

Studies on germplasm resources of wild grape species (*Vitis* spp.) in China

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S u m m a r y : China is the country rich in germplasm resources of the genus *Vitis*, with nearly 40 native species. This paper introduces into their geographical distribution and chief characteristics, utilization and research on 11 wild species.

K e y w o r d s : gene resources, China, geography, *Vitis*, variety of vine, new breeding, ampelography, enzyme, selection, must quality, frost resistance, disease resistance.

Introduction

China has a vast territory with complex geographical environments and greatly different climate, soil and topography in various areas, possessing various species of plants. Among these there are abundant species of Vitaceae and *Vitis* germplasm resources. The collection of *Vitis* species and study on them made by the present authors over many years show that nearly half of the 80 or so species of *Vitis* in the world are native to China (and 10 more new species yet to be published), some of which have been directly used in winemaking industry or used for breeding or as rootstock, and *V. amurensis* is the most valuable one. By means of updated biological techniques an overall study of wild grape germplasm resources in China may offer a glorious prospect for breeding.

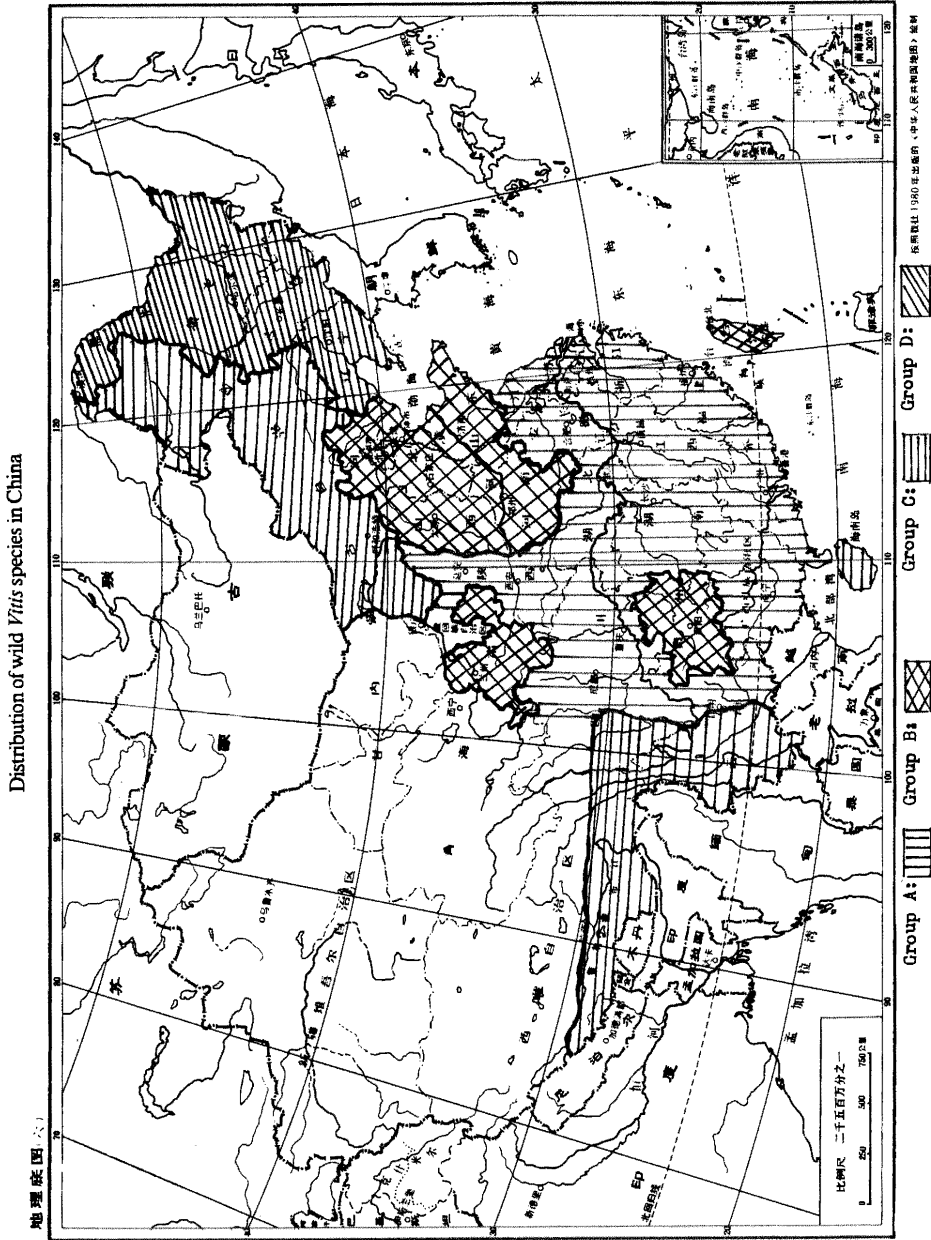
I. Distribution of wild grape germplasm resources in China

There are over 30 species of the genus, distributed almost throughout China. According to their geographical distributions, one may distinguish 4 groups: Group A of 20 species are in Jiangxi, Guangdong, Hubei, Hunan, Henan, Zhejiang, Shaanxi, Fujian, Sichuan, Jiangsu, Anhui, Guangxi, Yunnan, with 12-20 species in each province. Group B of 10 species are in Guizhou, Gansu, Hebei, Shanxi, Shandong, Taiwan, with 6-10 species in each. Group C of 3 species are in Hainan, Tibet and Inner Mongolia, with 2-3 species in each. Group D has only one species in Heilongjiang, Jilin and Liaoning. The distribution map shows that *Vitis* species are most numerous in the middle and lower reaches of the Yangtze River and the region of the Nanling range, whereas in the vast areas of Northwest and Northeast China the number of wild species is very small, and it is noteworthy that in North-East China there is only one species, *V. amurensis*. This is due to their different places of origin, ecological conditions in their areas of distribution and the result of evolution and development of the species.

1. From the map of distribution it can be seen that Jiangxi, Guangdong, Hubei, Hunan, Henan, Zhejiang Provinces have the most species, with over 17 species in each. The further away from this central area of distribution, the fewer species there are. For example, only 1 species is found in North-East China, in Inner Mongolia 2, in Tibet 3, and in Hainan Province 3.

2. Among these species *V. flexuosa* is most widely distributed, followed by *V. ficifolia*, *V. quinquangularis* REHD., *V. davidii* FOEX, *V. bryoniaefolia* BGE.; *V. amurensis* and *V. yenshanensis* are not found in this area.

3. The central area of distribution is not only abundant in the number of species, but also has species which are regarded as primitive, such as *V. quinquangularis*, *V. davidii*, *V. davidii* var.



cyanocarpa, *V. pseudoreticulata* and *V. romanetii*; *V. piasezkii* and *V. wenchowensis*, *V. adstricta* var. *ternata*, *V. hui* are endemic species in the area.

4. Based on the study of the morphology, origin, distribution and eco-geography of each of the species, as well as on their quantitative classification and isoenzyme analysis, we regard Central China as the center of distribution of the *Vitis* species in China, and probably also their center of origin.

II. Several important wild species of grape

1. *Vitis amurensis* RUPR.

The growing tip is yellow-green with a purplish red tone and covered with thick, long, canescent tomentum. The young leaf is yellowish green with a light purplish red tone. The lower surface of the young leaf is covered with extremely thick, light yellow tomentum. The leaf is thick and rough. The leaf is 3-5 lobed or entire, with shallow and obtuse serrature and with setae on the vein of the lower surface. The petiole is often shorter than the mid vein. In autumn, the leaf turns bright purplish red.

It is dioecious, but some have perfect flowers. The cluster is conical or cylindric. The berries are uniform in size, loosely born. The mean length of the clusters measures 12.0 cm, the width 6.7 cm, each weighs 38 g. The berry is small, weighing 0.56 g, near round, diameter near 1 cm, dark purple, with thick skin, less flesh and juice, tastes very sour; on average there are 4 seeds in each berry.

Trained on espalier, the vine is vigorous. In Beijing, it breaks bud in early April, 10-15 d earlier than other common cultivars of *V. vinifera*, and blooms in mid May. In mid and late July shoots begin to mature; the berries ripen in mid August. The growing period is 137 d on average. Active temperatures sum up to 2985 °C. The fertility of bearing canes is best between the 4th and the 9th nodes, in general a shoot bears 1-2 (3) clusters. The juice is bright reddish purple. The juice extraction rate is 51.3 %, the °Brix content 10.5 %, the acid content 2.53 %.

The distribution of species is the most north of China. This species is very hardy. It tolerates severe below zero temperature down to -40-52 °C. It is resistant to powdery mildew, scab and white rot, but not to downy mildew. It is mainly used locally for red wine, but also as pigment for food. It is also a valuable hardy and disease resistant parent for breeding.

2. *Vitis ficifolia* BUNGE

The young shoots, petioles and rachis are covered with thick, white, arachnoid tomentum which is later lost. The mature shoot presents dark brown color, covered with thick, white pubescence. The tendril is long, up to 20 cm but few in number. The growing tips are yellowish-green with a light yellow tone, and covered with thick, milky, arachnoid tomentum. The young leaf is yellowish-green with a dark red tone. The lower surface of the leaf is covered with thick, milky and arachnoid tomentum. Sometimes the lower leaves have a ferruginous tone. The leaves are thick, scabrous, dark green, finely serrated, 11-25 cm long, most with 3 shallow lobes or entire, 5 deep lobes at lower part of vines. The leaf stalk is often shorter than the mid vein. In autumn, the leaf turns brownish yellow.

The cluster is nearly conical, small and loose; the berries are uniform; the length and width of clusters are 14.5 cm and 9.35 cm respectively, each cluster weighing 29.5 g on average. The berry is small and round, weighing 0.81 g, black, with thick skin and little pulp, tastes sour and astringent; most berries contain 1-2 seeds.

Under espalier training, the vine growth is moderate. Its phenological periods are later than those of common cultivars of *V. vinifera* and a month later than that of *V. amurensis*. In Beijing, it breaks bud in mid April and blooms in early June. The shoot begins to mature in late August and has reached maturity in early October. The growing period lasts 158 d. The accumulated active temperature requires for ripening 3518 °C. Its fruiting ability is the best of all wild species. Over 80 % of all buds form fruiting shoots, often the canes bear 5-7 fruiting shoots, some up to 10, each with 3-4 (5) clusters. The juice is dark red; the juice content is 57.5-63.8 %, the °Brix content 12.2-14.6 %, the acid content 1.35-1.73 %.

This species tolerates below zero temperature down to -20 °C. It can survive winter safely without being buried in North China. It is resistant to scab, powdery mildew, downy mildew. As the berry is small and of poor quality it is not used as table grape. Since the lower surface of the leaf

is covered with very beautiful thick, silvery tomentum, it is used for ornamental purpose. It is also a good high-yield, hardy and disease resistant parent for breeding.

3. *Vitis davidii* FOEX

The vine is sturdy and covered densely with spines. The spine is straight or slightly bending on top. The leaf is large with undulated teeth; the upper surface is dark green and the lower surface is gray; only the vein axils are covered with glandular hair; the leaf stalk is usually covered sparsely with small spines.

It is dioecious, but in recent years hermaphrodite individuals were also found with panicles, which are often longer than the leaf. 21.5 cm in length. The berry is large, round, dark purple, 1-1.5 cm in diameter, 3 g in weight; the skin of berry is thick; the berry contains little juice, tastes lightly sweet and matures late; it endures long storage and transport; most berries contain 2 (1-4) seeds. The sugar content is 11.5-15.0 %, the acid content is 0.62-0.91 %.

It tolerates very humid, shaded conditions and hot, dry climates. It is long-lived, high yielding, resistant to scab, anthracnose and other diseases and insect pests. In Nanjing Sun Yat-sen Botanical Garden, it has been used as a pollen parent in breeding for disease resistance.

There is a variety of this species, with nodule vines, *V. davidii* var. *cyanocarpa* SARG., which is slender, with fewer spines and smaller leaves than *V. davidii*. The cluster is 20-35 cm in length, the berry is larger than that of *V. davidii*, blue in color, contains much juice and tastes sweet. This variety is more tolerant to humid and shaded conditions than *V. davidii* and is a better parent for breeding new cultivars adaptable to the wet and hot climate in South China.

4. *Vitis flexuosa* THUNB.

The vine is slender, the young shoot is canescent, the tendril is thin and long; the leaf is small, wide cordiform or near truncate at the base; the leaf margin is undulate with uneven teeth; the leaf is thin and tough; the vein axils on the lower surface of the leaf are puberulent; the leaf stalk is 3-7 cm long, covered with canescent, arachnoid tomentum.

The panicle is slender, 6-14 cm in length; the berry is round, 6-8 mm in diameter, dark purple, very acid. It contains 2-3 seeds. The °Brix content is 12 %.

This species has strong sprouting ability and adaptability, it tolerates humid and hot climate, lives long, is lightly less resistant to scab than *V. davidii* and *V. adstricta*. There is a variety *V. flexuosa* var. *parvifolia* (ROXB.) GAGNEP. within this species.

5. *Vitis pentagona* DIELS et GILG (synonym *V. quinquangularis* REHD.)

Growing tip and young leaves are covered with white or brownish red, thick, arachnoid tomentum, mature shoots purplish brown. The leaf is narrow ovate or pentagonal, with or without three obscure lobes, 10-15 cm in length; the margin teeth are thin, shallow and obtuse; the base is near truncate or shallow cordiform; the lower surface is covered with thick, brownish red tomentum; leaf stalk is covered with white pubescence.

The vine is dioecious with panicle 8-16 cm long. It produces many clusters with sparsely borne berries; the berry is dark purple and round; 6-8 mm in diameter; the juice extraction rate is 63.7 %; the °Brix content is 17 %; most berries contain 2-3 seeds.

It is resistant to scab and can be used as breeding material for disease resistance.

V. pentagona var. *honanensis* REHD. has leaves with marked incisions with narrower sinuses. It is distributed over the north slope of Qinling range in Shaanxi Province.

6. *Vitis piasezkii* MAXIM.

The young shoot and leaf stalks are covered with brown, puberulent and glandular hairs. Almost all shoots sprouted from the canes bear fruit. Leaves are very variable in shape, either simple or compound on the same shoot. The simple leaf is ovate, 4-9 cm in length; the leaf tip is

acute, the base is wide cordiform; the leaf is lobed, partite or sected with 3-5 leaflets, most have 5 leaflets. The mid leaflet is rhombic, 9-12 cm long. The leaf base is cuneate, with short stalk; the leaflets on both sides have no stalk, the base is oblique; some leaves have all the leaflets with stalks. The leaf margin has coarse teeth. The upper surface is glabrous, dark green; the lower surface light green with yellowish-brown tomentum.

The panicle is 5-15 cm in length; the cluster is cylindrical; the berries are borne evenly. The diameter of the dark purple berry measures 1 cm. The berry is covered with thick bloom, is sweet to eat; the berry brush is scarlet.

This species yields bountifully, with well-adapted character. It is resistant to fungus disease; besides for eating and winemaking it is valuable for breeding.

V. piasezkii var. *pagnuccii* (ROMAN) REHD. has young shoots and leaf stalks nearly glabrous; the lower surface of leaves has little hair.

7. *Vitis adstricta* HANCE

The vine is slender. The young shoots are covered with ferruginous (in South China) or pale (in North China) pubescence; leaf is small, tripartite with the central part rhombic, or trilobate, or entire and with few obtuse teeth; the lobes on both sides are unequally bilobous or entire; the lower surface is covered with rusty or canescent pubescence. The leaves turn red in autumn.

The panicle is short, covered with ferruginous pubescence; the berry is round and dark purple, 8-10 mm in diameter, with °Brix content up to 10-16 %; sweet to eat; the juice proportion is over 60 %.

The plant is resistant to scab, it can be used as a parent for breeding new cultivars which are of good production and resistant to humid, hot climates and also to diseases.

V. adstricta var. *ternata* W. T. WANG is only native to Zhejiang Province. The leaf is completely trisected (ternately compound) and the middle leaflet with or without stalk. *V. bryoniifolia* BGE. is similar to this one. The leaf measures up to 15 cm; it has larger leaves compared with others in North China; the lower surface is covered with thin, white or brown pubescence. Inflorescence measures 12 cm in length; the blue-black berries are borne loosely. The fruit bearing character is good, one fruiting shoot can produce up to 7 clusters.

8. *Vitis yenshanensis*

This is a woody climber with slender vines. Old wood is light brown; the surfaces of young leaves and shoots are mauve, smooth and glabrous. The tendrils are slender. The leaf is small and thin, 7-14.5 cm in length, with 3-5 partitions, the lobe at center is often with 2-3 partitions again; the leaf base truncate or wide cordiform; the margin has coarse and large teeth; the upper surface is smooth and the lower surface is covered with setae. The petiole is thin, purple.

It is dioecious, but some have perfect flowers. The panicle is small, the cluster also small, cylindrical, 6-8 cm in length, subcluster large, weighing 25.2 g. The round berry is small, dark purple; the extraction of the bright-coloured juice is over 60 %; the °Brix content is 21.5 %; acid content 2.3 %; each berry contains 2-3 seeds.

This species tolerates drought and below zero temperature down to -25 °C and is resistant to diseases, especially scab, white rot, downy mildew and anthracnose. Considering the high sugar content, it is a valuable breeding material for resistance.

9. *Vitis romanetii* ROM. or *V. rutilans* GARR.

This species is a sturdy woody climber which grows vigorously. The purple young shoots and leaf stalks are thickly covered with ferruginous, pubescence and glandular setae (gland spines). The leaf is large, thick, obscurely shallow trilobed or entire; leaf margin finely toothed; the tip spiny; the upper surface is dark green, the lower surface is covered with light ferruginous, dense

pubescence; the veins are covered with glandular hair; the leaf stalk is 4-9 cm in length and is also covered with dense pubescence and glandular setose hair.

The panicle is loose and as long as or longer than the leaf blade; the rachlets are short. The berry is round, 1 cm in diameter, dark purple. The °Brix content is 12-16 %; the berry is edible but with only weak taste; juice rate is 67 %.

The species tolerates humid and hot climate and resists anthracnose.

10. *Vitis pseudoreticulata* W. T. WANG

The young shoots are at first puberulent and later on glabrous. The leathery leaf is large, cordiform, cordate-pentagonal or reniform; margin entire with fine teeth; the lower surface of the leaf along the vein is covered with short, light brown pubescence or is pruinose.

The panicle is large with many branches. The berry is round, dark purple. Yield is high.

This species is well adapted and tolerant to humid and hot climate; it is useful for breeding new cultivars adapted to the climatic conditions of South China.

11. *Vitis wilsonae* VEITCH or *V. reticulata* PAMP.

The young leaf is sometimes red; the young shoot is covered with white tomentum, later it becomes glabrous. The leaf is thick, leathery, usually entire, with fine teeth; the lower surface along the veins is covered with ferruginous tomentum; the veins on both surfaces are prominent, forming a clear net, they are often pruinose.

The panicle is slender, 8-15 cm in length; the berry is large, round, 7-12 mm in diameter, dark blue and covered with bloom.

V. wilsonae is a sun-loving vine which does not tolerate shade and wet condition, but is resistant to fungus diseases.

III. Study on and use of grape germplasm resources

1. Selection and use

Many achievements have been made since we began to study and utilize wild grape germplasm in the 1950's especially with research on *V. amurensis*. Its berry is not only used for making superior red wine of famous brand but also for breeding new varieties which are adapted in different regions for its cold and disease resistant genes. For example, in the Beijing Botanical Garden we crossed this species with the cultivar Muscat Hamburg and selected the new cultivars Beichun, Beihong and Beimei which are hardy and disease resistant, with high yield and with high sugar content in fruits. In addition, the juice is bright-coloured and suitable for winemaking. The Institute of Pomology of Jiling Province selected several *V. amurensis* seedlings including Gongniang No. 1 and Gongniang No. 2. The Institute of Grape for Winemaking in Shandong Province crossed Sweet Water with *V. amurensis* and selected new variety Baotuhong. All these varieties possess fine characteristics for winemaking together with hardy property of *V. amurensis*. At present, repeated cross and back-cross for breeding F_2 and F_3 hybrids are being carried out in order to screen out the progenies with superior wine quality. In recent years, the Beijing Botanical Garden crossed F_1 hybrid of *V. amurensis* with European varieties and selected the new variety Beiquan, which is hardy, with fine quality, high yield and disease resistance, and is suitable for white wine. In the mean while, we have also selected a F_3 variety 79-3-172 which is disease resistant and good for winemaking. The Institute of Pomology in Liaoning Province also crossed the F_1 hybrid of *V. amurensis* with the native Chinese variety Longyan and selected a hardy new variety Xiongynebai for white wine. A series of new selections, such as Shuangqing, with perfect flowers, and Tonghua No. 1, Tonghua No. 2, Tonghua No. 3, Changbai No. 6, Changbai No. 9, Zuoshan No. 1 and Zuoshan No. 2, etc., with big cluster and berry have been distributed into production.

In North-East China, *V. amurensis* is used as rootstock to increase the cold resistance and disease resistance for local cultivars to reduce the depth of covering in winter, thereby saving large amount of labour and burying material and expanding the area of viticulture further north. Grafting of tender shoots on rootstocks of *V. amurensis* can also speed up the propagation rate.

In Benxi, Liaoning Province, *V. amurensis* is also used instead of *Parthenocissus* spp. PLANCH. in vertical greening of the city, with excellent effects of beautification.

V. ficifolia is also used as a relatively hardy and good parent for breeding. In the Beijing Botanical Garden, we crossed this species with Muscat Hamburg and Muscat of Alexandria and selected the new varieties Beifeng and Beizi, which have the characters of cold and disease resistance and high yield and are suitable for producing juice with beautiful colour and good taste.

V. pseudoreticulata, distributed in the lower reaches of the Yangtze River, is one of the wild species with utilization value. Through selection, the sugar content of the berry of some individual plants is as high as 19%. With downy mildew resistance, it is also a good parent material for breeding. In recent years, the Institute of Horticulture of Shanghai Academy of Agriculture Sciences used this species as a parent in breeding new varieties.

Furthermore, many wide-spreading wild species such as *V. flexuosa*, *V. pentagona*, *V. davidii*, *V. piasezkii*, *V. bryoniifolia*, *V. adstricta*, *V. flexuosa* var. *parvifolia* etc. produce berries good for eating fresh and for winemaking, seeds for oil, roots and the whole plants used for medicine which cures rheumatic disease, muscle pains, broken bones, swelling and inflammation. Some of them are also good ornamental plants for gardening or used as rootstocks. It is worth mentioning that a purple-leaved species of *Vitis*, newly discovered in Xishuangbanna, Yunnan Province, and not yet named, is good to be introduced as a new foliage vine.

2. Studies on resistance

In recent years, Chinese scientists conducted research on resistance of wild species of grapes in North China. They tested the cold resistance of 8 species and a variety, using electric conductance method. The results showed that the cold resistance of *V. amurensis* is the best; that of *V. adstricta*, *V. bryoniifolia* and *V. piasezkii* is reasonably good; that of *V. romanetii* and *V. davidii* is slightly better than that of Muscat Hamburg; and that of *V. pentagona* is poor.

Much research work has been done on the resistance to downy mildew (*Plasmopara viticola*), scab (*Sphaceloma ampelinum*), white rot (*Coniathyrium diplodiella*) and anthracnose (*Glomerella cingulata*), the four major diseases of some wild grape species. Through natural determination in the field, inoculation test in the field and on detached leaves in laboratory, it was shown that the following species are almost immune to scab: *V. flexuosa*, *V. yenshanensis*, *V. adstricta* var. *ternata*, *V. adstricta*, *V. wilsonae* and *V. piasezkii*. Different lines of some species show other resistance, for example *V. davidii*, *V. pseudoreticulata*, *V. piasezkii*, *V. pentagona*, *V. amurensis*, *V. davidii* var. *cyanocarpa*, *V. romanetii*, and two species without Latin names.

So far, no species immune to downy mildew has been found. There exist only disease resistant and susceptible species. The disease resistant species and varieties are: *V. flexuosa*, *V. wilsonae*, *V. bryoniifolia*, *V. pseudoreticulata*, *V. romanetii*, *V. davidii* var. *cyanocarpa*, *V. piasezkii*, *V. hancockii*, and *V. yenshanensis*. The disease susceptible species and varieties are: *V. davidii*, *V. pentagona*, *V. amurensis*, *V. wilsonae*, *V. adstricta*, *V. adstricta* var. *ternata*, *V. betulifolia*, *V. flexuosa* var. *parvifolia*, and a species without a Latin name. Though the number of disease susceptible species is over that of disease resistant species, most of the species are less susceptible to the disease than *V. vinifera* cultivated in vineyards.

The resistances of the lines of *V. davidii*, *V. pseudoreticulata* and a species without Latin name do not vary greatly. But the variation of the resistances between the lines of *V. davidii* var. *cyanocarpa*, *V. piasezkii*, *V. romanetii*, *V. amurensis* etc. is very great.

All of the species mentioned above are not immune to white rot. Nevertheless, in the field they are not infected. After artificial inoculation, they are infected to various degrees. The species of

strong disease resistance are a non-denominated *Vitis* sp., *V. davidii*, *V. amurensis* and *V. yenshanensis*. The susceptible species is *V. rotundifolia*. But all these species are better in resistance than *V. vinifera*.

The disease resistance of different lines within one species is different. The variation of resistance between the lines of *V. adstricta*, *V. bryoniifolia* and *V. davidii* is little. But lines of *V. piasezkii*, *V. pseudoreticulata*, *V. rotundifolia*, *V. amurensis* and *V. pentagona* include both disease resistant and susceptible types.

Some lines of a non-denominated *Vitis* sp., *V. davidii*, *V. amurensis* and *V. pentagona* are almost immune to anthracnose. Lines of *V. amurensis*, *V. davidii*, *V. pentagona*, *V. rotundifolia* and *V. pseudoreticulata* have very strong disease resistance.

All the experiments mentioned above showed that the resistance character is not related to the geographical origin of the species. The disease resistances of lines of some species show evident variation. Only lines which passed disease resistance tests should be chosen as the most reliable parents for effective breeding work of disease resistant cultivars.

Through much research effort it has been determined that the disease resistances of some species are not only inherited but also expressed in the structure of their tissues. For example, the thickness of the skin and the cuticle on the fruit are positively correlated to the potentiality of resistances to white rot and anthracnose. The density of stomata on the leaf is negatively correlated to the resistance of lines of a species to downy mildew. In leaf and berry, the less the content of soluble sugars and the higher the free organic acids are, the stronger is the anti-disease potentiality of a line to scab, white rot and anthracnose. The activity of peroxidase is positively correlated to the resistance potentiality against white rot.

The results of research also show that the isozymes of peroxidase in functional leaf of grapevine possess characters which are stable and can be tested repeatedly within a species. This offers the possibility of identification by use of isozyme test. The isozyme spectrum of peroxidase in berries of wild grape species native to China is distinct from and much more complicated than that of European grapevines. This shows that China is one of the major centers of *Vitis* origin.

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