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Evaluation of foliar resistance to *Uncinula necator* in Chinese wild *Vitis* species

by

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Summary: Resistance to grape powdery mildew (*Uncinula necator* BURR.) of 13 known *Vitis* species and 5 unclassified grapes native to China was evaluated. 88 clones were tested with natural infection and a subset of 34 were artificially inoculated during the years of 1991-1992. 68 clones showed resistance to *U. necator*. In general, we found clones of *V. bryoniifolia*, *V. davidii*, and *V. piasezkii* resistant to *U. necator*. However, intraspecific variations were observed. Results from this study indicate that Chinese native wild grapes may provide valuable germplasm resources for powdery mildew resistance.

Key words: China, germplasm, grapes, resistance, Uncinula necator, Vitis.

Introduction

Powdery mildew disease of grapevines is of world-wide importance. The pathogen, *Uncinula necator* BURR., is believed to have originated in North America and spread to Europe before 1850 (PEARSON 1990). Powdery mildew was first observed in China in the 1950's (WANG 1993). Grape production in China has dramatically increased in the past ten years and the cultivated area now occupies at least 87,000 ha (FU 1988). There have been reports of local powdery mildew (WANG and HE 1993) disease outbreaks and the potential for damage in northern and northwestern China, the major grape production areas, is high.

Like many other crops, utilization of host resistance through breeding could be the most effective and economical strategy to control grape powdery mildew. However, a suitable grape germplasm is needed as the foundation for such a breeding program (LENNE and WOOD 1991; SPRAGUE 1980). China is one of the major centers of origin of *Vitis* species. Among the nearly 70 known species in *Vitis*, more than 27 have their origins in China (HE and WANG 1988; HE *et al.* 1991). Native grapes can be found in every section of China (WANG 1993). The rich resource of Chinese wild *Vitis* germplasm for grape breeding programs has been largely overlooked until recently (STAUDT 1989, ZHANG *et al.* 1989). In addition to the potential source of disease resistance, Chinese native wild grapes do not have the foxy flavor, which limits the use of some American native grapes in breeding programs (ALLEWELDT and POSSINGHAM 1988).

The research, reported herein, details the results of an evaluation of Chinese wild *Vitis* species for resistance to powdery mildew, with the hope that this poorly documented germplasm will benefit future viticultural research.

Materials and methods

A total of 13 described species and 5 unclassified ones encompassing 88 clones of Chinese *Vitis* were evaluated from 1991 to 1992 (Tab. 1 and 2). These clones were collected in mountain and piedmont areas from 12 provinces and autonomous regions (Fig. 1) and maintained at the wild grape germplasm nursery of Northwestern Agricultural University, Yangling, Shaanxi, P. R. China by grafting onto *V. vinifera* cv. Muscat Hamburg. Most of these clones were taken as cuttings from the individual wild plants on site. Investigation and screening were based on sugar content, potential yield, berry size, flower type, disease-resistance etc. from 1981 to 1985. The clones were evaluated for powdery mildew resistance in the field on a 1.5 m x 2.5 m spacing in a vineyard of Northwestern Agricultural University, Yangling, Shaanxi, the People's Republic of China. Each clone had three plants. *V. riparia* and *V. vinifera* cv. Carignane were used as resistant and susceptible controls, respectively. All the grapevines were subjected to the same cultural practices. No pesticides were used during the period of disease evaluation.

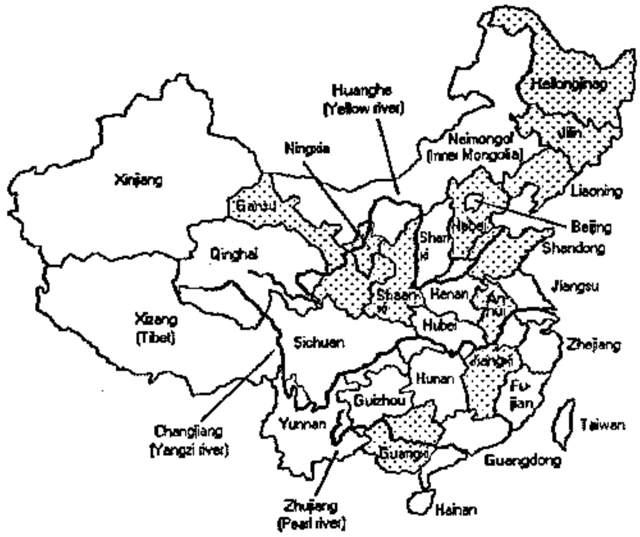

Fig. 1: A simplified map of the People's Republic of China. The shaded areas indicate the sources of Chinese *Vitis* spp. used in this study.

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Table 1

Names and sources of 90 *Vitis* clones*

Species	Clones	Sources
V. adstricta Hance	Yanshan-2	Hebei
V. adstricta Hance	Taishan-1	Shandong
V. adstricta Hance	Taishan-2	Shandong
V. amurensis Rupr.	Shanputao	Heilongjiang
V. amurensis Rupr.	74-1-88 [1])	Jilin
V. amurensis Rupr.	74-1-326 [1])	Jilin
V. amurensis Rupr.	Shuangqing [2])	Jilin
V. amurensis Rupr.	Taishan-11	Shandong
V. bryoniifolia Bunge	Anlin-16	Anhui
V. bryoniifolia Bunge	Anlin-18-1	Anhui
V. bryoniifolia Bunge	Anlin-18-2	Anhui
V. bryoniifolia Bunge	Anlin-28	Anhui
V. bryoniifolia Bunge	Anlin-29	Anhui
V. bryoniifolia Bunge	Anlin-25	Anhui
V. davidii Foex	Xuefeng	Hunan
V. davidii Foex	Jiangxi-4	Jiangxi
V. davidii Foex	Tangwei [2])	Jiangxi
V. davidii Foex	Lue-4	Shaanxi
V. davidii Foex	Ning-5	Shaanxi
V. davidii Foex	Ning-6	Shaanxi
V. davidii Foex	Ning-7	Shaanxi
V. davidii Foex	Jinan-1	Shandong
V. davidii Foex	Jinan-2	Shandong
V. davidii var. *cyanocarpa* Sarg.	Nan-6	Shaanxi
V. davidii var. *cyanocarpa* Sarg.	Zhen-3	Shaanxi
V. flexuosa Thunb.	Yang-2	Shaanxi
V. flexuosa var. *parvifolia* Gagn.	Shang-2	Shaanxi
V. hancockii Hance	Jiangxi-5	Jiangxi
V. piasezkii Maxim	Ninggu-1	Ningxia
V. piasezkii Maxim	Bai-22-1	Shaanxi
V. piasezkii Maxim	Liu-6	Shaanxi
V. piasezkii Maxim	Liu-7	Shaanxi
V. piasezkii Maxim	Liu-8	Shaanxi
V. piasezkii Maxim	Liu-9	Shaanxi
V. piasezkii Maxim	Mei-4	Shaanxi
V. piasezkii Maxim	Mei-6	Shaanxi
V. piasezkii Maxim	Nan-2	Shaanxi
V. pseudoreticulata W.T. Wang	Guangxi-1	Guangxi
V. pseudoreticulata W.T. Wang	Guangxi-2	Guangxi
V. pseudoreticulata W.T. Wang	Jiangxi-3	Jiangxi
V. pseudoreticulata W.T. Wang	Bai-13-1	Shaanxi
V. pseudoreticulata W.T. Wang	Bai-35-1	Shaanxi
V. pseudoreticulata W.T. Wang	Bai-36-1	Shaanxi
V. pseudoreticulata W.T. Wang	Shang-1	Shaanxi
V. pseudoreticulata W.T. Wang	Xun-1	Shaanxi
V. quinquangularis Rehd.	Yongfu	Guangxi
V. quinquangularis Rehd.	83-4-93 [3])	Shaanxi
V. quinquangularis Rehd.	83-4-96 [3])	Shaanxi
V. quinquangularis Rehd.	Dan-1	Shaanxi
V. quinquangularis Rehd.	Dan-2	Shaanxi
V. quinquangularis Rehd.	Dan-4	Shaanxi
V. quinquangularis Rehd.	Dan-11	Shaanxi
V. quinquangularis Rehd.	Mei-1	Shaanxi
V. quinquangularis Rehd.	Mei-2	Shaanxi
V. quinquangularis Rehd.	Shang-24	Shaanxi
V. quinquangularis Rehd.	Xun-3	Shaanxi
V. quinquangularis Rehd.	Wei-2	Shaanxi
V. quinquangularis Rehd.	Wei-3	Shaanxi
V. quinquangularis Rehd.	Wei-4	Shaanxi
V. quinquangularis Rehd.	Taishan-12	Shandong
V. riparia Michaux	Unknown	Shaanxi
V. romanetii Roman.	Ping-2	Guangxi
V. romanetii Roman.	Ping-7	Guangxi
V. romanetii Roman.	Jiangxi-1	Jiangxi
V. romanetii Roman.	Jiangxi-2	Jiangxi
V. romanetii Roman.	Bai-22-2	Shaanxi
V. romanetii Roman.	Liu-1	Shaanxi
V. romanetii Roman.	Liu-11	Shaanxi
V. romanetii Roman.	Liu-2	Shaanxi
V. romanetii Roman.	Liu-13	Shaanxi
V. romanetii Roman.	Shang-23	Shaanxi
V. sinocinerea W.T. Wang	Lan-2	Shaanxi
V. sp. (Maihuang grape)	Bai-36-2	Shaanxi
V. sp. (Maihuang grape)	Bai-41	Shaanxi
V. sp. (Maihuang grape)	Bai-42	Shaanxi
V. sp. (Maihuang grape)	Bai-44	Shaanxi
V. sp. (Maihuang grape)	Xun-8	Shaanxi
V. sp. (Maihuangfuye grape)	Bai-40	Shaanxi
V. sp. (Maihuangfuye grape)	Bai-117	Shaanxi
V. sp. (Mi grape)	Xun-4	Shaanxi
V. sp. (Qinling grape)	Dan-6	Shaanxi
V. sp. (Qinling grape)	Lan-6	Shaanxi
V. sp. (Qinling grape)	Lan-174	Shaanxi
V. sp. (Qinling grape)	Ning-10	Shaanxi
V. sp. (Qinling grape)	Ping-5	Shaanxi
V. sp. (Xiaofuye grape)	Lui-10	Shaanxi
V. sp. (Xiaofuye grape)	Ning-3	Shaanxi
V. vinifera L.	Carignane	Shaanxi
V. wilsonae Veitch	Yang-1	Shaanxi
V. yenshanensis	Yanshan-1	Hebei

* [1]) The clones were derived from the intraspecific hybridization of *V. amurensis*; [2]) The flower type of the clones from the cuttings as described below is hermaphrodite under natural conditions; [3]) The clones were selected by seedlings derived from the seeds of *V. qinquangularis.* The clones from Shaanxi province were taken as cuttings from individual wild plants on site through investigation from 1981 to 1985. The clones from other provinces were obtained by exchange with other research institutions in China.

Evaluation of natural infection was performed during July and August when powdery mildew symptoms were fully developed. 300 leaves were surveyed for each clone. Each leaf was graded as: 0, 1, 2, 3, 4, 5, 6 and 7, based on the estimated percentage of lesions over the whole leaf area: 0, 0.1-5.0, 5.1-15.0, 15.1-30.0, 30.1-45.0, 45.1-65.0, 65.1-85.0 and > 85.0, respectively. Results of grading were then converted to the severity index: SI = {[Sum of (Grade value x number of leaves in that grade)]/(Total leaf number x Highest grade value)} x 100. The resistance level of each clone was rated based on its SI: ER, Extremely Resistant, SI = 0; HR, Highly Resistant, SI= 0.1 - 5.0; R, Resistant, SI = 5.1 - 25.0; S, Susceptible, SI = 25.1 - 50; and HS, Highly susceptible, SI = 50.1 - 100.

To verify the results obtained from natural inoculation, 34 clones (Tab. 1 and 2) were selected and inoculated artificially. Conidia of *U. necator* were collected from symptomatic leaves by washing with 0.78 % glucose in a sterilized water solution, imitating the osmotic pressure of powdery mildew conidia (Fang 1979). 50 leaves from 10 young shoots were sprayed for each clone with the concentration of 2 x 10^5 conidia per ml of 0.78 % glucose solution to the point where tiny liquid drops just appeared but no runoff occurred. Inoculated leaves were immediately covered with thin paper bags. After 21 d they were evaluated in the manner described above.

Results and discussion

Tab. 2 lists the results of the powdery mildew disease evaluation from both natural and artificial infections. In the natural infection experiment, 11 clones were ER, 15 clones were HR, 42 clones were R, 15 clones were S, and 5 clones were HS, showing that Chinese *Vitis* species have a high degree of variation in their resistance to *U. necator*. Clones with SI between 5.1 to 25 were considered to be resistant (R) because *V. riparia* had its SI fall into this range and *V. riparia* was considered as R. *Vitis vinifera*, on the other hand, was highly susceptible (SI = 67.36). Overall 77.2 % of the clones (68 out of the 88) were resistant to *U. necator.*

In general, the artificial inoculation agreed with the results from natural infection (Tab. 2). In Shaanxi province, P. R. China, the lowest temperature is about -15 °C (January) and the highest temperature is about 35 °C (July). The rainy season occurs from July to September with an average yearly rainfall of about 580 mm. Under natural conditions, powdery mildew usually appears in May and peaks in July and August. For this reason, artificial infection experiments were performed in June, so that enough conidia were available as inocula. It was found that covering the sprayed young shoots for a period as long as 21 days was necessary for successful inoculation. The heavy rainfall this area receives may wash away *U. necator* conidia and influence the results of the natural infections.

Out of the 13 species of Chinese *Vitis*, 8 of them were tested with 5 or more clones. Based on the ratio of resistant clones to total tested clones, *V. bryoniifolia* (6/6), *V. davidii* (10/11), and *V. piasezkii* (9/9) were judged to be broadly resistant species. However, intraspecific variations are obvious overall. For example, SIs of *V. quinquangularis* (15 clones) ranged from ER to HS (Tab. 2). Fig. 2 presents a histogram showing the variation in resistance within species of the 90 *Vitis* clones tested in this study.

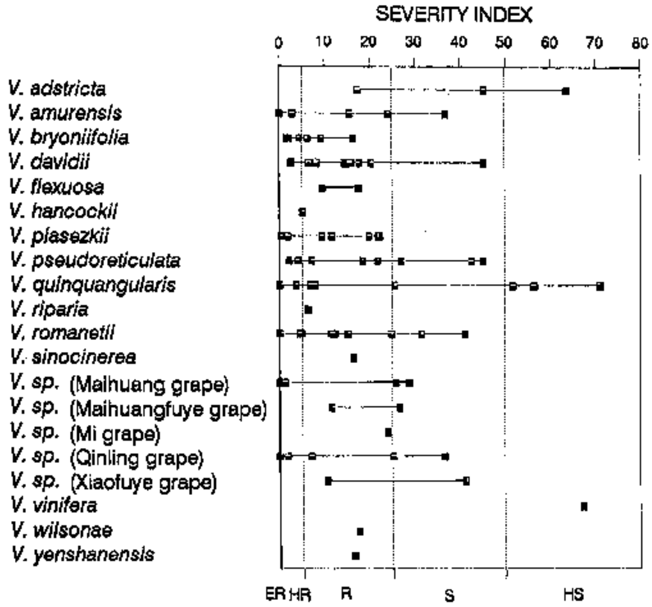

Fig. 2: A histogram directly showing the resistance variations of the 90 *Vitis* clones to *Uncinula necator* in natural infection experiments at Yangling, Shaanxi, P. R. China. The solid squares represent the means of severity index from 1991 and 1992. ER, extremely resistant; HR, highly resistant; R, resistant; S, susceptible; HS, highly susceptible.

The intraspecific variation found in this experiment has been found in other resistance evaluations (Doster and Schnathorst 1985; Gadoury and Pearson 1991). Early reports (Boubals 1961) on Chinese *Vitis* usually focused on the interspecific variation, likely because of the small number of available accessions of Chinese *Vitis*. Therefore, parents for breeding should be selected from specific clones identified in this study, or clonal variability within species should be considered before crosses are made.

We also observed that the resistance to *U. necator* of the studied species is not related to their geographical origins. For example, three clones of *V. pseudoreticulata*, collected from Guangxi province (southern China) had SIs from 4.22 to 45.26, whereas the SIs of four clones from northern China (Shaanxi province) ranged from 2.19 to 27.01 (Tab. 2). Thus, resistance is not unique to either southern or northern accessions.

Gadoury and Pearson (1991) explained that resistance or susceptibility variations of some grape cultivars might be due to the presence of pathogenicity specialization in *U. necator*. No study on pathogenicity specialization of *U. necator* has been done in China, therefore our results can only be interpreted in the context of exposing plants to isolates of uncharacterized pathogenicity and virulence.

This work is the most extensive and comprehensive evaluation of Chinese *Vitis* for resistance to powdery mildew disease. 13 out of the 27 known *Vitis* species from 12 provinces were tested (Tab. 1, Fig. 1). Five Chinese native

Table 2

Severity index and resistance ratings of 90 *Vitis* clones resistant to *Uncinula necator* from experiments in 1991 and 1992

	Natural Infection				Artificial Inoculation			
No.	1991	1992	Mean±Deviation	Rating	1991	1992	Mean±Deviation	Rating
V. adstricta								
1	46.55	43.93	45.24 ± 1.31	S	-	-	-	-
2	18.32	16.34	17.33 ± 0.99	R	16.92	9.52	13.22 ± 3.70	R
3	44.31	82.78	63.55 ± 19.24	HS	-	-	-	-
V. amurensis								
4	25.57	22.71	24.14 ± 1.43	R	-	-	-	-
5	16.98	14.28	15.63 ± 1.35	R	0	0	0	ER
6	4.45	1.47	2.96 ± 1.49	HR	-	-	-	-
7	42.65	30.91	36.78 ± 5.87	S	52.58	43.54	48.06 ± 4.52	S
8	0	0	0	ER	0	0	0	ER
V. bryoniifolia								
9	1.64	1.641	1.64 ± 0.00	HR	-	-	-	-
10	2.46	2.04	2.25 ± 0.21	HR	0	0	0	ER
11	10.71	8.06	9.39 ± 1.33	R	-	-	-	-
12	19.13	13.86	16.50 ± 2.64	R	6.36	9.90	8.13 ± 1.77	R
13	4.73	4.29	4.51 ± 0.22	HR	-	-	-	-
14	7.54	5.12	6.33 ± 1.21	R	-	-	-	-
V. davidii								
15	4.11	1.63	2.87 ± 1.24	HR	-	-	-	-
16	48.83	41.69	45.26 ± 3.57	S	-	-	-	-
17	3.60	1.76	2.68 ± 0.92	HR	-	-	-	-
18	8.41	5.33	6.87 ± 1.54	R	-	-	-	-
19	16.87	15.16	16.02 ± 0.86	R	-	-	-	-
20	24.46	6.88	15.67 ± 8.79	R	-	-	-	-
21	23.76	17.12	20.44 ± 3.32	R	-	-	-	-
22	9.40	7.30	8.35 ± 1.05	R	-	-	-	-
V. quinquangularis Rehd.Dan-4Shaanxi								
23	8.60	4.74	6.67 ± 1.93	R	-	-	-	-
24	23.15	12.41	17.78 ± 5.37	R	0	0	0	ER
25	14.96	14.16	14.56 ± 0.40	R	4.19	4.33	4.26 ± 0.07	HR
V. flexuosa								
26	20.06	15.04	17.55 ± 2.51	R	-	-	-	-
27	12.65	6.49	9.57 ± 3.08	R	-	-	-	-
V. hancockii								
28	6.57	3.78	5.18 ± 1.40	R	-	-	-	-
V. piasezkii								
29	0	3.43	1.72 ± 1.72	HR	-	-	-	-
30	24.44	19.14	21.79 ± 2.65	R	10.39	19.54	14.97 ± 4.57	R
31	0.88	2.78	1.83 ± 0.95	HR	-	-	-	-
32	12.65	10.21	11.43 ± 1.22	R	-	-	-	-
33	18.12	5.40	11.76 ± 6.36	R	-	-	-	-
34	0.54	0.19	0.37 ± 0.18	HR	-	-	-	-
35	13.24	5.52	9.38 ± 3.86	R	-	-	-	-
36	24.78	14.86	19.82 ± 4.96	R	-	-	-	-
37	23.81	20.61	22.21 ± 1.60	R	-	-	-	-
V. pseudoreticulata								
38	6.14	2.29	4.215 ± 1.93	HR	-	-	-	-
39	39.29	45.87	42.58 ± 3.29	S	-	-	-	-
40	49.16	41.36	45.26 ± 3.90	S	-	-	-	-
41	24.75	18.79	21.77 ± 2.98	R	-	-	-	-
V. pseudoreticulata								
42	7.67	6.55	7.11 ± 0.56	R	0	0	0	ER
43	3.30	1.07	2.19 ± 1.12	HR	0	0	0	ER
44	27.14	26.88	27.01 ± 0.13	S	49.01	38.77	43.89 ± 5.12	S
45	29.12	7.86	8.49 ± 10.63	R	-	-	-	-

Table 2, continued

	Natural Infection				Artificial Inoculation			
No.	1991	1992	Mean±Deviation	Rating	1991	1992	Mean±Deviation	Rating
V. quinquangularis								
46	61.78	51.32	56.55 ± 5.23	HS	-	-	-	-
47	8.36	5.04	6.70 ± 1.66	R	-	-	-	-
48	10.33	5.47	7.90 ± 2.43	R	-	-	-	-
49	0	0	0	ER	0	0	0	ER
50	8.55	5.31	6.93 ± 1.62	R	0	0	0	ER
51	0	0	0	ER	0	0	0	ER
52	4.66	2.62	3.64 ± 1.02	HR	0	0	0	ER
53	0	0	0	ER	-	-	-	-
54	0	0	0	ER	-	-	-	-
55	0	0	0	ER	0	0	0	ER
56	30.16	20.96	25.56 ± 4.60	S	-	-	-	-
57	55.18	48.32	51.75 ± 3.43	HS	-	-	-	-
58	59.11	53.69	56.40 ± 2.71	HS	29.58	24.22	26.90 ± 2.68	S
59	77.16	64.88	71.02 ± 6.14	HS	-	-	-	-
60	0	0	0	ER	0	0	0	ER
V. riparia								
61	8.19	4.41	6.30 ± 1.89	R	0	0	0	ER
V. romanetii								
62	13.36	9.44	11.40 ± 1.96	R	-	-	-	-
63	45.58	36.56	41.07 ± 4.51	S	37.99	28.41	33.20 ± 4.79	S
64	14.34	10.20	12.27 ± 2.07	R	3.06	2.94	3.00 ± 0.06	HR
65	7.40	2.67	5.04 ± 2.37	R	-	-	-	-
66	25.72	23.86	24.79 ± 0.93	R	-	-	-	-
67	47.05	15.77	31.41 ± 15.64	S	58.92	8.16	33.54 ± 25.38	S
68	12.05	11.43	11.74 ± 0.31	R	16.50	9.74	13.12 ± 3.38	R
69	4.88	4.14	4.51 ± 0.37	HR	-	-	-	-
70	15.08	15.18	15.13 ± 0.05	R	9.11	6.36	7.74 ± 1.38	R
71	0	0	0	ER	-	-	-	-
V. sinocinerea								
72	17.12	15.38	16.25 ± 0.87	R	-	-	-	-
V. sp. (Maihuang grape)								
73	0	0	0	ER	0	0	0	ER
74	0	0	0	ER	0	0	0	ER
75	24.98	26.69	25.84 ± 0.86	S	44.74	39.88	42.31 ± 2.43	S
76	31.15	26.31	28.73 ± 2.42	S	-	-	-	-
77	2.04	0.58	1.31 ± 0.73	HR	6.25	4.47	5.36 ± 0.89	R
V. sp. (Maihuangfuye grape)								
78	28.39	25.13	26.76 ± 1.63	S	44.92	37.94	41.43 ± 3.49	S
79	14.44	8.82	11.63 ± 2.81	R	2.80	1.14	1.97 ± 0.83	HR
V. sp. (Mi grape)								
80	25.41	22.61	24.01 ± 1.40	R	0	0	0	ER
V. sp. (Qinling grape)								
81	0	0	0	ER	-	-	-	-
82	45.11	28.15	36.63 ± 8.48	S	-	-	-	-
83	29.59	20.83	25.21 ± 4.38	S	-	-	-	-
84	2.33	1.43	1.88 ± 0.45	HR	-	-	-	-
85	10.28	3.86	7.07 ± 3.21	R	20.07	17.13	18.60 ± 1.47	R
V. sp. (Xiaofuye grape)								
86	43.15	39.54	41.35 ± 1.81	S	40.16	37.76	38.96 ± 1.20	S
V. sp. (Xiaofuye grape)								
87	11.85	9.43	10.64 ± 1.21	R	-	-	-	-
V. vinifera								
88	74.84	59.88	67.36 ± 7.48	HS	48.76	43.62	46.19 ± 2.57	S
V. wilsonae								
89	19.70	15.34	17.52 ± 2.18	R	-	-	-	-
V. yenshanensis								
90	30.10	3.06	16.58 ± 13.52	R	11.42	6.12	8.77 ± 2.65	R

species (Maihuang, Qinling, Mai-huangfuye, Xiaofuye, and Mi), which are awaiting taxonomic description, were also evaluated.

The introduction of American native grapes has greatly facilitated disease-resistance breeding programs in viticulture (ALLEWELDT and POSSINGHAM 1988). The breeding potential of Chinese *Vitis*, accounting for more than 40 % of the known species, has, in contrast, been neglected for a long time. Chinese *Vitis* do not possess undesirable foxy flavors, as does *V. labrusca*, and are much more compatible in crossing with *V. vinifera* than the multi-disease-resistant *Muscadinia rotundifolia*. The authors (HE and WANG) had made successful crosses between 13 clones from five species of Chinese *Vitis* (*V. davidii*, *V. piazeskii*, *V. pseudoreticulata*, *V. quinquangularis*, and *V. romanetii*) and *V. vinifera* (data not shown) and are preparing to assess their progeny for fruiting characteristics in addition to powdery mildew resistance. We, therefore, conclude that Chinese native *Vitis* species are a valuable resource for future grape disease resistance breeding programs.

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