedly have shorter vegetative cycles than some other rootstocks (Pongracz, 1983). This could theoretically allow more degree-days between veraison and harvest and allow late-season cultivars to mature more thoroughly. As with winter hardiness, this apparently anecdotal response needs to be tested with vines of similar sizes; small vines on 101-14 will obviously mature their fruit faster than large vines on 5BB or SO4.

At the time that this trial was initiated, there was no rootstock research in the Pacific northwest. Moreover, only three or four grape rootstocks were readily available to Canadian nurseries and growers. It was hypothesized that despite the intended growing conditions (no phylloxera;

**Table 1. Effect of use versus nonuse of rootstock on vine performance and fruit composition of nine grape scion cultivars, Summerland, B.C., 1989–96.**

| Variable | Own-rooted | Grafted[z] | Significance | Interaction[y] |
|---|---|---|---|---|
| Yield ($t \cdot ha^{-1}$)[x] | 16.7 | 16.0 | NS | ** |
| Clusters/vine | 71 | 69 | NS | * |
| Cluster weight (g)[x] | 138 | 139 | NS | *** |
| Berries/cluster | 85 | 85 | NS | *** |
| Berry weight (g)[x] | 1.63 | 1.62 | NS | NS |
| Soluble solids (%) | 21.7 | 22.4 | *** | *** |
| Titratable acidity ($g \cdot L^{-1}$)[x] | 11.8 | 12.1 | *** | *** |
| pH | 3.36 | 3.33 | *** | *** |
| Weight of cane prunings (kg/vine)[x] | 1.31 | 1.26 | ns | *** |
| Crop load (kg yield/kg cane prunings)[x] | 10.7 | 10.7 | ns | ** |

[z]Based on means of Couderc 3309, Kober 5BB, Teleki 5C, and Selektion Oppenheim 4 rootstocks across all scion cultivars.
[y]Represents interactions between scion cultivar and use/nonuse of rootstock.
[x]Metric conversions: 1 $t \cdot ha^{-1}$= 0.45 tons/acre; 28.4 g= 1.0 oz; 1.0 $g \cdot L^{-1}$= 0.13 oz/gal; 1.00 kg= 2.2 lb.
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.5$, 0.01, or 0.001, respectively.

low nematode populations; virus-free vines; soil pH 6.5, no visible nutrient deficiencies or toxicities; deep, coarse-textured soil; irrigation), rootstocks might nonetheless have significant impact upon yield components or fruit composition through any of the aforementioned mechanisms.

## Materials and methods

**EXPERIMENTAL DESIGN AND PLANT MATERIAL.** Nine scion cultivars ('Chardonnay', 'Gewurztraminer', 'Ortega', 'Riesling', 'De Chaunac', 'Marechal Foch', 'Okanagan Riesling', 'Seyval blanc', and 'Verdelet'), own rooted or grafted to four rootstocks ('Couderc 3309', 'Kober 5BB', 'Teleki 5C', 'Selektion Oppenheim 4') were planted at the Agriculture and Agri-Food Research Center, Summerland, B.C. in 1985. Scion and rootstock wood for all cultivars was collected the previous season (1984) from the Research Center cultivar collection and local vineyards. All own-rooted vines were propagated in 1984, hybrid cultivars and 'Ortega' were bench grafted and field grown at the Research Center, while grafted 'Chardonnay' and 'Gewurztraminer' (clones not specified), and 'Riesling' (clone 21B Weis) vines were purchased. Care was taken to collect scionwood for own-rooted *V. vinifera* vines from vineyards supplied by the same nursery from which grafted vines were purchased, to avoid confounding due to clone differences. The experimental design was a randomized complete block with four blocks and three-vine treatment replicates. Interspecific hybrids were included to observe whether rootstocks could impact on vine performance of cultivars that are well-known to be phylloxera-resistant.

Soil was a Osoyoos gravelly sandy loam with a field capacity of 15% soil water (Kelley and Spilsbury, 1949). Irrigation was provided by drip emitters that delivered 16 L (4.2 gal) of water per vine per day until veraison, and 8 L (2.1 gal) per day thereafter. Pest control practices were consistent with those recommended (British Columbia Ministry of Agriculture and Fisheries, 1996). The vineyard was fertilized annually at budburst with 85 $kg \cdot ha^{-1}$ (75.8 lb/acre) ammonium nitrate (34N–0P–0K). Vineyard floor management consisted of clean cultivation until veraison, followed by a natural weed cover that was retained until budbreak the following spring. Vines were trained to bilateral cordons at a height of 1.7 m (66 inches), spaced 3.0 m between rows and 1.8 m in row (10 × 6 ft), and pruned to 20 nodes/m (6 shoots/ft) of row in the form of two-node spurs.

**VINE SIZE AND YIELD COMPONENTS.** Weight of cane prunings (vine size) was measured annually at pruning time. Clusters per vine and yield per vine were recorded at harvest. Cluster weight was determined from these data. Crop load (Bravdo et al., 1984, 1985) was calculated from the yield and vine size data. A random 100-berry sample was taken from each treatment replicate, and the berry weight was utilized along with cluster weight to obtain data on berries per cluster.

**FRUIT COMPOSITION.** The berry samples were stored at –40 °C (–40 °F) until analysis. A 50 g (1.8 oz) subsample from each berry sample was processed into extracts according to Mattick (1983) and was subsequently used to determine titratable acidity (TA) with the aid of a Brinkmann automatic titrating ensemble (Metrohm, Herisau, Switzerland). The remainder of each sample was juiced, and soluble solids and pH were measured thereon by a temperature-compensated Abbé refractometer (AO Scientific, Buffalo, N.Y.) and Fisher Accumet 825MP pH meter (Fisher Scientific, Vancouver, B.C.), respectively.

**STATISTICAL ANALYSIS.** All data were analyzed using the SAS statistical package (SAS Institute, Cary, N.C.). The General Linear Models Procedure was utilized for analysis of variance. Single degree-of-freedom contrasts were used to ascertain species-based differences between the rootstocks.

## Results and discussion

**GENERAL TRENDS.** Data were first analyzed by combining 8 years of data from the nine cultivars and five root systems, and comparing the performance of all grafted vines as a group (four rootstocks × nine cultivars) versus all own-rooted vines (nine cultivars). These analyses showed that grafting had no effect on vine size or any of the yield components (yield/vine, clusters/vine, cluster weight, berries/cluster, berry weight, crop load). Grafting increased %SS and TA, and decreased pH (Table 1). However, there were cultivar × grafting interactions for all but berry weight, indicating that these trends did not hold true for all cultivars.

When the variance was partitioned by root system, but with scion cultivars pooled, yield, clusters per vine, cluster weight, and berry weight were not

**Table 2. Vine performance and fruit composition of nine grape scion cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| Rootstock | Yield ($t{\cdot}ha^{-1}$)$^z$ | Clusters/ vine | Cluster wt (g)$^z$ | Berries/ cluster | Berry wt (g)$^z$ |
|---|---|---|---|---|---|
| Own root | 16.2 | 71 | 133.8 | 83 ab | 1.61 |
| 3309$^y$ | 15.3 | 67 | 135.4 | 86 a | 1.57 |
| 5BB | 16.2 | 69 | 135.5 | 82 ab | 1.61 |
| 5C | 15.5 | 67 | 139.7 | 86 a | 1.59 |
| SO4 | 15.1 | 68 | 128.4 | 78 b | 1.64 |
| Significance | NS | NS | NS | * | NS |

| Rootstock | Wt of cane prunings (kg/vine)$^z$ | Crop load (kg/yield/ kg cane prunings)$^z$ | Soluble solids (%) | Titratable acidity ($g{\cdot}L^{-1}$)$^z$ | pH |
|---|---|---|---|---|---|
| Own root | 1.34 a$^x$ | 9.9 ab | 22.1 b | 11.5 | 3.37 a |
| 3309$^y$ | 1.25 ab | 10.3 ab | 22.7 ab | 11.8 | 3.33 b |
| 5BB | 1.14 b | 11.1 a | 23.0 a | 11.3 | 3.38 a |
| 5C | 1.31 ab | 9.3 b | 22.8 ab | 11.9 | 3.33 b |
| SO4 | 1.40 a | 9.3 b | 22.7 ab | 11.7 | 3.34 b |
| Significance | * | * | * | NS | *** |

$^z$Metric conversions: 1 $t{\cdot}ha^{-1}$= 0.45 tons/acre; 28.4 g= 1.0 oz; 1.0 $g{\cdot}L^{-1}$= 0.13 oz/gal; 1.00 kg= 2.2 lb.
$^y$Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
$^x$Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
$^{NS,*,**,***}$Nonsignificant or significant at $P \leq 0.5$, 0.01, or 0.001, respectively.

**Table 3. Yield ($t{\cdot}ha^{-1}$)$^z$ of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| Rootstock | De Chaunac | Marechal Foch | Okanagan Riesling | Seyval blanc | Verdelet |
| Own root | 22.2$^x$ | 15.3 b | 20.5 | 13.2 abc | 28.0 a |
| 3309$^y$ | 20.1 | 16.4 ab | 18.2 | 15.2 a | 22.3 b |
| 5BB | 19.9 | 18.8 a | 20.5 | 11.3 bc | 28.4 a |
| 5C | 21.9 | 15.5 b | 19.6 | 14.1 ab | 26.2 ab |
| SO4 | 22.0 | 15.7 ab | 19.7 | 10.1 c | 23.7 ab |
| Significance | NS | * | NS | ** | * |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| Rootstock | Chardonnay | Gewurztraminer | Ortega | Riesling$^w$ |
| Own root | 15.1 ab | 18.5 | 19.6 a | 16.1 |
| 3309$^y$ | 15.7 ab | 18.5 | 18.9 a | 19.9 |
| 5BB | 18.2 a | 16.2 | 12.6 b | --- |
| 5C | 14.5 b | 17.5 | 19.4 a | 16.9 |
| SO4 | 16.9 ab | 19.1 | 18.2 a | 18.1 |
| Significance | * | NS | * | NS |

$^z$Metric conversions: 1 $t{\cdot}ha^{-1}$= 0.45 tons/acre.
$^y$Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
$^x$Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
$^w$'Riesling' on 5BB was not commercially available and is hence not included.
$^{NS,*,**}$Nonsignificant or significant at $P \leq 0.5$ or 0.01, respectively.

affected (Table 2). There were more berries per cluster in 3309 and 5C, and the least in SO4; other stocks did not differ from these statistically. Own root, 5C and SO4 displayed lowest crop loads and highest vine sizes; 5BB had highest crop load and lowest vine size. Own root had lowest %SS, TA was unaffected, and own-root and 5BB had highest pH. Others didn't differ much from each other.

**SPECIFIC 8-YEAR TRENDS.** Yield components tended to be affected weakly to moderately by rootstock. Yield, cluster weight, and berries per cluster were affected moderately (five to six of nine cultivars; Tables 3,5,6). Yield differences between root systems tended to be barely significant at $P \leq 0.05$, and trends in the data were not strong. 'Chardonnay', 'Marechal Foch', and 'Verdelet' yielded highest on 5BB, but no other clear trends were apparent (Table 3). Clusters per vine was impacted very little (three of nine cultivars), and in all cases $P \leq 0.05$ (Table 4). Own rooted 'Ortega' and 'Verdelet', and 'Marechal Foch'/5BB had highest cluster numbers. Cluster weight also responded moderately to rootstock (six of nine cultivars), wherein 3309 and 5C produced highest weight in four of six cultivars, while

**Table 4. Clusters/vine of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 92 | 109 b[y] | 117 | 50 | 70 a |
| 3309[z] | 92 | 120 ab | 103 | 54 | 58 ab |
| 5BB | 98 | 128 a | 119 | 51 | 66 ab |
| 5C | 99 | 107 b | 112 | 52 | 57 b |
| SO4 | 95 | 115 ab | 111 | 40 | 59 ab |
| Significance | NS | * | NS | NS | * |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 63 | 94 | 61 a | 74 |
| 3309[z] | 65 | 85 | 57 ab | 82 |
| 5BB | 75 | 83 | 42 b | --- |
| 5C | 67 | 84 | 58 ab | 71 |
| SO4 | 67 | 84 | 56 ab | 82 |
| Significance | NS | NS | * | NS |

[z]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[y]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[x]'Riesling' on 5BB was not commercially available and is hence not included.
[NS],*Nonsignificant or significant at $P \leq 0.5$, respectively.

**Table 5. Cluster weight (g)[z] of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 131.7 a[x] | 75.9 ab | 91.9 | 154.1 ab | 220.6 b |
| 3309[y] | 115.4 ab | 70.9 bc | 89.9 | 162.6 a | 233.1 a |
| 5BB | 111.3 b | 81.7 a | 91.2 | 133.9 b | 231.2 ab |
| 5C | 116.4 ab | 79.6 a | 90.2 | 159.4 a | 266.5 a |
| SO4 | 116.5 ab | 68.4 c | 89.7 | 152.3 ab | 212.0 b |
| Significance | * | *** | NS | * | * |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 130.2 | 104.1 b | 172.3 a | 119.4 |
| 3309[y] | 126.3 | 121.7 a | 187.9 a | 132.6 |
| 5BB | 125.6 | 103.1 b | 135.6 b | --- |
| 5C | 128.7 | 109.9 ab | 185.0 a | 123.7 |
| SO4 | 136.3 | 118.7 a | 172.3 a | 116.8 |
| Significance | NS | *** | * | NS |

[z]Metric conversions: 28.4 g= 1.0 oz.
[y]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]'Riesling' on 5BB was not commercially available and is hence not included.
[NS],*,***Nonsignificant or significant at $P \leq 0.5$ or 0.001, respectively.

vines grafted to 5BB tended to have lowest cluster weight (Table 5). Berries per cluster were influenced by rootstock in five of nine cultivars, and trends in the data were similar to those for cluster weight (Table 6). Highest berry number was found in 3309 and/or 5C in three of five cultivars, while 5BB and/or SO 4 tended to lead to lowest berry number (Table 6). Berry weight was strongly affected by rootstock (seven of nine cultivars; all but 'Riesling' and 'Okanagan Riesling') (Table 7). Trends in the data were not entirely clear; own-rooted vines and those on 5C led to highest berry weight in four of seven and three of seven cultivars, respectively (Table 7). Lowest berry weight was most frequently found in cultivars grafted to 5BB (three of seven instances).

Weight of cane prunings (vine size) was strongly impacted by rootstock; all cultivars except 'Riesling' showed some response (Table 8). Trends in the data suggested that vines grafted to 5BB and/or 3309 were among the lowest vine size ('Chardonnay', 'Gewurztraminer', 'Ortega', 'De Chaunac', 'Marechal Foch', 'Verdelet'), while own-rooted vines (four of eight cultivars) and/or 5C (two additional cultivars) had highest vine size. Own-rooted vines had lowest vine size for 'Okanagan Riesling' and 'Seyval blanc' only (Table 8). Crop loads were low to moderate (5 to 12 kg fruit per kg cane prunings) by usually accepted standards (Bravdo et al., 1984;

**Table 6. Berries/cluster of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 83 | 79 a[y] | 53 | 109 a | 92 b |
| 3309[z] | 75 | 69 b | 51 | 116 a | 98 ab |
| 5BB | 75 | 81 a | 51 | 94 b | 100 ab |
| 5C | 78 | 80 a | 51 | 106 ab | 110 a |
| SO4 | 75 | 63 b | 50 | 104 ab | 89 b |
| Significance | NS | *** | NS | ** | ** |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 96 | 73 b | 81 a | 87 |
| 3309[z] | 89 | 87 a | 95 a | 91 |
| 5BB | 89 | 76 b | 65 b | --- |
| 5C | 92 | 78 b | 94 a | 88 |
| SO4 | 89 | 85 a | 84 a | 82 |
| Significance | NS | *** | ** | NS |

[z]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[y]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[x]'Riesling' on 5BB was not commercially available and is hence not included.
**,***Significant at $P \leq 0.01$, or 0.001, respectively.

**Table 7. Berry weight (g)[z] of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 1.58 a[x] | 0.96 c | 1.75 | 1.41 cd | 2.42 a |
| 3309[y] | 1.55 a | 1.02 ab | 1.72 | 1.39 d | 2.34 ab |
| 5BB | 1.45 b | 1.03 b | 1.76 | 1.43 bc | 2.31 b |
| 5C | 1.52 a | 1.00 bc | 1.76 | 1.49 a | 2.43 a |
| SO4 | 1.57 a | 1.06 a | 1.77 | 1.45 ab | 2.40 ab |
| Significance | *** | *** | NS | *** | ** |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 1.37 c | 1.43 a | 2.16 a | 1.37 |
| 3309[y] | 1.41 bc | 1.40 ab | 2.01 bc | 1.46 |
| 5BB | 1.43 b | 1.36 b | 2.14 a | --- |
| 5C | 1.39 bc | 1.40 ab | 1.97 c | 1.42 |
| SO4 | 1.53 a | 1.40 ab | 2.10 ab | 1.44 |
| Significance | *** | * | ** | NS |

[z]Metric conversions: 28.4 g= 1.0 oz.
[y]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]'Riesling' on 5BB was not commercially available and is hence not included.
NS,*,**,***Nonsignificant or significant at $P \leq 0.5$, 0.01, or 0.001, respectively.

1985) except for 'Ortega', 'Seyval blanc', and 'Verdelet' (Table 9), and were affected by rootstock in six of nine cultivars. Four of the six cultivars grafted to 5BB had highest crop loads, which is consistent with the general trend towards lower vine size and/or higher yields for 5BB. Lowest crop loads were most frequently found in own-rooted vines or those grafted to 5C (four of six cultivars; Table 9).

Rootstock trials in New York (Pool et al., 1992) demonstrated a clear advantage with respect to yield and vine size of 'Riesling' and 'Chardonnay' if *V. riparia* x *V. rupestris* (3309, 101-14) or *V. berlandieri* x *V. riparia* (SO4, 5BB, 5C) rootstocks were used. However, much of this advantage over own-rooted or *V. labrusca*-derived rootstocks was attributed to phylloxera tolerance. On nonphylloxerated sites in California, yields of own rooted 'Chardonnay' and 'Cabernet Sauvignon' vines were equal to those grafted to 3309, 5C, and several other rootstocks (Wolpert 1992). Among 19 rootstocks (plus a own-rooted control) tested in Oregon, no differences were found in 'Pinot noir' yield, but '1103 Paulsen', 'Kober 125AA', and '1616 Couderc' produced the largest vines (McAuley and Vasconcelos, 2000). Own-rooted vines had relatively high cluster weights (fourth among 20 root systems) and berries per cluster (fifth among 20 root systems), but berry weight was 19th of 20 root systems. These authors did not

**Table 8. Weight of cane prunings (kg/vine)[z] of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 1.73 ab[x] | 1.78 b | 1.04 c | 0.27 c | 0.86 a |
| 3309[y] | 1.68 ab | 2.26 a | 1.16 bc | 0.44 b | 0.57 b |
| 5BB | 1.61 b | 1.11 c | 1.72 a | 0.38 bc | 0.62 b |
| 5C | 1.92 a | 1.24 c | 1.24 b | 0.79 a | 0.82 a |
| SO4 | 1.85 ab | 2.27 a | 1.01 c | 0.37 bc | 0.60 b |
| Significance | * | *** | *** | *** | *** |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 1.71 a | 1.96 a | 1.04 a | 1.18 |
| 3309[y] | 1.70 a | 1.11 c | 0.65 c | 1.36 |
| 5BB | 1.32 b | 1.30 c | 0.68 bc | --- |
| 5C | 1.66 a | 1.63 b | 0.63 c | 1.37 |
| SO4 | 1.82 a | 1.75 ab | 0.86 b | 1.29 |
| Significance | *** | *** | *** | NS |

[z]Metric conversions: 1.00 kg= 2.2 lb.
[y]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]'Riesling' on 5BB was not commercially available and is hence not included.
[NS,*,***]Nonsignificant or significant at $P \leq 0.5$ or 0.001, respectively.

**Table 9. Crop load (kg yield/kg cane prunings)[z] of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 9.1 | 5.3 b[x] | 12.9 a | 32.2 a | 23.5 b |
| 3309[y] | 8.5 | 5.1 b | 10.6 bc | 27.4 ab | 25.6 ab |
| 5BB | 7.8 | 9.9 a | 8.1 c | 24.7 ab | 30.9 a |
| 5C | 7.5 | 9.4 a | 9.9 bc | 21.5 b | 25.6 ab |
| SO4 | 8.1 | 5.1 b | 11.7 ab | 25.5 ab | 26.3 ab |
| Significance | NS | *** | ** | * | * |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 5.4 b | 6.6 b | 14.3 | 8.6 |
| 3309 | 5.8 b | 8.7 a | 18.5 | 9.4 |
| 5BB | 7.4 a | 8.5 a | 13.4 | --- |
| 5C | 5.1 b | 6.6 b | 17.1 | 8.2 |
| SO4 | 6.4 ab | 7.5 ab | 16.0 | 8.8 |
| Significance | *** | ** | NS | NS |

[z]Metric conversions: 1.00 kg= 2.2 lb.
[y]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]'Riesling' on 5BB was not commercially available and is hence not included.
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.5$, 0.01, or 0.001, respectively.

speculate whether any of the growth and yield responses were related to degree of phylloxera tolerance.

Fruit composition variables (%SS, TA, pH) were less responsive to rootstock than vine size and yield components. Soluble solids was highest in berries from vines grafted to 5BB in two of four instances, and lowest in own-rooted vines in three of four cultivars (Table 10). Highest TA was found in own-rooted vines of 'Okanagan Riesling' and 'Verdelet', but lowest in own-rooted 'De Chaunac' (Table 11). Own-rooted vines led to highest pH in three of five cultivars, and lowest pH was usually found in combinations involving the *V. berlandieri*-based rootstocks 5BB, 5C, and SO4 (Table 12). This is consistent with Hedberg et al. (1986), Ruhl (1989a, 1989b, 1991, 1992), and Ruhl et al. (1988), among others, who have reported both lower pH and potassium concentration in berries from graft combinations which involved berlandieri-based rootstocks.

Own-rooted 'Riesling' vines in New York trials had lower %SS than those grafted to 3309, 101-14, SO4, 5BB, or 5C (Pool et al., 1992). This response may have been related to low leaf area in own-rooted vines resulting

**Table 10. % Soluble solids of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| Rootstock | De Chaunac | Marechal Foch | Okanagan Riesling | Seyval blanc | Verdelet |
| Own root | 21.9 | 24.2 | 21.8 c[y] | 22.2 c | 19.3 |
| 3309[z] | 21.8 | 24.1 | 22.5 bc | 22.4 bc | 19.9 |
| 5BB | 21.8 | 23.2 | 23.8 a | 22.9 ab | 19.1 |
| 5C | 22.3 | 24.0 | 23.6 ab | 22.8 abc | 19.2 |
| SO4 | 22.3 | 24.0 | 23.3 ab | 23.2 a | 19.8 |
| Significance | NS | NS | ** | *** | NS |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| Rootstock | Chardonnay | Gewurztraminer | Ortega | Riesling[w] |
| Own root | 22.2 b | 21.0 | 19.6 ab | 19.8 |
| 3309[z] | 23.2 a | 20.5 | 19.5 ab | 19.5 |
| 5BB | 22.1 b | 21.1 | 20.1 a | --- |
| 5C | 23.4 a | 21.4 | 19.0 b | 20.2 |
| SO4 | 23.0 a | 21.2 | 19.7 ab | 20.3 |
| Significance | *** | NS | * | NS |

[z]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[y]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[x]'Riesling' on 5BB was not commercially available and is hence not included.
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.5$, 0.01, or 0.001, respectively.

**Table 11. Titratable acidity (g·L$^{-1}$)[z] of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| Rootstock | De Chaunac | Marechal Foch | Okanagan Riesling | Seyval blanc | Verdelet |
| Own root | 13.3 b[x] | 13.5 | 14.2 a | 11.8 | 12.8 a |
| 3309[y] | 14.4 a | 13.5 | 12.9 c | 12.4 | 12.0 b |
| 5BB | 14.0 ab | 13.6 | 13.7 ab | 11.6 | 11.8 b |
| 5C | 13.9 ab | 13.6 | 13.7 ab | 11.9 | 12.2 ab |
| SO4 | 14.1 ab | 14.1 | 13.2 bc | 11.6 | 11.8 b |
| Significance | * | NS | ** | NS | ** |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| Rootstock | Chardonnay | Gewurztraminer | Ortega | Riesling[w] |
| Own root | 12.7 | 10.0 | 6.6 | 13.3 |
| 3309[y] | 12.9 | 9.6 | 6.4 | 12.8 |
| 5BB | 12.6 | 10.0 | 6.4 | --- |
| 5C | 13.4 | 9.7 | 6.7 | 13.2 |
| SO4 | 13.3 | 10.1 | 6.8 | 13.5 |
| Significance | NS | NS | NS | NS |

[z]Metric conversions: 1.0 g·L$^{-1}$= 0.13 oz/gal.
[y]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[x]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[w]'Riesling' on 5BB was not commercially available and is hence not included.
[NS,*,**]Nonsignificant or significant at $P \leq 0.5$, 0.01, respectively.

from phylloxera-induced stress. McAuley and Vasconcelos (2000) found that own-rooted Pinot noir had lowest %SS among 20 root systems, as well as being ranked 19th in TA and 16th in pH. As with their growth and yield data, they did not speculate as to the basis for this response. They noted that rootstocks typical of cool climate regions such as 3309 did not induce early fruit maturity.

Overall, vine size and yield components in the British Columbia trial tended to be more responsive to rootstock than fruit composition variables (Table 13). Also, it appeared that interspecific hybrid cultivars were more responsive than *V. vinifera*, despite their well-known adaptability to both biotic and abiotic factors. This may be due to the lack of significant phylloxera and nematode populations at the chosen site, as well as relatively optimum drainage, fertility, and moisture conditions.

Specifically, own-rooted vines of the following cultivars were associated with: lower %SS ('Chardonnay'; 'Okanagan Riesling'; 'Ortega'; 'Seyval blanc'; 'Verdelet'); higher pH ('Chardonnay'; 'De Chaunac'; Foch; 'Verdelet'); higher TA ('Okanagan Riesling'; 'Ortega'; 'Riesling'; 'Verdelet'); and, largest vine size ('Ortega'; 'Verdelet'). Vines of the following cultivars grafted to 3309 were associated with: lower vine size ('Gewurztraminer'; 'Verdelet'); and lower TA ('Gewurztraminer';

**Table 12. pH of nine grape cultivars as affected by five root systems, Summerland, B.C., 1989–96.**

| | Interspecific hybrids | | | | |
|---|---|---|---|---|---|
| **Rootstock** | **De Chaunac** | **Marechal Foch** | **Okanagan Riesling** | **Seyval blanc** | **Verdelet** |
| Own root | 3.27 a[y] | 3.52 a | 3.19 | 3.25 | 3.19 |
| 3309[z] | 3.18 b | 3.43 b | 3.19 | 3.24 | 3.16 |
| 5BB | 3.17 b | 3.39 c | 3.21 | 3.26 | 3.17 |
| 5C | 3.18 b | 3.43 b | 3.16 | 3.25 | 3.17 |
| SO4 | 3.18 b | 3.38 c | 3.18 | 3.27 | 3.19 |
| Significance | *** | *** | NS | NS | NS |

| | *Vitis vinifera* | | | |
|---|---|---|---|---|
| **Rootstock** | **Chardonnay** | **Gewurztraminer** | **Ortega** | **Riesling[w]** |
| Own root | 3.37 a | 3.43 | 3.44 ab | 3.09 ab |
| 3309[z] | 3.34 ab | 3.48 | 3.41 ab | 3.10 a |
| 5BB | 3.30 b | 3.49 | 3.43 ab | --- |
| 5C | 3.33 ab | 3.48 | 3.38 b | 3.09 ab |
| SO4 | 3.31 b | 3.49 | 3.45 a | 3.05 b |
| Significance | ** | NS | * | ** |

[z]Rootstock abbreviations: 3309: Couderc 3309; 5BB: Kober 5BB; 5C: Teleki 5C; SO4: Selektion Oppenheim 4.
[y]Means followed by different letters are significantly different, $P \leq 0.05$, Duncan's multiple range test.
[x]'Riesling' on Kober 5BB was not commercially available and is hence not included.
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

**Table 13. Summary of significant rootstock effects upon yield components, weight of cane prunings and fruit composition of nine grape cultivars, Summerland, B.C., 1989–96.**

| Cultivar | Yield (kg/vine)[z] | Clusters/ vine | Cluster wt (g)[z] | Berries/ cluster | Berry wt (g)[z] | Wt of cane prunings (kg/vine)[z] | Crop load (kg yield/kg cane prunings)[z] | Soluble solids (%) | Titratable acidity (g·L$^{-1}$)[z] | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| Interspecific hybrids | | | | | | | | | | |
| De Chaunac | | | * | | *** | * | | | * | *** |
| Marechal Foch | * | * | *** | *** | *** | *** | *** | | | *** |
| Seyval blanc | ** | | * | ** | *** | *** | * | *** | | |
| Verdelet | * | * | * | ** | ** | *** | * | | ** | |
| Okanagan Riesling | | | | | | *** | ** | ** | ** | |
| *Vitis vinifera* cultivars | | | | | | | | | | |
| Chardonnay | * | | | | *** | *** | *** | *** | | ** |
| Gewurztraminer | | | *** | *** | * | *** | ** | | | |
| Ortega | * | * | * | ** | ** | *** | | * | | * |
| Riesling | | | | | | | | | | ** |

[z]Metric conversions: 1 t·ha$^{-1}$= 0.45 tons/acre; 28.4 g= 1.0 oz; 1.0 g·L$^{-1}$= 0.13 oz/gal; 1.00 kg= 2.2 lb.
[*,**,***]Significant at $P \leq 0.05$, 0.01, or 0.001, respectively; otherwise nonsignificant.

'Okanagan Riesling'; 'Riesling'), but little else. Other rootstocks did not show any consistent trends (Tables 3 to 12). There were also year-to-year influences that complicated the picture still further.

## Conclusions

Grape rootstocks have had a long history of improving vine performance and fruit composition on phylloxerated and/or nematode-infested soils, mediated through vine size increases. Results from this trial suggest that grape rootstocks may have similar effects on sites with minimal or no biotic stress, perhaps through differential abilities for nutrient uptake and translocation, tolerance to water stress, and/or differing winter hardiness. Genotypic differences between scion cultivars mediated the impact of grape rootstock upon yield, vine size, and fruit composition. This underscores the need for regional rootstock trials.

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# A Profile of Juvenile Offenders in a Vocational Horticulture Curriculum

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**ADDITIONAL INDEX WORDS.** horticultural therapy, youth at risk, human issues in horticulture, juvenile delinquent, probation

**SUMMARY. This study provides a profile of six juvenile offenders' responses to a vocational horticulture curriculum. The results indicate that vocational horticulture curricula may be a tool to strengthen a delinquent individual's bonds with society and, subsequently, evoke changes in attitudes about personal success and perceptions of personal job preparedness. The youths in this study increased their social bonds in all six categories addressed by the pretest and posttests, and were motivated to think more practically about their careers. Due to the limitations on size and scope of the study, it is exploratory in nature and provides ideas for future research and possible assessment methods for further research.**

The average juvenile offender is either incarcerated in a county juvenile hall, thus exposed to severe forms of deviant behavior from peers, or is released to the streets with little, if any, skills to succeed in the community. These youths must be educated in creative ways to meet their unique needs and to help deter unlawful tendencies. To label youths as deviant and incarcerate

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