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Development of Grape Rootstocks with Broad and Durable Nematode Resistance

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ABSTRACT Several species of plant-feeding nematodes are present in most vineyards, however few rootstocks have resistance to more than one species. Our goal is to develop grape rootstocks with broad and durable resistance to important nematode species. We have screened rootstock candidates against: the root knot nematode (*Meloidogyne incognita* race 3), two strains of root-knot nematode that overcome the resistance of Harmony rootstock (*Meloidogyne arenaria* strains A and C), and the dagger nematode (*Xiphinema index*). From these selections, several candidate rootstocks with strong resistance to the individual nematode species, and some with broad resistance to two or more of the nematode species, were selected.
Of the thousands of seedlings produced from these crosses, only 14 have graduated through the rooting trial and individual nematode screening trials. These are extremely valuable plants. We know of no other examples of rootstocks for perennial crops selected for broad (multi-species) nematode resistance.
To test the durability of the resistance, some of the rootstock selections resistant to all four nematodes when inoculated individually were exposed to all of the species at the same time. Preliminary results are puzzling and need to be repeated. When inoculated together there appeared to be some galling. However, there were some logistical problems in conducting these preliminary experiments. We also need to test durability of resistance to root-knot and dagger nematodes when the plants are inoculated with other nematode species, including ring, citrus, pin and lesion nematodes.

OBJECTIVES

1. To continue the development of grape rootstocks with resistance to a broad range of nematodes species and aggressive strains.
2. To evaluate the durability of resistance in advanced selections with multiple nematode resistance.
3. Field testing of selected rootstocks for horticultural characteristics and durability of nematode resistance.
4. To develop and employ new rootstocks with resistance to a broad range of key nematode species as a sustainable alternative to the use of preplant fumigation.

PROCEDURES

The sources of plant material used in this study are crosses made by Walker in the UC Grape Rootstock Breeding Program:

Year	Included in Parentage
1989	*Vitis rupestris, Muscadinia rotundifolia*
1993	*V. rufotomentosa*, *V. champinii*, *V. candicans*

1994	*V. riparia*, *V. champinii*, *V. candicans*
1994	*V. rufotomentosa, V. cinerea*

Seedlings from the crosses were established in the field. Dormant cuttings from the vines that resulted from the seedlings were evaluated for rooting. 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 now completed screening of all these selections against populations of the common root-knot nematode species *Meloidogyne incognita* race 3, two strains of root-knot nematode that overcome the resistance of Harmony rootstock (*Meloidogyne arenaria* strains A and C), and the dagger nematode (*Xiphinema index*).

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

Our 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.

During this funding period, we conducted preliminary experiments to test durability of resistance when other nematode species were present. Selections that graduated through the screening trials with resistance to all the nematode species individually were inoculated with all the selections at the same time.

RESULTS

Broad Resistance

Of the plants from the 1989, 1993 and two 1994 crosses, 1, 7, 6 and 0, respectively, (Tables 1-4) were resistant to the four nematodes tested individually. That means that of thousands of seedlings produced in these crosses, only 14 have survived the rooting and nematodes screens (Table 5). Those should provide a rich source for field testing as rootstocks.

Durable Resistance

Preliminary results are puzzling and a little troubling. The susceptible response to all the nematodes tested is root galling. On the selections with broad resistance (Table 5), there was no galling with any of the species when inoculated alone. However, when a subset of these plants was inoculated with the four nematodes together, there appeared to be some galling. This is a red flag. If the nematodes individually do not feed, how are they altering root response in combination? There were some inconsistencies in our methods in the combination experiments

as there are logistical problems in ensuring that all of the nematodes and the plant material are ready at the same time. We need to repeat the experiments and explore this issue more thoroughly. We also need to test durability of resistance to root-knot and dagger nematodes when the plants are inoculated with other nematode species, including ring, pin and lesion nematodes.

CONCLUSIONS Crosses made among a series of *Vitis* and *Muscadinia* species have resulted in selection of candidate rootstocks with multiple nematode resistance. Some rootstock candidates have now progressed 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. We need to continue testing of durability of the resistance when plants are exposed to other nematode species. We also need to determine whether the broad resistance identified in 14 genotypes is effective against other nematodes not yet tested.

BUDGET SUMMARY
This project has been 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		$21,441
UC-SAREP	$49,382	$27,799

Table 1. One genotype of a series of 1989 selections had broad resistance to the four nematode species

Genotype	X.index	M.incognita 3	Harmony C	Harmony A
8901-01	R	S	S	
8913-13	R	S	S	
8909-08	R	S		
8909-20	R	S		
8909-23	R	S		
8909-25	R	S		
8913-08	R	S		
8913-09	R	S		
8913-11	R	S		
8913-14	R	S		
8913-26	R	S		
8913-28	R	S		
8913-49	R	S		
8916-04	R	S		
8916-07	R	S		
8916-08	R	S		
8916-09	R	S		
8916-16	R	S		
8916-17	R	S		
8916-23	R	S		
8916-26	R	S		
Schwarzman	R	S		
1616c	R	S		
8909-04	R	R	S	S
8909-11	R	R	S	
8909-17	R	R	S	
8909-19	R	R	S	
8909-24	R	R	S	S
8913-02	R	R	S	
8913-04	R	R	S	
8913-16	R	R	S	
8913-29	R	R	S	
8913-45	R	R	S	
8913-46	R	R	S	
8916-12	R	R	S	
8916-19	R	R	S	
8916-20	R	R	S	
8916-22	R	R	S	S
8904-04	R	R	R	S
8909-05	R	R	R	R
8909-15	R	R	R	S
8913-21	R	R	R	S
8913-38	R	R	R	S
8913-40	R	R	R	S
8913-43	R	R	R	S
5C	R	R	*	*
5BB	R	R	*	*
Borner	R	R	*	*
101-14	R	R	*	*
8913-39	R	*	R	*

Table 2. Seven genotypes of a series of 1993 selections had broad resistance to the four nematode species:

Genotype	*M. incognita* race 3	*X. index*	*M. arenaria* - Harmony A	*M. arenaria* - Harmony C
9362-09	R	S	S	R
9310-80	R	S	S	
9310-96	R	S	S	
9310-102	R	S	S	
9327-55	R	S	S	
9359-09	R	S	S	
9310-87	R	S	R	
9309-05	R	S		
9310-39	R	S		
9310-43	R	S		
9310-58	R	S		
9310-70	R	S		
9310-94	R	S		
9352-11	R	S		
9327-96		S		
9327-37	R	R	S	R
9327-43	R	R	S	R
9357-05	R	R	S	R
93100-27	R	R	S	R
9328-17	R	R	S	S
9310-86	R	R	S	
9317-06	R	R	R	R
9332-43	R	R	R	R
9344-03	R	R	R	R
9363-16**	R	R	R	R
9365-43	R	R	R	R
9365-62	R	R	R	R
9365-85	R	R	R	R
9327-67	R	R	*	*
9309-42	R	R	*	R
9310-34	R	R	*	R
9327-62	R	R	*	R
9309-33	R	R	*	S
9350-02	R	*	S	R

** Needs further testing

Table 3. Six genotypes of a series of 1994 selections had broad resistance to the four nematode species

Genotype	*M. incognita* race 3	*X. index*	*M. arenaria* - Harmony A	*M. arenaria* - Harmony C
9420-4	S	S	S	
9401-31	S	R	S	
9401-32	S	R	S	
9401-49	S	R	S	
9402-3	S	R	S	
9403-13	S	R	S	
9403-16	S	R	S	
9403-40	S	R	S	
9403-110	S	R	S	
9406-01	S	R	S	
9420-9	S	R	S	
9420-11	S	R	S	
9401-37	S		S	
9401-18	R	S	S	
9401-51	R	S	S	
9403-18	R	S	S	
9420-5	R	S	S	
9438-31	R	S	S	
9401-10	R	R	S	
9401-35	R	R	S	
9401-42	R	R	S	
9401-48	R	R	S	
9401-52	R	R	S	
9403-17	R	R	S	
9407-5	R	R	S	
9420-8	R	R	S	
9420-13	R	R	S	S
9403-35	R	R	R	R
9403-107	R	R	R	R
9407-14	R	R	R	R
9438-18	R	R	R	S
9449-17	R	R	R	R
9449-23	R	R	R	R
9449-25	R	R	R	S
9449-27	R	R	R	R
9403-44	R	R	*	*
9403-37	R	*	*	*
9420-3	R	*	*	*

Table 4. None of a series of seventeen 1994 selections had broad resistance to the four nematodes species:

Genotype	*M. incognita* race 3	*X. index*	*M. arenaria* - Harmony A	*M. arenaria* - Harmony C
9409-03	R	S	S	S
9409-09	R	R	S	S
9409-15	S			
9409-18	R	*	S	S
9409-20	S			
9409-22	R	S	S	S
9409-28	S	S	S	S
9409-35	R	*	S	R
9409-36	S	R		
9409-39	S	S	S	S
9409-42	R	R	S	S
9409-54	R	*	S	S
9409-55	R	R	S	S
9413-07	S			
9413-10	S			
9414-97	R	R	S	S
9414-105	R	S	S	S

Table 5. Summary Table: Genotypes with broad resistance to four nematodes.

Genotype	*M. incognita* race 3	*X. index*	*M. arenaria* - Harmony A	*M. arenaria* - Harmony C
8909-05	R	R	R	R
9317-06	R	R	R	R
9332-43	R	R	R	R
9344-03	R	R	R	R
9363-16**	R	R	R	R
9365-43	R	R	R	R
9365-62	R	R	R	R
9365-85	R	R	R	R
9403-35	R	R	R	R
9403-107	R	R	R	R
9407-14	R	R	R	R
9449-17	R	R	R	R
9449-23	R	R	R	R
9449-27	R	R	R	R

** Needs further testing