Fruit Varieties Journal 53(1):22-29 1999

Evaluation of Grape Germplasm for Downy Mildew Resistance

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Abstract

Grape accessions from the University of Arkansas table grape collection at the Fruit Substation, Clarksville, Ark., and the USDA-ARS grape germplasm repositories in Geneva, N.Y., and Davis, Cal. were evaluated for downy mildew resistance. Evaluations were done in two trials, in a fungicide-free vineyard, established in 1993 and 1994 at Fayetteville, Ark. Ratings for sporulation, chlorosis, and necrosis were taken twice, once in August and once in September, in 1994, 1995, and 1996. Several grape accessions, including 'Bacchus,' 'Ives,' 'Lady Patricia,' 'Oberlin 595,' 'Mid-South,' 'Atoka,' 'Cottage,' 'Long John,' 'Loretto,' 'Aurelia,' 'Patricia,' 'Lutie,' 'Cynthiana,' *V. riparia, V. vulpina, V. thunbergii, V. champinii, V. cinerea helleri, V. cinerea, V. flexuosa, V. aestivalis argentifolia, V. cordata, V. mustangensis,* and D-210 were rated as downy mildew resistant in all three years. Certain accessions showed good resistance in 1994, but showed less resistance in 1995 and 1996. Differences in downy mildew ratings on some accessions were found between Fayetteville and other reported locations, while some showed no location effects. In general, susceptible grape accessions had much higher levels of sporulation, chlorosis, and necrosis by the second rating in September.

Additional index words: *Plasmopara viticola,* grape accessions, fungi, fruit breeding

Downy mildew, caused by *Plasmopara viticola* (Berk. & Curt.) Berl. & de Toni, is a destructive disease found on grapes (*Vitis* spp.) worldwide (5). On susceptible genotypes, this disease can develop and spread rapidly during a single growing season. The most damage occurs on the foliage, but flower clusters can also be affected. Symptoms include yellowish-oily lesions on the adaxial surface of leaves, and reddish or brown necrotic areas that develop as the disease progresses. Sporangiophores with sporangia emerge through stomata on the abaxial leaf surface. Without resistant plant material or a regular spray program, many secondary disease cycles can occur during a growing season (7, 8). As a result of leaf infection and premature defoliation, photosynthesis is reduced, resulting in low carbohydrate reserves and winter injury. Consecutive years of severe downy mildew can lead to eventual death of the vine.

Screening grape germplasm for downy mildew resistance provides important information for breeders to select appropriate material for enhancing resistance in breeding material and for developing new downy mildew resistant cultivars. As grape breeding programs are terminated, germplasm is being consolidated into fewer locations, thus limiting the number of researchers that are evaluating germplasm for disease resistance (11). It will be important in the future to maintain global grape germplasm collections as sources of disease resistant genes useful in breeding programs (1, 9). Germplasm trials have been conducted in several countries to screen for downy mildew resistance.

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Received for publication _____. Accepted for publication _____. Published with approval of the Director, Arkansas Agricultural Experiment Station, Manuscript no. 98043.

Cultivars that have American *Vitis* species as a component of their pedigree were found to be resistant to downy mildew in screening trials conducted by Demaree et al. (3). Patil et al. (10) screened 100 grape cultivars and 14 *Vitis* species of which, 'Muscat,' 'Rose of Peru,' 'Rubired,' 'Zinfindel,' *V. aestivalis* Mich., *V. arizonica* Engelmann, *V. berlandieri* Planchon, *V. californica* Bentham, *V. candicans* Engelm., *V. champinii* Pl., *V. longii* Prince, *V. palmata* Vahl, *V. riparia* Mich., *V. rupestris* Scheele, and *V. tiliaefolia* Humboldt and Bonpland, were resistant to downy mildew. Staudt and Kassemeyer (13) concluded that 21 *Vitis* spp. were resistant to downy mildew, including *V. aestivalis*, *V. amurensis* Ruprecht, *V. candicans*, *V. cinerea* Engelm., *V. doaniana* Munson, *V. munsoniana* Munson, *V. palmata*, *V. piasezkii* Maximowicz, *V. riparia*, *V. rotundifolia* Mich., *V. rubra* Mich., *V. shuttleworthii* House, *V. solonis* Hort. Berol ex Planchon, *V. tiliaefolia*, *V. vulpina* L., and *V. yenshanensis* nomen nudum. In highly resistant clones of *V. riparia* and *V. rupestris*, initial penetration of *P. viticola* into the substomatal cavity or haustoria initiation was inhibited within 24 to 48 h after inoculation (4).

'Amber Queen,' 'Champion,' and 'Digraset' were rated by Datar (2) as resistant (≤10% leaves infected) to downy mildew, and 'Athens,' 'Buckland Sweet Water,' 'Isabella,' 'Goethe,' 'James,' 'Malaga,' 'Khalili,' 'Westfield,' and *V. solonis* X *V. riparia* were found to be moderately resistant (20-30% leaves infected). Of the 233 cultivars screened for downy mildew resistance by Sohi and Sridhar (12), 'Amber Queen,' 'Cardinal,' 'Champa,' 'Champion,' 'Dog Ridge,' 'Red Sultana,' 'St. George,' and 'Seibel' were resistant, and 27 cultivars, including 'Buffalo,' 'Canada,' 'Exotic,' 'Grenache,' 'James,' 'Salt Creek,' and 'Westfield,' were moderately susceptible. He and Wang (6) discovered that genotypes derived from *V. riparia* Michx., *V. pseudoreticulata* W. T. Wang, and *V. davidii* var Cyanocarpac (Gagn.) Sang. showed good resistance to downy mildew, and that some genotypes of *V. flexuosa* Thunb., *V. bryoniifolia* Bunge, *V. romanetii* Roman., *V. piasezkii* Maxim., *V. yenshanensis*, and *V. hancockii* Hance possessed moderate resistance to downy mildew.

This study was conducted to screen grape germplasm for downy mildew resistance and to determine whether certain material may be useful in the University of Arkansas table grape breeding program. Downy mildew resistance was assessed as the proportion of foliar tissue affected by sporulation, chlorosis, and necrosis. Disease ratings for certain grape accessions were compared with results at other locations to determine if germplasm performed similarly at different locations.

Materials and Methods

Germplasm was selected from the University of Arkansas table grape collection at the Fruit Substation, Clarksville, Ark., and the USDA-ARS grape germplasm repositories in Geneva, N.Y., and Davis, Cal. Evaluation trials were established in 1993 (Table 1) and 1994 (Table 2) at Fayetteville, Ark.

Hardwood cuttings three nodes long and at least 10 mm in diameter were placed, basal end (no hormone treatment), in a perlite-mist bed in a greenhouse by 15 January each year. After leaves and root systems developed, the rooted cuttings were transplanted to peat pots (10.2 cm diameter) containing potting soil amended with Osmocote 18-18-18 (Hummerts, St. Louis, Mo.) fertilizer at 100 g per 0.06 m^3. Cuttings were returned to the mist system to condition the plants to the new soil environment.

Beginning in early March, Peters 20-20-20 (Hummerts, St. Louis, Mo.) liquid fertilizer at the concentration of 300 ppm was applied every two weeks. Plants were grown in the greenhouse until the fifth or sixth leaf stage and then acclimatized to the outdoors by reducing greenhouse temperatures. Grapes were transplanted in May when nighttime temperatures were consistently above 10 °C. Planting was done in a randomized complete block de-

sign with four single-plant replications. Plants were placed 0.9 m apart within rows on trellises set on 3.0 m row centers designed for a bilateral-cordon training system. A rye-fescue mixture was sown to establish and maintain a perennial grass strip between vineyard rows.

Vineyard maintenance included an early spring application of herbicides, fertilizer (13-13-13, 13.6 kg N per acre) by 1 April, or applied following transplanting, and drip irrigation applied as needed to avoid drought stress. No fungicides or insecticides were applied to this vineyard.

Accessions planted in 1993 and 1994 were screened in 1994, 1995, and 1996 for downy mildew resistance. Downy mildew resistance was evaluated by rating sporulation, chlorosis, and necrosis on the leaves. Disease ratings were made on a scale of 0-5: 0 = no sign, no symptoms; 1 = >0 to 10%; 2 = >10 to 30%; 3 = >30 to 60%; 4 = >60 to 80%; and 5 = >80 to 100% of all leaves on a plant affected by downy mildew disease. Plant ratings of ≤1.0, >1.0 to 2.0, and >2.0 were considered resistant, moderately resistant, and susceptible, respectively. Ratings for the 1993 trial were made on 23 August and 26 September, 22 August and 25 September, and 13 August and 3 September in 1994, 1995 and 1996, respectively. The 1994 trial was rated on 22 August and 21 September, 21 August and 27 September, and 12 August and 2 September in 1994, 1995, and 1996, respectively.

Data were analyzed using a general linear model (SAS), and results were combined over years. Due to the large volume of information, accessions were placed in categories based on their level of downy mildew resistance. More detailed information regarding the statistical analyses of sporulation, chlorosis, and necrosis data can be made available upon request.

Results

Evaluations of the 1993 Grape Trial. There was a wide range in ratings for downy mildew resistance in the 1993-germplasm trial (Table 1). Mean ratings for sporulation, chlorosis, and necrosis for certain accessions were greater in 1996 than in 1994 or 1995. Generally, ratings for sporulation, chlorosis, and necrosis were greater at the second rating, except in 1995, when the second sporulation ratings were less than the first ratings. Most of the accessions in the 1993 germplasm trial had the same level of downy mildew resistance over all three years. *V. bourquina* Munson, *V. tiliaefolia*, and *V. coignetiae* Pulliat had mean sporulation, chlorosis, or necrosis values at either the first or second rating that were considerably different for each of the three years (data not shown).

Of the 23 *Vitis* species evaluated, 11 were considered resistant to downy mildew with sporulation, chlorosis, and necrosis mean ratings of <1.0 in 1994, 1995, and 1996 (Table 1). Those *Vitis* species with a mean >1.0 to 2.0 for sporulation, chlorosis, or necrosis in at least one of the three years were *V. andersonii* Rehder, *V. coignetiae*, *V. doaniana*, *V. tiliaefolia*, and *V. bourquina*. *Vitis* yenshanensis, however, was the most susceptible of the *Vitis* species in the 1993 trial with overall means for sporulation, chlorosis, and necrosis of 1.3 and 1.9, 1.1 and 2.2, and 1.0 and 2.4, for the first and second ratings, respectively.

Several cultivars in the 1993 trial showed good resistance to downy mildew (Table 1), among them were 'Bacchus,' 'Ives,' 'Lady Patricia,' 'Midsouth,' 'Atoka,' 'Cottage,' 'Long John,' 'Loretto,' and 'Aurelia.' Susceptible (>2.0) cultivars in 1994, 1995, and 1996 were 'Sovereign Coronation,' 'Yates,' 'Athens,' 'Campbell,' 'Captivator,' 'Westfield,' 'Manito,' and 'Diamond.' The grape selections NY65.0479.1, NY70.0834.6, and NY70.0834.5 had among the highest sporulation, chlorosis, and necrosis ratings at both the first and second ratings during 1994, 1995, and 1996 in the 1993 germplasm trial. 'Loretto,' D-230, and NY64.0029.1 had too few replicate plants for statistical analysis; however, ratings indicated that 'Loretto' and D-230 appeared resistant and NY64.0029.1 appeared to be susceptible to downy mildew.

Table 1. Cultivars, selections, and *Vitis* species planted in a vineyard at Fayetteville, Ark. in 1993.

Accession	Source[z]	Accession No.	Downy Mildew Rating[yxw]
Athens	Geneva	177	Susceptible
Bath	Geneva	109	Moderately Resistant
Campbell	Geneva	231	Susceptible
Captivator	Geneva	178	Susceptible
Clinton	Geneva	522	Moderately Resistant
Concord	Geneva	51	Moderately Resistant
Cottage	Geneva	1078	Resistant
D-210	FRSS		Resistant
D-230[v]	FRSS		Resistant
Diamond	Geneva	124	Susceptible
Goeth	Geneva	431	Moderately Resistant
Isabella	Geneva	254	Moderately Resistant
Ives	Geneva	107	Resistant
Lady Patricia	Geneva	72	Resistant
Long John	Geneva	768	Resistant
Loretto[v]	Geneva	1335	Resistant
Manito	Geneva	517	Susceptible
Mid-South	FRSS		Resistant
Oberlin 595	Geneva	379	Resistant
Sov. Coronation	FRSS		Susceptible
Suelter	Geneva	397	Resistant
Vanessa Seedless	Geneva	458	Moderately Resistant
Westfield	Geneva	140	Susceptible
Yates	Geneva	113	Susceptible
NY62.0122.1	NYSAES		Moderately Resistant
NY64.0029.1[v]	NYSAES		Susceptible
NY65.0479.1	NYSAES		Susceptible
NY70.0834.5	NYSAES		Susceptible
NY70.0834.6	NYSAES		Susceptible
V. acerifolia	Geneva	138	Moderately Resistant
V. aestivalis arg.	Geneva	214	Resistant
V. andersonii	Geneva	701	Moderately Resistant
V. bourquina	Davis	94	Moderately Resistant
V. champinii	Geneva	677	Resistant
V. cinerea	Geneva	250	Resistant
V. cinerea	Geneva	831	Resistant
V. coignetiae	Geneva	13	Resistant
V. cordata	Davis	2128	Resistant
V. doaniana	Geneva	165	Moderately Resistant
V. flexuosa	Davis	1385	Resistant
V. gigas	Davis	1721	Moderately Resistant
V. labrusca	Geneva	1023	Moderately Resistant
V. monticola	Geneva	1258	Moderately Resistant
V. mustangensis	Davis	NA	Resistant
V. riparia	Geneva	404	Resistant
V. rubra	Geneva	239	Moderately Resistant
V. rupestris	Geneva	180	Resistant

Table 1. Continued.

V. solonis	Geneva	685	Moderately Resistant
V. thunbergii	Geneva	814	Resistant
V. tiliaefolia	Davis	1715	Moderately Resistant
V. treleasei	Davis	1149	Moderately Resistant
V. vulpina	Geneva	442	Resistant
V. vulpina	Geneva	677	Resistant
V. yenshanensis	Geneva	742	Susceptible

[z]Geneva = USDA Germplasm Repository, Geneva, N.Y.
Davis = USDA Germplasm Repository, Davis, Cal.
[y]Resistant = mean ratings for sporulation, chlorosis, and necrosis were (≥0 and <1.0 averaged over 1994, 1995, and 1996.
[x]Moderately resistant = mean ratings for sporulation, chlorosis, and necrosis were (≥1.0 and <2.0 averaged over 1994, 1995, and 1996.
[w]Susceptible = mean ratings for sporulation, chlorosis, and necrosis were (≥2.0 averaged over 1994, 1995, and 1996.
[v]Accessions had less than three replications and were not included in the statistical analysis.

Downy mildew ratings for the five N.Y. selections at Fayetteville were similar to ratings taken in 1995 near Geneva, N.Y. In the Geneva trial, NY62.0122.1, NY64.0029.1, NY65.0479.1, and NY70.-0834.5 had downy mildew ratings of 3.3, 6.0, 5.7, and 4.0, respectively, based on a scale of 0 to 10, 10 being the most susceptible (Bruce Reisch, personal communication). NY62.0122.1 was the most resistant NY selection in the Fayetteville trial with very low mean sporulation, chlorosis, and necrosis ratings. One exception, NY70.0834.6, was rated as highly susceptible in the Fayetteville trial; whereas, in the New York trial, it was rated as moderately resistant.

Evaluations of the 1994 Grape Trial. There was a wide range of downy mildew resistance among cultivars in the 1994 germplasm trial (Table 2). The ratings for sporulation, chlorosis, and necrosis tended to increase from 1994 to 1996. The 1994 germplasm trial was planted one year after the vineyard was established, which could indicate that *P. viticola* inoculum levels were not high enough to challenge the cultivars in 1994. Mean ratings for sporulation, chlorosis, and necrosis were generally greater for the second rating. Unlike the 1993 germplasm trial, sporulation increased from the first to the second rating in 1995. This was not easily explained since both trials were located in the same vineyard; thus, both trials were exposed to the same inoculum levels, weather, and cultural practices.

Statistical analysis was conducted on 25 of the 34 cultivars. Nine cultivars did not have at least three replications and were not included in the analysis. Of the 25 cultivars analyzed, four cultivars were rated resistant to downy mildew. There were several cultivars in the 1994 trial that did not show the same level of downy mildew resistance each year. 'Champanel,' 'Campbells Early,' 'Buffalo,' and 'America' had significantly greater means for sporulation, chlorosis, and necrosis in 1996 than in either 1994 or 1995. Overall ratings for the more susceptible cultivars, 'Reliance,' 'Venus,' 'Erie,' 'Seneca,' 'Moored,' 'Schuyler,' and 'Alwood,' usually showed greater amounts of sporulation, chlorosis, and necrosis in 1994, 1995, and 1996 than other entries.

Discussion

Grape accessions evaluated over three years were found to express a wide range of resistance to downy mildew. Downy mildew occurred throughout the vineyard at Fayetteville. The high levels of downy mildew resistance found in *V. aestivalis*, *V. champinii*, *V. riparia*, *V. rupestris*, *V. tiliaefolia*, *V. cinerea*, *V. doaniana*, *V. rubra*, *V. solonis*, and *V. vulpina* were similar to the results of He and Wang (6), Patil et al. (10), and Staudt and Kassemeyer (13). However, *V. yenshanensis*, rated as resistant to downy mildew by He and Wang (6) and Staudt and Kasseymer (13), was found to be highly susceptible in the 1993 trial. As in the Fayetteville trial, Demaree et al. (3) also found that the cul-

Table 2. Cultivars planted in a vineyard at Fayetteville, Ark. in 1994.

Accession	Source[z]	Accession No.	Downy Mildew Rating[yxw]
Alwood	FRSS		Susceptible
America	Geneva	122	Moderately Resistant
Bath	Geneva	109	Moderately Resistant
Brighton	Geneva	519	Moderately Resistant
Buffalo	Geneva	682	Moderately Resistant
Campbells Early	Geneva	128	Moderately Resistant
Caywood[v]	Davis	28	Moderately Resistant
Champanel	Davis	29	Moderately Resistant
Concord	Geneva	51	Moderately Resistant
Cynthiana	Davis	43	Resistant
Erie	Geneva	255	Susceptible
Glenora[v]	FRSS		Moderately Resistant
Greek Perfume	Geneva	755	Susceptible
Himrod[v]	FRSS		Himrod
Island Belle[v]	Geneva	153	Susceptible
Italia[v]	Davis	424	Susceptible
Ives	Geneva	107	Moderately Resistant
Lakemont[v]	FRSS		Susceptible
Lomanto	Geneva	198	Moderately Resistant
Long John[v]	Geneva	768	Moderately Resistant
Loretto	Geneva	1335	Resistant
Lutie	Geneva	1334	Resistant
Mars[v]	FRSS		Susceptible
McCampbell	FRSS		Moderately Resistant
Moored	FRSS		Susceptible
Ontario	Geneva	45	Moderately Resistant
Patricia	Geneva	1252	Resistant
Pearl	Davis	132	Susceptible
Reliance	FRSS		Susceptible
Saturn[v]	FRSS		Susceptible
Schuyler	Geneva	89	Susceptible
Seneca	FRSS		Susceptible
Steuben	Geneva	111	Susceptible
Venus	FRSS		Susceptible

[z]Geneva = USDA Germplasm Repository, Geneva, N.Y.
Davis = USDA Germplasm Repository, Davis, Cal.
FRSS = U of A Fruit Substation, Clarksville, Ark.
[y]Resistant = mean ratings for sporulation, chlorosis, and necrosis were (≥0 and <1.0 averaged over 1994, 1995, and 1996.
[x]Moderately resistant = mean ratings for sporulation, chlorosis, and necrosis were (≥1.0 and <2.0 averaged over 1994, 1995, and 1996.
[w]Susceptible = mean ratings for sporulation, chlorosis, and necrosis were (≥2.0 averaged over 1994, 1995, and 1996.
[v]Accessions had less than three replications and were not included in the statistical analysis.

tivars 'Clinton,' 'Cottage,' 'Loretto,' 'Bacchus,' 'Concord' and 'Suelter' were resistant to downy mildew. 'Diamond' and 'Manito,' rated as resistant in 1937, were found to be susceptible in the 1993 germplasm trial.

The N.Y. selections evaluated at Fayetteville had similar levels of downy mildew resistance as found near Geneva, N.Y. NY62.0122.1 was the most resistant of the N.Y. selections at both Fayetteville, Ark., and Geneva, N.Y. Although NY70.834.6 was rated as highly susceptible at Fayetteville, it was rated moderately resistant to downy mildew in New York. Except for the difference in downy

mildew reactions for NY70.834.6 at Fayetteville and Geneva, there was no wide variation in the amount of resistance to downy mildew between locations. There may be little genotype X environmental interaction influencing downy mildew reactions in the N.Y. selections, or there are no major differences in *P. viticola* inoculum at the two locations. Also, two prebloom fungicide applications in the N.Y. vineyard in 1995 may account for some of the differences in downy mildew ratings between locations.

Downy mildew ratings have previously been conducted by giving one rating to each plant based on the proportion of sporulation, chlorosis, and necrosis observed (2, 3, 6, 10, 12). Rating germplasm for all three characteristics individually requires considerable time. To accurately rate each plant, all of its leaves must be evaluated on the adaxial and abaxial surfaces to determine the percentage of canopy affected by chlorosis and necrosis, and sporulation, respectively. To make an accurate as possible rating all leaves were observed on each plant. Plants that were found to be susceptible generally showed sign and symptoms of downy mildew from mid-July into early or mid-October. As new tissue emerged, downy mildew would appear on fully expanded leaves. Accessions that were moderately resistant had considerably fewer chlorotic and necrotic lesions on older as well as younger leaves. Resistant plants were found, for the most part, to be free of sporulation, chlorosis, and necrosis each year.

In the present study, sporulation, chlorosis, and necrosis were evaluated separately to determine if there were differences in the expression of these three factors among accessions. Based on the results of this study, any one of the three rating factors could be used to accurately assess the amount of downy mildew resistance of an accession. This would greatly reduce the amount of time required to rate each plant. One concern about using symptom expression is that chlorosis and/or necrosis caused by some other disease may be mistaken for downy mildew. Generally, the susceptible cultivars had small angular areas of chlorosis on the leaves that would eventually become necrotic as the tissue senesced. Most necrotic lesions coalesced into a single area of necrosis as the disease progressed. To make an accurate identification, downy mildew would have to be verified by the presence of sporangiophores of *P. viticola* on the abaxial leaf surface. Sporulation appeared shortly after the first signs of chlorosis and often would continue after the leaf tissue became necrotic. Downy mildew on grape leaves can be accurately identified from mid-July through early October when the disease sign and symptoms are fully expressed.

This study has shown that several grape accessions possess good resistance to downy mildew. These could be used as donors of resistance genes in grape breeding programs to develop cultivars resistant to downy mildew.

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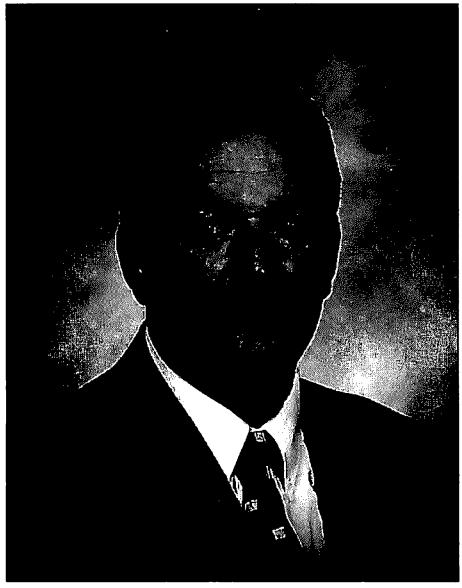

Recipient of the 1998 Wilder Medal

The American Pomological Society (APS) is pleased to announce that Dr. James (Jim) Ballington was the recipient of the 1998 Wilder Silver Medal Award. The Wilder Award was established in 1873 in honor of Marshall P. Wilder, the founder and first president of APS. The Wilder Medal is presented to individuals that have rendered outstanding service to horticulture in the area of pomology. Special consideration is given to work relating to the origination and introduction of meritorious fruit cultivars. This year's Wilder Medal was presented to Dr.