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Viticultural characteristics of VR hybrid rootstocks in a vineyard site infected with grapevine fanleaf virus

by

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S u m m a r y : Two *Vitis vinifera* x *Muscadinia rotundifolia* hybrids (VR hybrids), O39-16 and O43-43, were tested for resistance to fanleaf degeneration over a 12-year period in the Napa Valley, California. Data comparing the vegetative growth and crop yields of these two VR hybrids to the fanleaf susceptible rootstocks AXR#1, Harmony, St. George and L171-6 (a LIDER selection) are presented for the last 8 years of the trial. Certified virus-tested Cabernet Sauvignon was used as the scion variety. Both VR hybrids became highly infected with grapevine fanleaf virus (GFLV) over the course of the trial, but neither showed the reduced crop yields associated with fanleaf degeneration. Information on the resistance of these two rootstocks to other soil-borne pests is also presented. Preliminary studies indicate that O43-43 may be susceptible to phylloxera, therefore, in sites infected with fanleaf degeneration and with potential for infestation with phylloxera, O39-16 is the only suitable choice.

K e y w o r d s : Vitis, rootstocks, fanleaf degeneration, GFLV, VR hybrid.

Introduction

The search for a fanleaf resistant rootstock at the University of California, Davis began with a survey of *Vitis* species for resistance to *X. index* (KUNDE *et al.* 1968). L. A. LIDER made crosses with the most resistant of these species and in 1979 seedlings from these crosses were planted in a field infested with the nematode-virus complex. This field trial was initially conducted by LIDER and GOHEEN who first reported on it in 1986. They patented two rootstocks from this trial in 1988, O39-16 and O43-43, both *V. vinifera* x *Muscadinia rotundifolia* SMALL (VR) hybrids; GFLV was not detected in O39-16 over a 9-year period. (LIDER *et al.* 1988 a + b, WALKER *et al.* 1991). However, by the time the trial was removed in January of 1992 high levels of GFLV were been found in scions grafted on both these resistant rootstocks. Despite the presence of GFLV, fruit yields of Cabernet Sauvignon grafted onto O39-16 and O43-43 appeared unaffected. We report here on the viticultural characteristics of O39-16 and O43-43 in comparison to the fanleaf susceptible rootstocks AXR#1, Harmony and St. George, during 12 years growth in a fanleaf-infested site.

Materials and methods

The screening trial was located near Rutherford in the Napa Valley, California. The previous vineyard was Cabernet Sauvignon planted on St. George rootstock and appeared to be uniformly infected with fanleaf and high populations of *X. index* were detected (A. C. GOHEEN, personal communication). The site was cleared of vines in the fall of 1978 and experimental rootstocks were replanted in June of 1979. No fumigants or nematicides were applied and there were no efforts to remove roots of the old vines. Vines were field budded so that the graft unions were at least 10 cm above the vineyard floor. They were head-trained and spur pruned, until the 1990 dormant season when the cooperating vineyard owner converted the vineyard to a 2-wire trellis with a bilateral cordon.

The plot was planted with 55 LIDER selections from the above-mentioned seedling populations that had been screened in pots for resistance to *X. index* (L. A. LIDER, unpublished data). The majority of these seedlings were chosen because they appeared to resist *X. index* feeding, while others were selected as susceptible controls. One of these LIDER seedlings, L171-6, is discussed in this study. Nine VR hybrids (PATEL and OLMO 1955) were also included for testing as resistant rootstocks. Two of these VR hybrids, O39-16 and O43-43, are reported on here. Three fanleaf susceptible controls were included for production comparisons, AXR#1, St. George and Harmony. The parentage and the number of replications that survived establishment of these rootstocks is shown in Tab. 1. An additional replication of AXR#1, St. George and Harmony was

T a b l e 1

Parentage and the number of replications tested of experimental rootstocks planted in a fanleaf degeneration site in the Napa Valley, California.

Rootstock	Parentage	Replicates Tested
O39-16	*vinifera* Almeria x *rotundifolia* male #1	4
O43-43	*vinifera* Hunisa x *rotundifolia* male #1	3
171-6	*vinifera* French Colombard x *rufotomentosa*	4
AXR#1	*vinifera* Aramon x *rupestris* Ganzin	4
St. George	Seedling selection of *rupestris*	5
Harmony	OP 1613C seedling x OP Dog Ridge seedling	5

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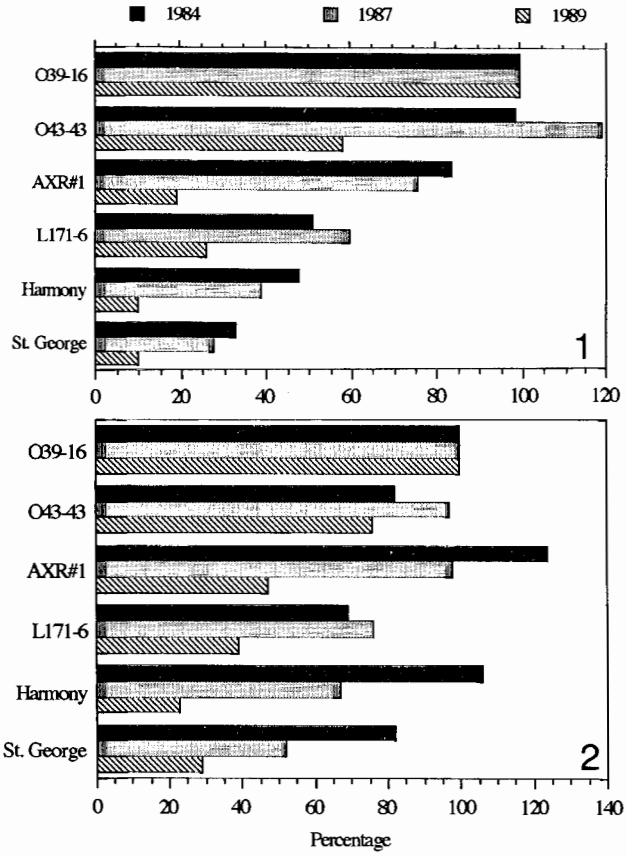
removed after data collection in 1990 to allow for vineyard conversion.

The soil type varied from a sandy to gravely clay loam of 1 to 1.5 m in depth overlaying a thick dark clay layer. Backhoe excavations revealed that some roots were able to penetrate into this clay layer. Once the vines were established they did not receive supplemental irrigation; the mean yearly rainfall for the Rutherford area is about 750 mm. The plot was laid out in a randomized complete block design with 5 single-vine replicates of each selection. The trial was concluded in January 1992.

The following samples were taken each year on an individual vine basis: pruning weights (kg), fruit yields (kg), cluster numbers, cluster weights (g), and berry weights (g). 100-berry samples were taken from each replicate and titratable acidity (g/l), °Brix and pH of the juice were determined. Data was first taken in September of 1984 and continued until December of 1991. Data were subjected to analysis of variance and means were separated by Duncan's multiple range test.

Results

The effect of fanleaf degeneration was apparent in fruit yields (Fig. 1). Both VR hybrids maintained normal yields throughout the trial. Yields on the susceptible rootstocks Harmony and St. George dropped rapidly, and were only 10 % of normal by 1989. Yields on AXR#1 were not greatly depressed until later years, supporting the observation of A. C. GOHEEN (personal communication) that it is more tolerant of fanleaf infection than the other susceptible rootstocks.



Figs. 1 and 2: Yield and cluster weight as a % of 039-16 rootstock.

Cluster numbers on the various rootstocks were not greatly affected by fanleaf until 1989 (Fig. 2). There were differences among the rootstocks in 1984 and 1987, but they were not significant (Tab. 2). Cluster numbers were reduced in 1989 on the susceptible rootstocks, but these measures were again variable in 1990. The vines were converted to cordons in 1990 and this caused unusually high numbers of clusters in 1991 (Tab. 2). The overall tendency of fanleaf was toward a reduction in cluster numbers on susceptible rootstocks.

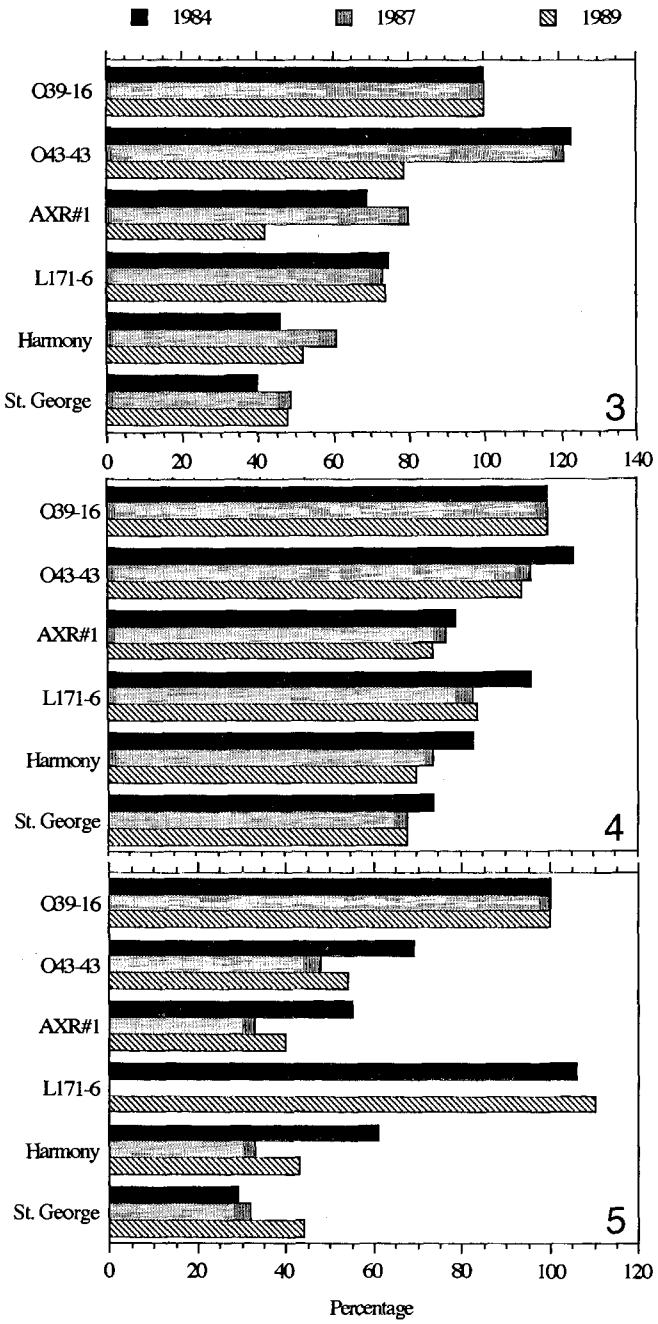
While cluster numbers on infected susceptible rootstocks decreased over time (Fig. 2), cluster weights did

Table 2

Vegetative growth and crop yield components collected over an 8-year period for experimental rootstocks in a trial assessing resistance to fanleaf degeneration in the Napa Valley, California. Data represent means of varying numbers of replicates and are followed by Duncan's multiple range separations at the 5 % level (– – weights not taken).

	Rootstock	Pruning weight kg	Yield kg	Cluster weight g	Cluster number	Berry weight g
1984	039-16	4.73a	10.4a	125ab	83NS	1.03a
	043-43	3.27ab	10.3a	151a	68	1.09a
	AXR#1	2.61ab	8.71ab	85cd	103	0.81b
	L171-6	5.01a	5.32bc	93bc	57	0.99a
	Harmony	2.86ab	5.01c	57d	88	0.85ab
	St. George	1.37b	3.42c	50d	68	0.76b
1985	039-16	4.38ab	12.23a	93a	134a	1.07ab
	043-43	3.59abc	11.11a	120a	95bc	1.12a
	AXR#1	3.00bc	6.67b	57bc	113ab	0.85cd
	L171-6	5.49a	6.95b	68b	101abc	0.93bc
	Harmony	2.12c	3.70bc	52bc	83bc	0.82cd
	St. George	1.35c	2.24c	28c	70c	0.76d
1986	039-16	6.23ab	16.02a	110a	149NS	1.22a
	043-43	3.38bc	12.82ab	132a	98	1.29a
	AXR#1	3.02c	6.73c	51bc	125	0.89c
	L171-6	6.58a	8.02bc	71b	109	1.06b
	Harmony	3.04c	4.26c	39bc	108	0.90c
	St. George	2.26c	3.20c	33c	98	0.89c
1987	039-16	6.67NS	9.39ab	85ab	113NS	1.28a
	043-43	3.74	11.17a	103a	109	1.23ab
	AXR#1	2.55	7.15abc	68bc	111	0.98cd
	L171-6	– –	5.67bcd	62bc	86	1.06bc
	Harmony	2.51	3.62cd	52bc	76	0.95cd
	St. George	2.46	2.66d	42c	59	0.87d
1988	039-16	– –	8.55NS	64NS	130a	1.07NS
	043-43	– –	5.46	45	108ab	0.98
	AXR#1	– –	1.86	27	64bc	0.72
	L171-6	– –	3.77	50	73abc	0.89
	Harmony	– –	1.32	36	37c	0.76
	St. George	– –	1.14	27	42c	0.70
1989	039-16	5.77a	11.36a	86a	129a	1.21a
	043-43	3.12b	6.59b	68ab	98ab	1.14ab
	AXR#1	2.30bc	2.18bc	36c	60bc	0.90c
	L171-6	6.36a	3.00bc	64ab	50bc	1.02b
	Harmony	2.48bc	1.13c	45bc	29c	0.85c
	St. George	2.55bc	1.16c	41c	37c	0.82c
1990	039-16	7.23NS	5.18ab	72a	71ab	1.10NS
	043-43	5.59	6.18a	72a	87a	1.04
	AXR#1	5.59	2.27c	47abc	42bc	0.94
	L171-6	9.96	2.64c	47abc	51bc	0.93
	Harmony	5.18	0.73c	25c	28c	0.87
	St. George	3.59	1.50c	33bc	46bc	0.85
1991	039-16	8.32NS	28.36a	145a	194NS	1.33a
	043-43	4.39	18.92b	139a	139	1.32a
	AXR#1	5.44	9.79bc	85bc	122	0.96c
	L171-6	8.98	13.86bc	109ab	123	1.13b
	Harmony	5.78	8.97c	63c	141	0.95c
	St. George	3.05	9.15c	67c	140	0.96c

not (Fig. 3). There was an initial rapid effect of virus infection on cluster weights, but as cluster numbers later declined, weights remained stable. This was likely due to the fact that assimilates were distributed to fewer clusters. Cluster weights were calculated by dividing the yield of each replicate by that replicate's number of clusters and averaging these values. These values are listed in Tab. 2 and were used for percentage calculations in Fig. 4.



Figs. 3-5: Cluster weight, berry weight, and pruning weight as % of 039-16 rootstock.

Berry weights, as percentage comparisons with O39-16, did not decline over time (Fig. 4). These values may be misleading, however, since they were calculated from the 100-berry samples that were used for juice quality parameters. It is difficult to berry sample fanleaf-infected clusters in an unbiased manner. Many berries are never set, some "shatter" very early, others are abnormally small seedless "shot" berries, while others appear normal but may only be that way because of redirected assimilates. If berry sampling of fanleaf infected clusters was done in a truly representative fashion the results could possibly be quite different.

Fanleaf infection had a depressing effect on vine growth as measured by pruning weights (Fig. 5). Vine growth on St. George was reduced the most when compared with that on O39-16. Neither O39-6 or O43-43 seemed to support a damaging level of *X. index* feeding, but vegetative growth on O43-43 was always less than that on O39-16 (Tab. 2). L171-6 was consistently the rootstock that induced the greatest vegetative growth in the trial, even when infected with fanleaf.

Differences in fruit maturity parameters, percent titratable acidity, °Brix, and pH, were not significant and are presented as means of the 8 years of sampling (Tab. 3).

Table 3

Berry juice maturity parameters of Cabernet Sauvignon grafted onto experimental rootstocks in a fanleaf degeneration resistance trial in the Napa Valley, California. The values represent 8-year means of data.

Rootstock	°Brix	Titratable acidity (g/L)	pH
O39-16	22.4	8.0	3.63
O43-43	22.4	7.5	3.56
L171-6	22.2	7.9	3.70
AXR#1	22.4	7.5	3.54
St. George	21.6	7.7	3.53
Harmony	22.6	7.1	3.58

This trial was designed to screen large numbers of seedlings for resistance and detectable differences in fruit quality were not expected. However, trials with greater numbers of vines have been established throughout California to determine whether O39-16 and O43-43 have an effect on fruit quality. As mentioned above, the berry sampling procedure may be biased since it poorly represents fanleaf-infected clusters; this likely affected our juice maturity measurements.

Discussion

The ability of O39-16 and O43-43 to resist infection by GFLV, relative to the other rootstocks tested in this trial, is discussed but not presented in this paper. However, the level of fanleaf infection in scions on these rootstocks is important to this discussion. When data were first taken in 1984, GFLV was detected by ELISA (enzyme-linked immunosorbent assay) in all the replicates of St. George, 3 of 5 replicates of Harmony, 2 of 4 replicates of AXR#1, 2 of 4 replicates of L171-6 and 1 of 3 replicates of O43-43. By 1987, GFLV was detected in scions on all of the rootstock replicates with the exception of O39-16. GFLV

was first detected in O39-16 in 1989 (1 of 4 replicates infected) and by 1991 all of its replicates had GFLV.

Fanleaf effects on crop yields: Cabernet Sauvignon grafted onto O39-16 and O43-43 maintained normal crop yields during the 12 years they were planted in this trial. AXR#1 performed relatively well for about 9 years and then declined rapidly. The degenerative effect of GFLV infection on yield was most evident on St. George and Harmony whose yields decreased to about 10 % of O39-16 over the course of the trial (Fig. 1).

L171-6 yielded poorly when compared to the VR hybrids, yet it is reported to resist *X. index* feeding (MCKENRY and KRETSCH 1989). Unpublished data of LIDER and studies with other seedlings from the L171 population (HARRIS 1983), also reported strong resistance to *X. index* feeding in this population. The strong growth of Cabernet Sauvignon on L171-6 in comparison to the other susceptible rootstocks also suggests that it is unaffected by dagger nematode feeding, and that its poor yield is a virus effect not due to the nematode. The VR hybrids are also resistant to *X. index* feeding, but all three of these rootstocks allow the nematode to vector GFLV, since the virus was detected in scions grafted onto them. The unique attribute of the VR hybrids is their ability to maintain high crop levels in the presence of high GFLV titers.

L171-6 derives its nematode resistance from *V. rufotomentosa* SMALL (Tab. 1), the other half of the cross is *V. vinifera* French Colombard. The two VR hybrids have the same *M. rotundifolia* male parent, but different *V. vinifera* female parents (Almeria in O39-16 and Hunisa in O43-43). Almeria and Hunisa are Middle Eastern cultivars, whereas French Colombard is of European origin. Because GFLV is thought to have coevolved with *V. vinifera* in the Middle East, cultivars from this region may possess GFLV resistance or tolerance. In addition, the nature and quantity of cytokinins produced by roots with *M. rotundifolia* parentage may be quite different from *Vitis* species and might allow compensation for the debilitating effects of GFLV on berry development. Cytokinins originate primarily in the root system and affect flowering and fruit set.

The crop year 1989 was chosen for relative comparisons (Figs 1-5) because 1990 and 1991 were atypical. Crop yields on O39-16 were reduced in 1990 following an abnormally cold winter that caused some bud death and cane die-back in northern California. This effect was not seen as commonly on O43-43 or the other rootstocks in the trial. Cabernet Sauvignon grafted on O39-16 typically produces abundant shoot growth that has a tendency to grow until frost, resulting in poor bud and wood maturity. Consequently, comparisons of yields as a percentage of those on O39-16 (Tab. 2) were misleading for 1990. Yields in 1991 were greater than normal because the vines were converted from head-training to bilateral cordons. Long canes were left to allow the conversion, which resulted in far more clusters the following year (Tab. 2). However the relative differences in yield were similar to previous years.

Fanleaf is described as a degenerative disease (MARTELLI and SAVINO 1988). It had a degenerative effect on fruit yields in this study, although one can question which component of fruit yield (cluster weights, cluster numbers or berry weights) was most affected by fanleaf infection. Fanleaf definitely reduced cluster weights of scions on susceptible rootstocks, however, that effect did not appear to intensify over time. Cluster weights on the highly susceptible rootstocks, St. George and Harmony, were reduced in comparison to the VR hybrids the first year data were taken (5 years after planting). The cluster weights on susceptible and resistant rootstocks remained relatively constant over time even in the presence of intensifying fanleaf infection (Fig. 3). In most years of the study, cluster weights on the susceptible rootstocks were not statistically separable (Tab. 2). Cluster weights were calculated by dividing total yields by cluster numbers. Cluster numbers may have been underestimated and therefore cluster weights might have been abnormally high.

The number of clusters produced on the susceptible rootstocks did decline over time (Tab. 2), suggesting that the degenerative effect on yields was due more to cluster production than to set. However, it was difficult to assess the true number of clusters on a fanleaf-infected grapevine. In some cases clusters are produced, but pollination and set are incomplete resulting in a withered rachis that falls from the vine. These withered clusters were not counted. Including these clusters in the calculations of average cluster weights would reduce that value. Data on cluster numbers should be taken at bloom and at harvest, then errors in cluster number calculations could be resolved.

Berry weights were also reduced in any given year when comparisons were made between the susceptible and resistant rootstocks (Fig. 4). However, berry weights did not degenerate over time. Berry weight measurements, as mentioned in the Results, were calculated from 100-berry samples, but this data was biased because of the need to have a berry sample with enough juice for juice quality measurements. If all berries were counted, shot and seeded, a degenerative trend in average berry size would likely be seen.

Better data collection could also improve our understanding of fanleaf's direct effect on crop yields. Data should be taken on the number of flowers in a cluster at bloom to determine if fanleaf's effect on berry number is due to flower formation or successful pollination of the flowers. Studies on fanleaf's effect on pollen viability and germination success are also needed.

Fanleaf effects on pruning weights: Pruning weights on the six rootstocks were variable and produced nonsignificant responses in a number of years, however differences were noted. Comparisons of pruning weights among the rootstocks show that O39-16 produced greater vegetative growth than did O43-43. St. George is a rootstock that normally induces high levels of vegetative growth, however it produced the lowest pruning weights in every year except 1989. This rootstock is known to be an excellent host for *X. index* (KUNDE *et al.* 1968), as evidenced by these low pruning weights. By contrast, L171-6, a rootstock with known *X. index* resistance (MCKERNY and KRETSCH 1989), maintained its ability to induce vegetative

growth while infected and produced the greatest pruning weights in all years. These pruning weights were probably increased by redirected assimilates that were not used in maturing fruit, since fruit yields on L171-6 were low. These results suggest that dagger nematode feeding may have a more direct effect on vegetative growth and that GFLV's effect is more closely related to fruit set.

Pruning weights remained relatively constant over time indicating that vine pruning was balanced and that alternate bearing due to overcropping/undercropping cycles was not a problem.

Resistance to other pests: The Rutherford area is also infested with phylloxera. In vineyards near the test site, own-rooted vines and those grafted to AXR#1 were declining. Phylloxera was not detected on either O39-16 or O43-43 in this trial. Phylloxera have been observed on the roots of O43-43 in a commercial planting (unpublished). The first author has screened both rootstocks for phylloxera resistance in the greenhouse (unpublished data). These tests involved growing potted vines in known phylloxerated soil and observing insect development and plant response. The results showed that O43-43 supported phylloxera colony development, but that it did not show decline due to phylloxera feeding. No phylloxera could be found on O39-16. GRANETT *et al.* (1987) also tested these two rootstocks in a laboratory bioassay which assesses phylloxera developmental rates and survival. They also found that O43-43 supported phylloxera and that O39-16 did not. Therefore, in sites infected with fanleaf degeneration and with potential for infestation with phylloxera, O39-16 is the only appropriate choice.

O39-16 and O43-43 have also been screened for resistance against the root knot nematode *Meloidogyne incognita* (KOFOID & WHITE) CHITWOOD (unpublished data from the first author). In these tests, potted vines were inoculated with 1000 nematodes. Reproduction and root damage were assessed after 120 days. O43-43 did not support nematode reproduction and had high root weights (>20 g). O39-16 supported nematode reproduction (343 larvae were counted), although root weights were high. MCKERNY (1991) has also tested O39-16 in field microplots and found it hosts *Meloidogyne* GOELDI spp., particularly *M. javanica* (TREUB) CHITWOOD, and the endoparasitic nematode, *Pratylenchus vulnus* ALLEN & JENZEN.

Past studies by LIDER (unpublished data) show that O39-16 and O43-43 do not support *X. index* reproduction. MCKERNY (1991) found O39-16 to be highly resistant to *X. index*, but he also found it to be a good host for a *X. americanum* COBB population, which casts doubt on the breadth of its ectoparasitic nematode resistance. STAUDT and KASSEMEYER (1990) reported that O39-16 resists transmission of GFLV by *X. index*, but they found that O43-43 allowed GFLV transmission and reported a low level of root damage due to nematode feeding. They did not assess nematode reproduction.

O39-16 and O43-43 acquired GFLV more slowly than other rootstocks in this trial, and even after they became infected crop yields were not depressed. Foliar symptoms, vein-banding, yellow mosaic and fanleaf deformation were present and ELISA readings of scions grafted on these two rootstocks indicated that virus levels were as high as those in susceptible rootstocks. However, the normal fruit production of Cabernet Sauvignon grafted on these two rootstocks indicates that they seem to be able to tolerate the effects of fanleaf infection. Because both rootstocks allow transmission of GFLV from *X. index* to the scion, the search for a fanleaf resistant rootstock must continue. O39-16 and O43-43 are sterile F1 hybrids due to their *Vitis* x *Muscadinia* parentage and the resulting incomplete chromosome pairing (PATEL and OLMO 1955). Consequently, neither can be used as a parent in crosses to improve nematode resistance or to add GFLV resistance. The screening of *Vitis* species for resistance to *X. index* continues, as does the study of GFLV resistance in the hope of combining these traits for optimal fanleaf resistance.

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