Resistance of Chinese *Vitis* species to *Elsinoë ampelina* (de Bary) Shear

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Abstract. Resistance to grape anthracnose [*Elsinoë ampelina* (de Bary) Shear] was evaluated in 13 known *Vitis* species and five taxonomically undescribed grapes native to China. One hundred and eight clones of Chinese *Vitis* species were tested under field conditions between 1990 and 1992. Berry infection did not occur in these species. Leaves displayed strong resistance to anthracnose, although intraspecific variations were observed. There was no relationship between anthracnose resistance and geographical origin of the species. Results from this study indicate that oriental grape species are useful for disease-resistance breeding.

Anthracnose disease may cause severe damage to grapevines and crop loss in most cultivars of *Vitis vinifera* L. grown in warm and humid climates. Brook (1973) described the growth, development, and epidemiology of the disease. Sources of resistance include *V. aestivalis* Michx., *V. champini*, *V. labrusca* L., *V. rupestris* Scheele, *V. shuttleworthii* House, *V. tiliifolia* Humb. & Bonp., *V. vulpina* L., *V. munsoniana* Simps., and *V. rotundifolia* Michx. (Mortensen, 1981). Evaluation for the disease based on vineyard observations was more reliable than an artificial inoculation technique.

Grape production in China has dramatically increased in the past 10 years and the cultivated area now occupies at least 87,000 ha (Fu, 1988). However, production in the Changjiang Valley and southern part of China has fluctuated since 1950, mainly because of the susceptibility of most *V. vinifera* cultivars to anthracnose disease. Utilization of host plant resistance through breeding would be an effective and economical strategy to control grape anthracnose (He and Wang, 1988). Sources of resistant grape germplasm are 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 (He et al., 1991). Among the ~70 known species, >27 have their origins in China, where they are found in every region (Wang, 1993). The value of wild Chinese *Vitis* germplasm has been largely overlooked until recently (Staudt, 1980; Wang et al., 1995;

Zhang et al., 1989). In addition to their potential as sources of disease resistance, Chinese *Vitis* species do not have the foxy flavor that limits the use of *V. labrusca* in breeding programs (Alleweldt and Possingham, 1988; He et al., 1991). Incorporating disease resistance genes from Chinese *Vitis* species into *V. vinifera* has proven successful. For example, 'Beichun', a hybrid of 'Muscat Hamburg' x *V. amurensis*, was released by the Beijing Botanical Garden and possesses a high level of resistance to anthracnose without a foxy flavor.

The objective of this study was to identify anthracnose-resistant grape genotypes among wild Chinese species.

Materials and Methods

A total of 13 Chinese *Vitis* species and five species not yet described taxonomically, comprising 108 genotypes, were evaluated from 1990 to 1992 (Table 1). These clones were collected from mountainous and piedmont regions in 12 provinces and autonomous regions in China (Fig. 1). The clones from Shaanxi and Gansu provinces were taken as cuttings from individual wild plants on site by the authors from 1981 to 1985, while all others were obtained from research institutions in China. The wild species were grafted onto *V. vinifera* 'Muscat Hamburg' rootstocks. Three plants for each clone were maintained in the vineyard of the Northwestern Agricultural Univ., Yangling, Shaanxi, People's Republic of China, at a 1.5 × 2.5-m spacing. *V. riparia* (the clone name or accession number was not known) and *V. vinifera* 'Carignane' were used as resistant and susceptible controls, respectively. No pesticides were used during the period of disease evaluation.

In Shaanxi province, the lowest temperature is about -15 °C (January) and the highest temperature is ~35 °C (July). The rainy season occurs from July to September with average

annual rainfall ~580 mm. Under natural conditions, anthracnose usually appears in May and peaks in June and July. For this reason, evaluation and screening was performed in June and July when anthracnose symptoms were fully developed.

Three hundred leaves and berries of 50 clusters were surveyed for each clone. The symptoms on each leaf and cluster were rated from 0 to 7, based on the estimated percentage of lesion over the whole leaf and cluster areas. Grade 0 = no symptoms, grade 1 = 0.1% to 5.0%, grade 2 = 5.1% to 15.0%, grade 3 = 15.1% to 30.0%, grade 4 = 30.1% to 45.0%, grade 5 = 45.1% to 65.0%, grade 6 = 65.1% to 85.0%, and grade 7 = >85.0%. The grades were then converted into a severity index (SI). $SI = \{[\text{sum of (grade value} \times \text{number of leaves or clusters in that grade)}] / [\text{total leaf or cluster number} \times 7 \text{ (the highest grade value)}]\} \times 100$. The resistance level of each clone was arbitrarily rated in five categories based on its SI, as follows: extremely resistant (ER), SI = 0; highly resistant (HR), SI = 0.1–5.0; resistant (R), SI = 5.1–25.0; susceptible (S), SI = 25.1–50; highly susceptible (HS), SI = 50.1–100.

Results and Discussion

Among the 64 clones of the Chinese species that set fruits, none of the berries were infected (SI = 0) (Table 1). The berries of *V. vinifera* 'Carignane' had an SI of 84.36, and were highly susceptible to the disease. *Vitis riparia* is a male vine and thus no information regarding the resistance of its fruits to the disease was obtained. The leaves among the 108 clones ranged from resistant (94 clones) to highly resistant (14 clones). *Vitis riparia*, a resistant control with an SI of 8.64, fell into the resistant category, whereas *V. vinifera* 'Carignane' was highly susceptible (leaf SI = 55.60).

Among the 12 Chinese *Vitis* species with three or more clones, six species showed intraspecific variation ranging from highly resistant to resistant, while the others uniformly fell into the resistant category. The results, demonstrated herein, are very similar to the previous report on the anthracnose resistance of 86 clones of wild Chinese *Vitis* species (He and Wang, 1988).

We also observed that the resistance to anthracnose is not related to a species' geographical distribution. For example, all nine clones of *V. davidii* were resistant to the disease, although these included clones from both southern (Jiangxi Province) and northern China (Shaanxi Province) (Table 1 and Fig. 1). Among the 15 clones of *V. piasezkii* collected from Shaanxi Province, the SI ranged from 3.07 (highly resistant) for Mei-4 to 12.90 for Baishui-27 and Hua-1 (resistant). Two clones of *V. quinquangularis* (Xun-3 and Shang-24) from northern China (Shaanxi province) were rated HR, with SIs of 1.51 and 4.06, respectively, while the other 11 clones from Shaanxi province had SIs ranging from 5.10 to 9.20, falling into the resistant category. The other two clones of this species, one (Yongfu) collected from southern China, Guangxi Prov-

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Table 1. Severity index and rating of resistance to *Elsinoë ampelina* of 108 Chinese *Vitis* clones under natural conditions in 1990–92.

Clone ^z	Source	SI ^y	RL ^x	Fruit set	Clone	Source	SI ^y	RL ^x	Fruit set
<i>V. adstricta</i> Hance									
Taishanputao-1	Shandong	1.5	HR	+	Yanshanputao	Hebei	7.8	R	–
Taishanputao-2	Shandong	7.0	R	–					
<i>V. amurensis</i> Rupr.									
74003	Jilin	6.9	R	+	Shuangqing ^b	Jilin	5.3	R	+
74-1-88 ^a	Jilin	7.5	R	+	Taishan-11	Shandong	10.9	R	+
74-1-326 ^a	Jilin	11.3	R	+	Tonghua-3	Jilin	13.1	R	+
Liaoning	Liaonin	4.1	HR	–	Zuoshan-1	Jilin	15.1	R	+
Shanputao	Heilongjiang	6.4	R	+					
<i>V. betulifolia</i> Diels & Gilg									
Liu-3	Shaanxi	5.6	R	+					
<i>V. bryoniifolia</i> Bunge									
Anlin-16	Anhui	9.7	R	–	Anlin-25	Anhui	14.6	R	–
Anlin-18-1	Anhui	17.5	R	+	Anlin-28	Anhui	6.8	R	+
Anlin-18-2	Anhui	8.3	R	+	Anlin-29	Anhui	6.4	R	–
<i>V. davidii</i> (Roman.) Foex.									
Jiangxi-4	Jiangxi	7.9	R	–	Ning-6	Shaanxi	18.5	R	+
Jinan-1	Shandong	9.1	R	–	Ning-7	Shaanxi	9.4	R	+
Jinan-2	Shandong	12.6	R	+	Tangwei ^b	Jiangxi	11.4	R	+
Lue-4	Shaanxi	9.3	R	+	Xuefeng	Hunai	7.3	R	+
Ning-5	Shaanxi	8.5	R	+					
<i>V. davidii</i> var. <i>cyanocarpa</i> (Gagn.) Sarg.									
Lan-5	Shaanxi	9.8	R	–	Zhen-3	Shaanxi	10.7	R	+
Nan-6	Shaanxi	10.1	R	–					
<i>V. flexuosa</i> Thunb.									
Yang-2	Shaanxi	4.5	HR	–					
<i>V. flexuosa</i> var. <i>parvifolia</i> (Roxb.) Gagn.									
Shang-2	Shaanxi	7.5	R	–					
<i>V. hancockii</i> Hance									
Jiangxi-5	Jiangxi	6.1	R	–					
<i>V. piasezkii</i> Maxim.									
Bai-22-1	Shaanxi	8.3	R	+	Liu-6	Shaanxi	11.0	R	+
Baishui-27	Shaanxi	12.9	R	–	Liu-7	Shaanxi	8.4	R	+
Baishui-30	Shaanxi	11.7	R	–	Liu-8	Shaanxi	12.3	R	+
Baishui-31	Shaanxi	12.3	R	–	Liu-9	Shaanxi	11.0	R	–
Baishui-40	Shaanxi	12.5	R	+	Mei-4	Shaanxi	3.0	HR	+
Gansu-91	Gansu	10.3	R	+	Mei-6	Shaanxi	12.0	R	+
Hua-1	Shaanxi	12.9	R	+	Nan-2	Shaanxi	9.1	R	–
Hua-2	Shaanxi	9.5	R	+	Ninggu-1	Ningxia	10.1	R	+
Hua-47	Shaanxi	8.7	R	+					
<i>V. pseudoreticulata</i> W.T. Wang									
Bai-13-1	Shaanxi	6.3	R	+	Guangxi-2	Guangxi	6.1	R	–
Bai-35-1	Shaanxi	7.8	R	+	Jiangxi-3	Jiangxi	5.3	R	–
Bai-36-1	Shaanxi	5.5	R	+	Shang-1	Shaanxi	7.3	R	+
Guangxi-1	Guangxi	7.6	R	+	Xun-1	Shaanxi	6.6	R	–
<i>V. quinquangularis</i> Rehd.									
83-4-93 ^c	Shaanxi	6.7	R	+	Shang-24	Shaanxi	1.5	HR	+
83-4-96 ^c	Shaanxi	5.8	R	+	Taishan-12	Shandong	13.3	R	+
Dan-1	Shaanxi	7.3	R	+	Wei-2	Shaanxi	9.2	R	+
Dan-2	Shaanxi	6.3	R	+	Wei-3	Shaanxi	8.9	R	+
Dan-4	Shaanxi	5.5	R	+	Wei-4	Shaanxi	8.0	R	+
Dan-11	Shaanxi	7.1	R	+	Xun-3	Shaanxi	4.1	HR	+
Mei-1	Shaanxi	5.1	R	–	Yongfu	Guangxi	13.3	R	–
Mei-2	Shaanxi	7.2	R	+					
<i>V. riparia</i> Michx.									
?	U.S.A.	8.6	R	–					
<i>V. romanetii</i> Roman.									
Bai-22-2	Shaanxi	10.8	R	–	Liu-12	Shaanxi	2.5	HR	–
Jiangxi-1	Jiangxi	5.5	R	+	Liu-13	Shaanxi	9.9	R	+
Jiangxi-2	Jiangxi	6.3	R	+	Ping-2	Guangxi	12.4	R	+
Liu-1	Shaanxi	4.9	HR	+	Ping-7	Guangxi	3.9	HR	+
Liu-11	Shaanxi	4.1	HR	+	Shang-23	Shaanxi	7.9	R	+
<i>V. sinocinerea</i> W.T. Wang									
Lan-2	Shaanxi	9.3	R	–					
<i>V. sp.</i> (Maihuan grape)									
Bai-36-2	Shaanxi	9.0	R	+	Bai-44	Shaanxi	7.1	R	–
Bai-41	Shaanxi	7.9	R	+	Xun-8	Shaanxi	6.3	R	+
Bai-42	Shaanxi	2.9	HR	+					

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Table 1. Continued.

Clone ^a	Source	SI ^b	RL ^c	Fruit set	Clone	Source	SI ^b	RL ^c	Fruit set
Bai-40	Shaanxi	1.7	HR	V. sp. (Maihuangfuye grape) +	Bai-117	Shaanxi	5.8	R	+
Xun-4	Shaanxi	9.0	R	V. sp. (Mi grape) —					
An-16	Shaanxi	8.5	R	V. sp. (Qinling grape) —	Ning-10	Shaanxi	9.9	R	—
Bai-13-2	Shaanxi	9.8	R	—	Ping-5	Shaanxi	7.4	R	+
Dan-6	Shaanxi	5.4	R	—	Shan-36	Shaanxi	11.2	R	—
Lan-6	Shaanxi	7.1	R	—	Shan-39	Shaanxi	9.7	R	—
Lan-174	Shaanxi	5.2	R	—	Shan-40	Shaanxi	7.8	R	—
Lue-8	Shaanxi	10.5	R	—					
Lui-10	Shaanxi	5.0	HR	V. sp. (Xiaofuye grape) +	Ning-3	Shaanxi	5.6	R	—
Carignane	France	55.6	HS	V. vinifera L. +					
Yang-1	Shaanxi	3.4	HR	V. wilsonae Veitch. —					
Yanshan-1	Hebei	1.4	HR	V. yenshanensis +					

^aa = Clones derived from intraspecific hybridization of *V. amurensis*; b = clones with hermaphrodite flowers; c = clones derived from open-pollinated seeds of *V. quinquangularis*.

^bSI = severity index.

^cRL = resistance level; HR = highly resistant; R = resistant; HS = highly susceptible.

ince, and the other (Taishan-12) from northern China, Shandong Province, were both rated resistant. Among the 10 clones of *V. rotundifolia*, three of the four highly resistant clones were from Shaanxi Province (northern China), and one clone was from Guangxi Province (southern China). The other six clones, regardless of whether collected from southern or northern China, were all resistant to the disease. These observations indicate that resistance is not unique to either southern or northern accessions of Chinese *Vitis* species.

This work greatly enhances our knowledge of resistance to anthracnose disease among Chinese *Vitis* species. Thirteen out of the 27 known Chinese *Vitis* species, and five undescribed species (Maihuang, Qinling, Maihuangfuye, Xiaofuye, and Mi) from 12 provinces and autonomous regions, were included in this evaluation.

Resistance to anthracnose disease was found in native American species such as *V. labrusca* L., *V. aestivalis* Sims., *V. champini* Planch., *V. rupestris* Scheele., *V. shuttleworthii* House, *V. vulpina* L. and *V. rotundifolia* Michx. (Mortensen, 1981). The introduction of American native grapes has greatly facilitated breeding for disease resistance (Alleweldt and Possingham, 1988). The breeding potential of Chinese *Vitis*, which accounts for >40% of the known species, has, in contrast, long been neglected by researchers outside China. Recent research (He and Wang, 1988; He et al., 1991) indicates that the Chinese *Vitis* species are another source for improving disease resistance of European grapes. In addition, the Chinese *Vitis* species do not possess undesirable foxy flavors, as does *V. labrusca*, and are much more compatible with *V. vinifera* than the multidisease-resistant *V. rotundifolia* Michx. The anthracnose-resistant genes seem dominantly inherited by the F₁ progenies of *V.*

vinifera × Asiatic species. He and Wang (unpublished data) successfully crossed 13 clones from five Chinese *Vitis* species (*V. davidii*, *V. piasezkii*, *V. pseudoreticulata*, *V. quinquangularis*, and *V. rotundifolia*) with *V. vinifera*, and produced 1565 interspecific hybrids. These hybrids, like their wild parents, were all resistant to anthracnose (data not shown). Another example is the cultivar 'Beichun', an interspe-

cific hybrid of *V. vinifera* 'Muscat Hamburg' × *V. amurensis* that has very good resistance to anthracnose. It has been successfully grown in the Changjiang Valley and the southern part of China. We therefore conclude that the Chinese *Vitis* species are a valuable resource for resistance to grape anthracnose disease and valuable materials for future breeding programs for disease resistance in grapes.

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

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