PROGRESS REPORT: JANUARY 2001:
DEVELOPMENT OF GRAPE ROOTSTOCKS WITH MULTIPLE NEMATODE RESISTANCE

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ABSTRACT

Rootstocks currently available for nematode resistance have either inappropriate horticultural characteristics (such as the inducement of excessive vigor in scions leading to poor production and quality) or they have insufficient resistance against aggressive nematode strains and species. Several species of plant-feeding nematodes are present in most vineyards, however few rootstocks have resistance to more than one species.

Sources of resistance to root-knot and dagger nematodes have been detected in several *Vitis* species. Crosses made among these species in 1989, 1993 and 1994 were screened first for rooting characteristics and then sequentially against three nematode species: the root knot nematode (*Meloidogyne incognita* race 3), a strain of root-knot nematode that overcomes the resistance of Harmony rootstock (*Meloidogyne arenaria*), and the dagger nematode (*Xiphinema index*).

We have selected several candidate rootstocks with strong resistance to the individual nematode species, and some with broad resistance to two or more of the nematode species. Candidate selections will progress to field trials for testing of resistance durability and horticultural characteristics in the coming year. Screening of candidate selections against other nematode species, and against combinations of nematode species, will proceed in greenhouse trials.

Rootstock candidates evaluated in these studies are selected from Dr. Walker's rootstock breeding program. This report adresses the nematode screening, not the breeding and horticultural components of that program.

OBJECTIVES

1 To accelerate the development of grape rootstocks with resistance to a broad range of nematodes species and aggressive strains.
2 To evaluate advanced selections from the grape rootstock-breeding program for resistance to a broad range of nematode species and aggressive strains.
3 To provide the grape rootstock-breeding program with data on nematode resistance enabling better crosses.

PROCEDURES Walker made crosses of *Vitis rupestris* x *Muscadinia rotundifolia* in 1989. During 1993 and 1994, he made crosses between species with very high levels of resistance to both the root-knot (*Meloidogyne* spp.) and dagger (*Xiphinema index*) nematodes (*V. arizonica, V. candicans, V. champinii,* and *V. rufotomentosa*) and readily-propagating species (*V. riparia* and *V. rupestris*). The seedlings were established in the field. Dormant cuttings from the vines that resulted from the seedlings were callused in moist peat moss at about 80°F, after a two month cold treatment. Rooting evaluations were done after 21 days with St. George, 420A and 110R used as standards. Selections in which at least 90% of the cuttings rooted were advanced for nematode testing. The rooting evaluations resulted in a group of 33 selections from the 1993 populations, two groups of 38 and 17 from the 1994 populations, and a group of 50 selections from the 1989 populations. We have made significant progress in all three objectives of the research project during the funding period and have provided the Grape Rootstock Breeding Program with considerable information on the resistance and suceptibility of selections to nematode species and aggressive strains.

Cuttings were rooted and five replicates of each selection were inoculated with 1,000 root-knot nematode juveniles each. Six weeks after inoculation the plants were scored for nematode reproduction. The number of nematode egg masses visible after staining (one hour in 0.25g/L eosin-Y) was used as a measure of resistance. Resistance screening for the dagger nematode was conducted by inoculating five replications of each selection with 300 dagger nematode individuals. After three months, root tip galling was assessed as a measure of resistance.

Our basic criteria for graduation of the selections to the next level of screening are absence of nematode reproduction and absence of obvious feeding damage or symptoms. For root-knot nematodes, the absence of galls and egg masses is a necessary indicator of acceptable resistance. The same measures are also applied to dagger nematode (root tip galls). If any one of the five replications exhibits symptoms or egg masses, that selection is considered not to be resistant. The selections resistant to root knot nematode (*Meloidogyne incognita* race 3) are now being screened against *M. arenaria* strains that are aggressive on Harmony rootstock.

RESULTS We reported last year that 45 selections from crosses made in 1989 (*Vitis rupestris x Muscadinia rotundifolia*) and previously evaluated as resistant to dagger nematode, were screened against root-knot nematode. Of the dagger-nematode-resistant selections tested, 23 were resistant to root-knot nematode (data shown last year). Some of these selections did not propagate well so only 18 were advanced for screening against Harmony-aggressive *M. arenaria* strains of root-knot nematode. Seven of the 18 selections did not allow reproduction of the more aggressive strain, and have excellent resistance against the three nematodes (Table 1).

Eighteen of the 34 1993 seedling selections that root well and resist root-knot nematode, did not form galls when inoculated with dagger nematode, *X. index* (Table 2). Many of these have *V. rufotomentosa*, *V. champinii* and *V. candicans* in their parentage. They will soon be tested against Harmony-aggressive *M. arenaria* strains and others.

Twenty six of the 38 1994 seedling selections that root well, did not form egg masses when inoculated with root-knot nematode (Table 3). Thirty of the seedlings were resistant to *X. index* (Table 4). Eighteen of the 1994 seedlings that are resistant to the dagger nematode are also resistant to the root-knot nematode, *M. incognita* race 3 (Table 4). These selections are in the process of being against Harmony-aggressive *M. arenaria* strains. These seedlings are primarily hybrids of *V. riparia*, *V. champinii* and *V. candicans*. Four of them, crosses of *V. rufotomentosa* x *V. cinerea*, should have excellent general nematode resistance but may be difficult to root.

An additional set of 1994 seedlings was screened for ease of propagation and 10 were selected. These were also challenged against root-knot nematode and 6 did not allow reproduction. These were all crosses of *V. rupestris* A. de Serres (an unusual selection with good nematode resistance) and *V. cinerea* (Table 5). They have strong potential as rootstock candidates.

Once the selections with the greatest breadth of nematode resistance are identified they will be grafted and planted in sites with extreme and diverse nematode pressure to evaluate the viticultural characteristics they induce.

CONCLUSIONS Crosses made among a series of *Vitis* and *Muscadinia* species have resulted in selection of candidate rootstocks with multiple nematode resistance. Rootstock candidates will now progress to field trials for tests of horticultural characteristics and to assess the durability of the resistance against field populations of nematodes in a range of environments. Screening of rootstock candidates against additional nematode species will continue in greenhouse trials. New experiments will be initiated to determine whether resistance to a nematode species holds up when other nematode species are present.

BUDGET SUMMARY

This project is jointly funded by the American Vineyard Foundation (AVF), California Competitive Grant Program in Viticulture and Enology (CCGPVE), California Table Grape Commission (CTGC), The Viticulture Consortium(VC) and UC SAREP.

Source	1999-2000	2000-2001
AVF, CCGPVE, CTGC, VC		$27,799
UC-SAREP	$49,382	$27,799

Table 1. Mean number of egg masses on selected 1989 seedlings after inoculation with an aggressive root-knot nematode, *Meloidogyne arenaria* ‘Harmony C’, capable of feeding on Harmony rootstock. Letters following means designate statistically different values at p = 0.05.

Selection	Parentage	# Egg Masses	
Colombard	vinifera	244.0	a
8916-20	rup 'Witchita Refuge' x rot 'Dixie'	92.2	b
8913-13	rup 'A. de Serres' x rot. Trayshed	31.4	c
St. George	rupestris	22.0	cd
Harmony	1613 C OP Sdlg x DogRidge OP Sdlg	18.4	cd
8909-17	rup 'A. de Serres' x 'Cowart'	2.2	d
8901-01	rip (C17:38) x rot 'Carlos'	2.0	d
8913-02	rup 'A. de Serres' x rot. Trayshed	0.8	d
8913-45	rup 'A. de Serres' x rot. Trayshed	0.8	d
8909-19	rup 'A. de Serres' x 'Cowart'	0.6	d
8916-12	rup 'Witchita Refuge' x rot 'Dixie'	0.4	d
8913-16	rup 'A. de Serres' x rot. Trayshed	0.4	d
8909-11	rup 'A. de Serres' x 'Cowart'	0.4	d
8913-21	rup 'A. de Serres' x rot. Trayshed	0	d
8909-15	rup 'A. de Serres' x 'Cowart'	0	d
8913-40	rup 'A. de Serres' x rot. Trayshed	0	d
8913-43	rup 'A. de Serres' x rot. Trayshed	0	d
8913-38	rup 'A. de Serres' x rot. Trayshed	0	d
8913-39	rup 'A. de Serres' x rot. Trayshed	0	d
8904-04	rip (C17:38) x rot 'Dixie'	0	d
8909-05	rup 'A. de Serres' x 'Cowart'	0	d

Table 2. Mean number of galls on roots of selected 1993 seedlings after inoculation with *Xiphinema index*, dagger nematodes. Letters following means designate statistically different values at $p = 0.05$.

Selection #	Parentage	# Galls	
9309-05	rup 1595 x L 25-19 (champ x (rip x Ram))	101.4	a
9310-94	rup 1595 x L 25- 6	70.4	b
9310-43	rup 1595 x L 25- 6	61.0	bc
9359-09	Ram x L 25- 6	56.4	bc
St. George	rupestris	50.0	cd
9310-70	rup 1595 x L 25- 6	45.8	cd
9310-80	rup 1595 x L 25- 6	33.8	de
9310-58	rup 1595 x L 25- 6	28.6	e
9310-87	rup 1595 x L 25- 6	26.4	e
9327-55	L176- 9 (rufo x rup) x L 25- 6	25.6	e
9352-11	rup 1595 x champ 9038	24.0	ef
9327-96	L176- 9 x L 25- 6	20.5	efg
9310-96	rup 1595 x L 25- 6	7.2	fgh
9310-39	rup 1595 x L 25- 6	6.4	gh
9362-09	L176- 9 x rip 1438	5.8	gh
9310-102	rup 1595 x L 25- 6	1.4	h
9310-86	rup 1595 x L 25- 6	0	h
93100-27	rufo 1416 X rip 1438	0	h
9327-37	L176- 9 x L 25- 6	0	h
9309-42	rup 1595 x L 25-19	0	h
9310-34	rup 1595 x L 25- 6	0	h
9317-06	rup 1595 x L513- 4 (rufo x rip)	0	h
9328-17	L176-9 (rufo X rup) X L25-19 (cham X (rip X Ram))	0	h
9332-43	L514-10 x champ 9038	0	h
9344-03	L514-20 (rufo X (rip X DR)) x L 25-19	0	h
9327-43	L176- 9 x L 25- 6	0	h
9357-05	Ram x L142- 2 (rufo x cand)	0	h
9327-62	L176- 9 x L 25- 6	0	h
9327-67	L176- 9 x L 25- 6	0	h
9363-16	L514-30 x rip 1438	0	h
9365-43	L514-14 x rip 1438	0	h
9365-62	L514-14 x rip 1438	0	h
9365-85	L514-14 x rip 1438	0	h
9309-33	rup 1595 x L 25-19 (champ x (rip x Ram))	0	h

Table 3. Mean number of egg masses on selected 1994 seedlings after inoculation with *Meloidogyne incognita* Race 3 root-knot nematodes. Letters following means designate statistically different values at p = 0.05.

Selection #	Parentage	Egg Mass #
9420-09	L 6-1 x cin 9041	25.8 a
Colombard	vinifera	24.6 a
9403-40	L 6-1 x L91-64 (rip x cand)	22.6 a
9406-01	L 6-1 x rotund Tara	13.8 b
St. George	rupestris	12.4 bc
9403-13	L 6-1 x L91-64 (rip x cand)	12.2 bc
9401-37	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	8.4 cd
9402-3	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 19 (champ x (rip x Ram))	6.0 de
9401-49	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	4.2 de
9403-16	L 6-1 x L91-64 (rip x cand)	3.6 de
9403-110	L 6-1 x L91-64 (rip x cand)	2.8 e
9401-32	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	2.8 e
9401-31	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	2.6 e
9420-04	L 6-1 x cin 9041	0.2 e
9420-11	L 6-1 x cin 9041	0.2 e
Harmony	1613 OP sdlg x DR OP sdlg	0 e
9401-10	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9401-18	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9403-17	L 6-1 x L91-64 (rip x cand)	0 e
9403-18	L 6-1 x L91-64 (rip x cand)	0 e
9401-52	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9403-37	L 6-1 x L91-64 (rip x cand)	0 e
9401-35	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9403-44	L 6-1 x L91-64 (rip x cand)	0 e
9403-35	L 6-1 x L91-64 (rip x cand)	0 e
9401-48	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9407-05	L 6-1 x champ 9021	0 e
9401-51	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9420-13	L 6-1 x cin 9041	0 e
9420-03	L 6-1 x cin 9041	0 e
9403-107	L 6-1 x L91-64 (rip x cand)	0 e
9420-8	L 6-1 x cin 9041	0 e
9407-14	L 6-1 x champ 9021	0 e
9438-18	L514-10 (rufo x (rip x Dog Ridge)) x champ 9038	0 e
9438-31	L514-10 (rufo x (rip x Dog Ridge)) x champ 9038	0 e
9449-17	rufo x cin 9008	0 e
9449-23	rufo x cin 9008	0 e
9449-25	rufo x cin 9008	0 e
9449-27	rufo x cin 9008	0 e
9401-42	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0 e
9420-05	L 6-1 x cin 9041	0 e

Table 4. Mean number of galls on roots of selected 1994 seedlings after inoculation with *Xiphinema index*, dagger nematodes. Letters following means designate statistically different values at p = 0.05.

Selection #	Parentage	# Galls	
St.George	rupestris	73.4	a
9401-51*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	1.6	b
9403-18*	L 6-1 x L91-64 (rip x cand)	1.6	b
9420-05*	L 6-1 x cin 9041	1.2	b
9438-31*	L514-10 (rufo x (rip x Dog Ridge)) x champ 9038	0.5	b
9401-18*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0.4	b
9320-4		0.2	b
9401-10*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-31	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-32	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-35*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-42*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-48*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-49	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9401-52*	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 6 (champ x (rip x Ram))	0	b
9402-3	L 6-1 [(rip Gloire x Ram) x (rip Gloire x Ram)] x L25- 19 (champ x (rip x Ram))	0	b
9403-107*	L 6-1 x L91-64 (rip x cand)	0	b
9403-110	L 6-1 x L91-64 (rip x cand)	0	b
9403-13	L 6-1 x L91-64 (rip x cand)	0	b
9403-16	L 6-1 x L91-64 (rip x cand)	0	b
9403-17*	L 6-1 x L91-64 (rip x cand)	0	b
9403-35*	L 6-1 x L91-64 (rip x cand)	0	b
9403-40	L 6-1 x L91-64 (rip x cand)	0	b
9403-44*	L 6-1 x L91-64 (rip x cand)	0	b
9406-01	L 6-1 x rotund Tara	0	b
9407-05*	L 6-1 x champ 9021	0	b
9407-14*	L 6-1 x champ 9021	0	b
9420-08*	L 6-1 x cin 9041	0	b
9420-09	L 6-1 x cin 9041	0	b
9420-11	L 6-1 x cin 9041	0	b
9420-13*	L 6-1 x cin 9041	0	b
9438-18*	L514-10 (rufo x (rip x Dog Ridge)) x champ 9038	0	b
9449-17*	rufo x cin 9008	0	b
9449-23*	rufo x cin 9008	0	b
9449-25*	rufo x cin 9008	0	b
9449-27*	rufo x cin 9008	0	b

Selections marked by * have also tested resistant to *Meloidogyne incognita* race 3 (Table 3)

Table 5. Mean egg mass number on 1994 seedlings (selected for their rooting ability) after inoculation with root-knot nematode, *Meloidogyne incognita* Race 3. Letters following means designate statistically different values at p = 0.05.

Selection #	Parentage	# Egg Masses	
Colombard	vinifera	38.4	a
9413-07	rupestris 1595 x champ 9038	11.8	b
9413-10	rupestris 1595 x champ 9038	7.6	bc
St. George	rupestris	7.0	bcd
9409-20	rupestris 1595 x cinerea 9041	2.4	cd
9409-15	rupestris 1595 x cinerea 9041	0.4	d
9409-28	rupestris 1595 x cinerea 9041	0	d
9409-42	rupestris 1595 x cinerea 9041	0	d
9409-55	rupestris 1595 x cinerea 9041	0	d
9409-18	rupestris 1595 x cinerea 9041	0	d
9409-54	rupestris 1595 x cinerea 9041	0	d
Harmony	1613C OP Sdlg x DogRidge OP Sdlg	0	d
9409-39	rupestris 1595 x cinerea 9041	0	d