3, covering the bloom period of 'Anjou' may insure good pollination. An example would be to have *P. calleryana* to cover the early bloom period, 'Bartlett' to cover the main bloom period and 'Bosc' to cover the later part of the bloom period of 'Anjou.'

In 1991 and 1993, there were differences in seed count but a difference in fruit weight was reported only in 1991 (Table 7). Seed count differences are a direct result of the number of ovules fertilized. Since the weight differences only occurred 1 out of 3 years, it may have been by coincidence. There were no differences in firmness, external color, internal color, soluble solids or titratable acidity during the 3 years. As there was no solid evidence from this study supporting the existence of metaxenia, (i.e. effect of the pollen source on quality), in 'Anjou' pear, agreement is more with Westwood (4) than with Nebel (2) or Nyecki (3).

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Influence of Eight Rootstocks on the Performance of 'White Riesling' and 'Cabernet Franc' Over Five Years

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Abstract

'White Riesling' clone Niederhausen 378 and 'Cabernet Franc' were established in 1986 on the following eight rootstocks at Kingsville, OH near Lake Erie: own rooted,3309C, 101-14 Mgt., 5C, 1616E, SO4, 18-815C and 5BB. 'Cabernet Franc' on its own roots had a lower cumulative yield and cluster number than on any other rootstock. Own rooted 'Riesling' also had low yields along with 'Riesling' on 101-14 Mgt., 1616E and 5BB. There was an interaction with yield and cluster number due to the much higher yields on 1616E and 5BB with 'Cabernet Franc' compared to 'Riesling.' 'Riesling' on 3309C, 5C, SO4 18-815C and 5BB had three times the cumulative pruning weight than own rooted vines. 'Cabernet Franc' on SO4 had very low cumulative pruning weights. No interaction between rootstock and cultivar occurred for cluster and fruit quality data. Own rooted vines had small clusters with smaller and fewer berries. Vines on SO4, 5C and 18-815C tended to produce large clusters with more berries. Soluble solids in berries from 101-14 were higher than from berries on 1616E and 5BB. Over five years, juice pH from fruit on 3309C, 5C and SO4 was higher than juice from 1616E. Rootstock had no effect on total acidity. 'Cabernet Franc' had higher pruning weights and yields than 'Riesling,' but did not survive the low winter temperatures as well and had more crown gall.

Introduction

Although most American type grapes are grown commercially on their own roots, *Vitis vinifera* cultivars are commonly grown on rootstocks, due to phylloxera, an insect inadvertently exported to Europe from the United States (8, 13). Since native American species survived in concert with phyl-

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loxera, cuttings were exported to Europe and vinifera cultivars grafted on them. Performance and resistance to phylloxera varied with species and a number of researchers began breeding and selection programs to improve rootstock reliability. Those early studies indicated that some rootstocks also varied in their tolerance to various soil types, nematodes and adaptation to calcareous soil as well as vine vigor, yield and berry quality. A summary taken from the literature of some of these characteristics and the origin of the rootstocks used in this study is presented in Table 1. Most of the rootstocks in this study have been tested in typical vinifera producing areas but have not been widely tested in the Midwest and eastern United States. The rootstock, 18-815C which was obtained from the collection in Vineland, Canada, has not been widely tested but since it performed well in a previous trial in Ohio (3) it was included in this study. Rootstocks selected in this trial were rated to have modest vigor and reasonable tolerance to wet and dry soils.

Since excessive vigor and winter injury are serious problems with vinifera production in Ohio, this trial was established to determine the influence of these eight rootstocks on the performance and berry quality of two vinifera cultivars under Midwest conditions.

Materials and Methods

In the spring of 1986 'Cabernet Franc' and 'White Riesling' clone Niederhausen 378 were planted at the Kingsville Grape Research Branch on the following eight rootstocks: 3309C, 101-14 Mgt., 5C 1616E, SO4, 18-815C, 5BB and own rooted. There were 4 vines of each combination in each replication and the study was established as a randomized block with 2 x 8 factorial arrangement with 6 replications. The vines were spaced 1.0 x 2.7 m and trained as low bilateral cordons with multiple trucks. The vines were pruned annually leaving 35-40 live nodes. The following data was collected yearly on each vine: pruning weight, yield and cluster number. A sample of 100 berries was taken at random over the 4 vines of each rootstock in each replication and the following measured: soluble solids, pH and total acidity (TA). After a low temperature of -22.4°F in January 1994 the number of growing shoots that occurred on wood that would be retained to crop were counted in late May. In November each vine was rated as follows for crown gall (*Agrobacterium tumefaciens*) development: Lower 60 cm of trunk 1 = 1-10%, 2 = 11-30%, 3 = >30% of the trunk covered; above 60 cm on trunk and cordons 0 = no galls present and 1 = galls present.

Results

The interaction between cultivar and rootstock was significant for yield, cluster number, pruning weight and crop load over five years (Table 2). 'Cabernet Franc' on its own roots had lower cumulative yields and cluster numbers than on any other rootstock. Cumulative yield of own rooted 'Riesling' also had low yields along with 101-14 Mgt., 1616E and 5BB. The interaction with yield was due to the much higher yields and cumulative cluster numbers on 1616E and 5BB with 'Cabernet Franc' compared to 'Riesling.' Cumulative cluster number was also much higher with 'Cabernet Franc' compared to 'Riesling.' Cluster number of 'Riesling' vines on 3309C, 101-14 Mgt., 5C, SO4 and 18-815C were higher than own rooted vines.

'Riesling' vines on their own roots had only a third of the pruning weight that occurred when growing on 3309C, 5C, SO4, 18-815C and 5BB (Table 2). 'Cabernet Franc' made very poor growth on SO4 as judged by cane pruning weight while growth on 101-14 Mgt. and 5C was greater than on own rooted vines. Cumulative pruning weights from 'Cabernet Franc' were higher than from 'Riesling' except on SO4.

Table 1. Description and characteristics of eight clonal rootstocks used in this study.*

Rootstock	Cross/ Originator	Relative** vigor	Soil adaptability wet	clay	dry shady	Resistance to phylloxera	nematodes	drought	Tolerance lime %
3309C	Riparia tomentosa x Rupestris/ 1881 Couderc	2	3	2	2	4	1	2	11
101-14 Mgt	Riparia x Rupestris/ 1882 Millardet	2	3	2	1	4	2	1	9
5C	Berlandieri x Riparia/ 1922 Teleki	3	-	3	1	4	4	1	17
1616E	Solonis x Riparia/ 1881 Couderc	3	2	1	2	3	1	5	11
SO4	Berlandieri x Riparia No. 4/ 1886 Teleki	2	3	2	1	4	4	3	17
18-815C	Rupestris x Riparia x Vinifera?/ 1899 Castel	2?	-	-	-	-	-	-	--
5BB	Berlandieri Seedling/ 1886 Teleki	2	3	2	1	4	3	1	20

*Information adapted from the following references (6, 8, 13).
**Vigor: 1 = low to 4 = high; Soil adaptability: 1 = poor to 4 = good; Resistance: 1 = very susceptible to 5 = very resistant.

Bravdo et al. (2) reported that crop load (grape yield to pruning weight ratio) was a better measure than crop level (yield per vine) for evaluating the relationships between cropping and wine quality. 'Riesling' had a higher cumulative crop load than 'Cabernet Franc' for all rootstocks except 5BB where crop load was equal. Differences between cultivars were particularly large for own rooted, 101-14 Mgt. and 5C.

There was no significant interaction between cultivar and rootstock for the various factors of berry quality averaged over five years. 'Cabernet Franc' had larger clusters, berries and numbers of berries per cluster than 'Riesling' (Table 3). 'Cabernet Franc' also had higher soluble solids and pH, but did not differ from 'Riesling' in TA.

Own rooted vines had small clusters with small and fewer berries than clusters on many of the other rootstocks. Vines on SO4, 5C and 18-815C tended to have large clusters with more berries/cluster. Clusters on 101-14 Mgt and 5C had larger average berry weights than on own rooted vines. Soluble solids from berries on 101-14 Mgt were higher than berries on 1616E and 5BB. Juice pH from fruit on 3309C, 5C, and SO4 was higher than fruit on vines grown on 1616E. Rootstock had no influence on TA.

'Riesling' survived the low winter temperature of January 1994 (-22°F) better than 'Cabernet Franc' (Table 4). 'Cabernet Franc' was severely damaged on all rootstocks, but due to heavy snow cover all vines produced new growth from the trunk base (Photo 1). Compared to own rooted vines 'Riesling' on 3309C, 101-14 Mgt and SO4 had better survival. Poorest 'Riesling' survival occurred in own rooted, 1616E and 5BB vines.

There was no interaction between cultivar and rootstock on crown gall development on the trunk following the severe winter temperatures. 'Cabernet Franc' had greater development of crown gall on the lower 60cm of trunk than 'Riesling' (Table 4). Vines on 101-14 Mgt had more crown gall on the upper trunk and cordons than vines on SO4 with no difference among the other rootstocks.

Table 2. Influence of 8 rootstocks on cumulative yield, cluster number/vine, crop load and pruning weight over 5 years of 'White Riesling' and 'Cabernet Franc.'

Rootstock	Cumulative Yield/vine (kg)		Cumulative Cluster number/vine		Cumulative Crop Load		Cumulative Pruning weight/vine (kg)	
	White Riesling	Cabernet Franc	White Riesling	Cabernet Franc	White Riesling	Cabernet Franc	White Riesling	Cabernet Franc
Own	10.6	11.6	231	222	12.8	6.9	0.7	3.3
3309C	16.5	19.2	308	306	9.6	7.2	2.0	3.3
101-14 Mgt	14.6	17.1	317	287	9.5	4.2	1.6	4.8
5C	17.5	19.7	333	305	8.8	4.1	2.2	4.9
1616E	11.8	19.2	220	297	7.2	4.4	1.5	3.7
SO4	18.4	20.4	348	324	8.7	4.9	2.1	1.9
18-815C	16.8	20.4	308	315	10.4	6.6	1.7	4.1
5BB	11.6	19.4	205	311	4.2	4.2	2.4	4.1
	LSD .05 = 3.1		LSD .05 = 62		LSD .05 = 2.0		LSD .05 = 1.0	
Average	14.7b	18.4a	284a	296a	9.1a	5.2b	1.8b	3.8a

Discussion

The lower yields produced on own rooted vines of both cultivars confirm work in other conventional vinifera production areas which are infested with phylloxera (3, 4, 10, 19). Howell (8) indicates that phylloxera is endemic in soils east of the Rocky Mountains where the parents of the phylloxera-resistant rootstocks were found. Whiting et al. (19) found that yield of own rooted 'Muscadelle' vines were similar to the highest yielding rootstock (ARG No. 1) during 4 years prior to inoculation with phylloxera, but was much lower than ARG No. 1 following inoculation. It is likely that the lower yields and reduced growth on own

Table 3. Influence of eight rootstocks on cluster and berry size and fruit quality of 'White Riesling' and 'Cabernet Franc' over 5 seasons.

Cultivar/Rootstock	Cluster weight (g)	Berry weight (g)	Berries/cluster	Berry Quality: Soluble solids %	Berry Quality: pH	Berry Quality: Total acidity
White Riesling	54.4b[1]	1.23b	43.3b	16.5b	3.04b	.92
Cabernet Franc	65.2a	1.38a	46.5a	18.3a	3.24a	.90
Rootstock						
Own	50.9d	1.23b	40.6c	17.2abc	3.17ab	.92
3309C	60.2abc	1.33ab	45.1bc	17.9ab	3.21a	.92
101-14 Mgt	56.8cd	1.34a	43.2bc	18.1a	3.19ab	.88
5C	63.7ab	1.36a	46.8ab	17.9abc	3.22a	.95
1616E	58.0bc	1.29ab	42.0bc	16.6c	2.98b	.87
SO4	65.4a	1.33ab	49.5a	17.5abc	3.23a	.94
18-815C	64.1ab	1.29ab	49.8a	17.5abc	3.18ab	.95
5BB	59.2abc	1.29ab	42.3bc	16.7bc	3.01ab	.89
F Significance						
Cultivar (CV)	***	**	*	***	***	NS
Rootstock (RS)	***	*	**	*	*	NS
CV x RS	NS	NS	NS	NS	NS	NS

[1]NS, *, **, and *** indicate not significant and significant at the 0.05, 0.01 and 0.001 levels of probability, respectively. Mean separation within columns by using Duncan's multiple range test at 5%.

Table 4. Influence of 8 rootstocks on bud survival and crown gall formation in 'White Riesling' and 'Cabernet Franc' following a low (−22°F) January 1994 temperature.

Rootstock	Surviving buds/vine* White Riesling	Surviving buds/vine* Cabernet Franc	Crown gall (60 cm)** Lower trunk	Crown gall (60 cm)** Above trunk
Own	10.4	1.6	1.31	.25
3309C	19.9	3.5	1.42	.17
101-14 Mgt	21.9	.4	1.52	.42
5C	14.1	5.8	1.60	.17
1616E	8.8	2.5	1.63	.27
SO4	17.5	1.4	1.79	.15
18-815C	16.0	1.8	1.26	.28
5BB	7.0	4.3	1.68	.25
	LSD .05 = 7.2		.64	.22

*All buds showing green in May 1994 were counted.
**Lower 60 cm rating: 1 = 1-10%, 2 = 11-30%, 3 = >30% trunk covered. Above 60 cm: 0 = no galls present and 1 = galls present, November 1994.

rooted vines in this study were due to damage by phylloxera, but this was not verified by root excavations.

The following rootstocks produced relatively vigorous (cumulative pruning weight) vines with both cultivars: 5C and 5BB. SO4 resulted in larger vine size with 'Riesling,' but very small vines with 'Cabernet Franc.' Rootstock 101-14 Mgt, resulted in modest vigor with 'Riesling,' but high vigor with 'Cabernet Franc.' Previous reports (6, 8, 13) report that 101-14 Mgt results in moderate vigor, but Pool et al. (15) found that 101-14 Mgt, 5BB and SO4 produced the largest 'White Riesling' vines and 1616E and 3309C resulted in moderate vigor in a New York study. In the present trial, 3309C and 1616E had moderate vigor with both cultivars.

The following rootstocks had relatively high yields with both 'Riesling' and 'Cabernet Franc': 3309C, 5C, SO4, and 18815C. In a previous Ohio study (4) over 6 years, 3309C and 18-815C produced relatively high yields with all 5 American and French hybrid cultivars, while SO4 resulted in high yields with 'Catawba.' In France a long-term study (8) with 'Merlot' in a non-phylloxera site indicated that vines on SO4 and 3309C were both more productive than own rooted vines, and SO4 had higher production than 3309C. SO4 consistently increased the cluster size of 'Merlot' compared to other rootstocks and this same trend was apparent in the present trial. In Australia, vines on SO4 had higher yields than several other rootstocks with 'Brown Muscat' and 'Cabernet Sauvignon' in sites with infestations of phylloxera and nematodes, respectively (19).

In apple rootstock trials one of the most meaningful measurements is "yield efficiency" as measured by yield divided by trunk cross sectional area (7, 11, 12). "Crop load" attempts to measure a similar efficiency. The inefficiency of 'Riesling' on 5BB stands out as well as the relative efficiency of own rooted vines. Vines on 3309C and 18-815C had relatively high yields and modest pruning weights with both cultivars resulting in relatively high crop loads, although not significantly better than several other rootstocks.

Fruit composition and quality can be influenced by rootstock (14, 18, 19). Results of this trial averaged over 5 years show that soluble solids in juice from vines on 101-14 Mgt were higher than 1616E and 5BB. Juice pH from fruit on 3309C, 5C, and SO4 was higher than fruit from vines on 1616E. Rootstocks had no influence on TA and there was no interaction between cultivar and rootstock. Whiting (18) compared the effects of 13 rootstocks on the quality of 'Chardonnay' and found generally lower soluble solids on own rooted vines, but little consistent influence of the other rootstocks (including SO4 and 3309C) on either soluble solids or TA. 'Merlot' on SO4 had the lowest sugar and highest acidity when compared on Riparia and 3309C (4). Rootstocks had no effect on the amino acids and other nitrogen compounds, as well as a complex of acids measured in musts of

Figure 1. 'Cabernet Franc' on 18-815C with regrowth from lower trunk following -22°F in January 1994.

'Merlot' (1). Interestingly, 'Merlot' on its own roots had lower yields than on Riparia or 3309C and also had lower sugar and higher acidity in musts (4).

Following record setting low temperatures in January 1994, grapevines in Ohio experienced significant winter injury (5). Vinifera cultivars suffered the most extensive injury with 'Riesling' being the hardiest of the vinifera surveyed. 'Riesling' vines on 3309C, 101-14 Mgt, SO4 and 18-815C had less injury than vines on 5BB, 1616E or own rooted. Pool (14) measured rootstock hardiness during fall acclimation in New York and found that 3309C attains cold hardiness early in the fall and has good ability to harden further in winter. This study also showed that 5BB had delayed hardiness acquisition and lacked deep winter hardiness. Miller et al. (9) in controlled freezing tests found that canes of 3309C were consistently hardier than 5BB with SO4 being intermediate. Bud survival of 'Riesling' in the present study followed this same pattern. In controlled freezing tests with 'White Riesling,' Miller et al. (10) found that 'White Riesling' on 3309C had hardier canes than when it was on 5BB. These studies support the field observations in this trial.

One of the likely consequences of winter damage to trunks is the development of crown gall. In this study, rootstock had no influence on crown gall formation on the lower 60 cm of trunk. On the upper portion of the vines on 101-14 Mgt had more gall development than vines on SO4. Stover (17) inoculated rootstocks directly and reported that 3309C and 1616C had less gall development than 101-14 Mgt and 5BB. Southey (16) gave the following degrees of resistance to actual rootstock infection by crown gall in South Africa: resistant-3309C, 101-14 Mgt, 5BB; moderately susceptible-SO4. There appear to be differences between the results of the inoculated trial on rootstocks and occurrence in the field of susceptibility of cultivars on some of those rootstocks. These differences could be due to the fact that vines in our study were naturally infected and had sustained rather severe winter injury that resulted in crown gall development.

Injury on these vines was severe enough that all produced new growth from the lower trunk and these canes will be used as replacement trunks to retrain the vines. With this new beginning, it is appropriate to summarize the 5 years of results. Rootstocks 3309C, 5C and 18-815C performed well with both cultivars, and SO4 was productive with 'Riesling' but not with 'Cabernet Franc.' Own rooted vines of both cultivars made poor growth and had low yields and should be avoided. The consistent effect over 5 years of rootstocks on juice parameters will be extended to the potential influence on wine quality in the future.

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