Variation and Breeding Potential of Some Northern Clones of *Vitis riparia* Michx.

PATRICK PIERQUET AND CECIL STUSHNOFF[1]

Compared to other areas of the world, North America is a vast storehouse of diversity for the genus *Vitis*. Taxonomists are not in full agreement concerning the systematics of this genus, but the two most authoritative texts, Bailey (7) and Munson (54), list the number of North American species at 30 and 26, respectively. In contrast, Europe and Asia combined have 10-15 species of *Vitis* (28). It was in fact the grapes of the North American continent, and not the Indians or wild game that most impressed the first explorers. The Norse explorer, Lief the Lucky, son of Eric the Red, landed in New England about 100 A.D., and was much impressed by the rich growth of native grapes (34, 62). He dubbed the New World "Wineland the Good."

In spite of the great diversity in North America, the only grape species present in the upper Midwest is the Riverbank or Frost Grape, *Vitis riparia* Michx. (*V. vulpina* L.))Fig. 1). This species has been considered of great promise for breeding cold hardy cultivars (34, 53).

Historically, the most hardy grape cultivars have been of *V. riparia* parentage. Hedrick (24) lists as among the most hardy cultivars Beta, Bacchus, Clinton, Elvira, Ironclad and Janesville, all of which are partially or pure *V. riparia.* Beta, Clinton and Elvira are still regarded as among the most hardy cultivars in New York (66).

In addition to cold tolerance, *V. riparia* has other desirable characteristics. The species has great resistance to the phylloxera root louse (*Dactylasphaera vitifoliae* Shimer), is easy to propagate and graft, the fruit ripens early (34, 54), and has a good flavor, described by Munson (54) as "juicy, pure and vinous."

The authors are interested in *V. riparia* primarily as a parent for breeding cold hardy wine grapes. Two successful wine cultivars of *V. riparia* parentage are Baco Noir and Foch, which have recently been planted in large acreage in eastern grape growing regions such as New York (55). Wines from these cultivars have scored well in a number of wine research programs (13, 18, 23, 32, 38, 60). These cultivars are recommended for planting over a wide area of North America (5, 6, 8, 14, 27, 29, 76). Brooks and Olmo (15) give the parentage of these cultivars as follows: 'Baco Noir' = *V. riparia* cv. Folle blanche x *V. riparia; 'Foch'* = (*V. riparia* x *V. rupestris*) x *V. vinifera* cv. Goldriesling. While neither cultivar is hardy in Minnesota (35) they illustrate that wine from grapes of *V. riparia* origin can be widely accepted.

The present situation in Minnesota: In his treatise on the climate of Minnesota, Amdur (2) found that the lack of a sufficiently long and/or warm growing season has not been the limiting factor in viticultural expansion in this region. He cited the very cold winters as being the limiting factor. Indeed, the only cultivar recommended as fully hardy in the state is Beta (35). The parentage of this cultivar is *V. riparia* x *V. labrusca* cv. Concord (59), and is of poor quality for wine.

There has recently been increasing

[1]Research Fellow and Professor, respectively, Department of Horticultural Science and Landscape Architecture, University of Minnesota, St. Paul, MN 55108. Journal Series paper No. 10,316 of the Minnesota Agricultural Experiment Station.

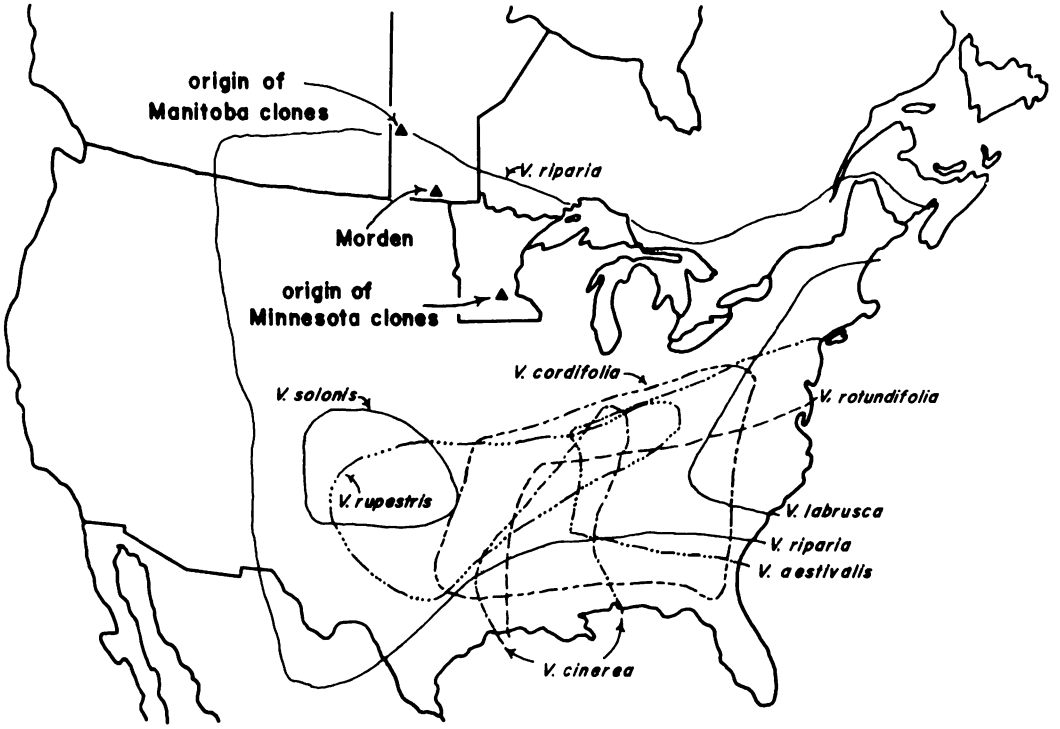

Fig. 1. Distribution of important native *Vitis* species in North America (78) and origin of the *Vitis riparia* clones sampled in this study.

interest among amateurs in Minnesota in the French hybrid wine grapes (31), but growers must bury these vines for winter protection. Hansen (33) labelled the growing of fruits which require winter protection "horticulture on crutches," an apt description. Labor requirements for growing grapes in the eastern U.S. have been calculated to be between 52 and 84 hr/acre/yr (40, 56, 68). Covering grapes for winter protection requires approximately 35 hr/acre/yr (16) thereby increasing labor costs by 42 to 67%. Even in Russia where machines have been developed that can bury 12-15 acres of vines per day, the concensus of opinion among research workers is that winter protection will never be economically feasible. Developing winter hardy cultivars is regarded as the only long term solution (24). It appears unlikely that wine grape growing in Minnesota will ever be economically competitive unless high quality, hardy cultivars are developed.

LITERATURE REVIEW

Vitis riparia has the most extensive range of any of the native species of *Vitis* (Fig. 1). Intraspecific variation is quite common in species with such wide ranges and particularly in dioecious species which are cross-pollinated and highly heterozygous (70). It seems likely that *V. riparia* should also exhibit variation. However, docu-

mentation of intraspecific variation in North America *Vitis* species is sparse.

In Hendrick's descriptions of the native grape species (34) most are described as being variable in at least one trait. Hedrick describes *V. riparia* as the most variable of species.

Munson (54) describes the North American *Vitis* species in much greater detail than Hedrick but the characters exhibiting significant variation are essentially the same. Munson, however, ascribes some of the observed variations to introgression with other species. With the exception of *V. rotundifolia,* with 40 chromosomes, all *Vitis* species have 38 chromosomes and are completely interfertile (28). The species are apparently separated for the most part by differences in time of blooming (54); there is some overlap in this character, however, and this would explain Munson's observation of natural hybrids.

Munson (54) also noted that species having wide distributions "vary greatly among their individual vines from different regions in nearly all their characters, hence vines for experimental purposes taken at random can promise little in development toward improvement of varieties for cultivation."

Bailey (7) also felt that there was much intraspecific variability but offered no documentation for it. He felt that most of the so-called hybrids which earlier taxonomists referred to could be explained on the basis of intraspecific variation. He stated that because of this variation, he found it difficult to construct an identification key for the genus. Bailey said that because of the wide distribution of *V. riparia,* the species "presents many aspects," though he did not elaborate.

In his detailed work with *V. cinerea,* Barrett (10) noted great variation in cluster size and shape, vine productivity and vigor, and sugar and acid content of the fruit. In another study (9) he noted intraspecific variations in black rot resistance in nine North American grape species. *V. riparia* was found to be the most variable of the species, some vines being entirely free of infection and others being infected in both foliage and fruit. Clones of this species derived from northern sources were more susceptible than were clones from southern areas.

Kliewer (44) measured the concentrations of tartrates, malates, glucose and fructose in 26 species of *Vitis* growing at Davis, California. Compared to other species *V. riparia* was very high in both percent soluble solids and total acidity.

METHODS AND MATERIALS

Fruit collection: Fruit was collected in mid-September from vines of *V. riparia* growing in their native habitat. The principal area of collection was along the Minnesota River between Belle Plain and Shakopee, Minnesota (Fig. 1). Fruit was collected only from vines growing on the north bank (i.e., south-facing) so as to minimize variations in sunlight exposure. Selection of particular vines was randomized as much as possible so as to represent a cross-section of the population. However, heavily diseased vines were not sampled.

Fruit was also collected from *V. riparia* vines growing at the Canadian Department of Agriculture Research Station at Morden, Manitoba (Fig. 1). These vines had originally been grown from seed collected in the Riding Mountains area of Manitoba (46), which is the northernmost population of this species (20, 54). The Morden population was sampled because it is known that plants on the periphery of a species' range often represent extremes of types (22, 36, 47, 70).

From 6 to 15 representative clusters were harvested from each vine and

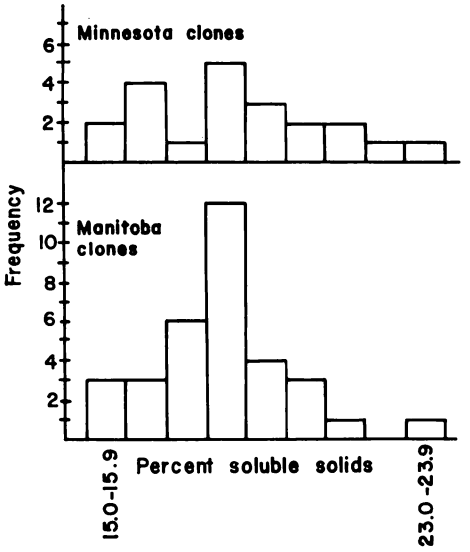

Fig. 2. Soluble solids variation in two populations of *Vitis riparia*. (Minnesota population comprised of clones collected September 12, 13, 1975.)

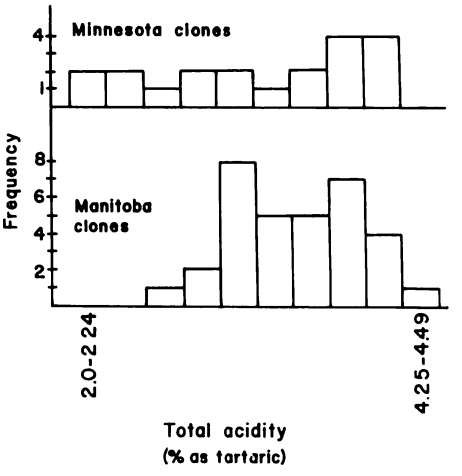

Fig. 3. Total acidity variation in two populations of *Vitis riparia*. (Minnesota populations comprised of clones collected September 12, 13, 1975.)

placed in sealed plastic bags until the juice was extracted (2-48 hours after picking). The clusters were sized visually into three classes: small (less than 5 cm in length), medium (5-10 cm in length) and large (greater than 10 cm).

The berries were stripped from the clusters, crushed and squeezed by hand through several layers of cheesecloth. This was effective since there appeared to be very little juice left in the pulp after sqeezing. The juice was strained once more through cheesecloth, placed in labelled test tubes, sealed with a cork and stored at approximately −23°C until analyzed (1-10 days).

The frozen juice samples were thawed quickly in a hot water bath, decanted and analyzed. Percent soluble solids was determined using a hand refractometer (American Optical Model No. 10430). Total acidity was determined by titrating 5 ml of juice to an endpoint of pH 8.2, using a 0.1 N sodium hydroxide solution (3). Juice pH was determined with a glass electrode pH meter.

RESULTS AND DISCUSSION

General observations: There appears to be considerable variability in fruit quality of *V. riparia* (Figs. 2, 3). The total acidity, 2.23 to 4.35% measured as tartaric acid, is considerably higher than those reported for other species of *Vitis* (17, 44, 49, 64) or for interspecific hybrids (6, 50, 71, 136). This agrees with the taxonomic literature which describe *V. riparia* as being a species of high acidity (7, 34, 54).

Soluble solids content ranged from 13.8° Brix to 26.5° with the best clones exceeding the values reported for most other species (17, 49, 64), and for interspecific hybrids (5, 23, 32, 38, 60, 63).

Fig. 4. Range in *Vitis riparia* cluster size.

In general, *V. riparia* has moderately small to small clusters. This agrees with taxonomic descriptions of the species (7, 34, 54). However, some clones have clusters noticeably larger than average (Fig. 4). These clones would be the most desirable for breeding purposes, providing their other characteristics (sugar and acid content, productivity, and disease resistance) were satisfactory.

There is considerable variation within a population in pH at any given level of total acidity (Figs. 5, 6). This is due to variations in buffering capacity of the juice and is also a characteristic of species other than *V. riparia* (4). In selecting clones of *V. riparia* for breeding wine grapes, it would probably be best to avoid those which have a high pH. A low pH in wines is generally desirable because it inhibits autolysis of yeast cells (enzymatic self-destruction), aids in extracting pigments from the skins of red grapes and inhibits spoilage bacteria (4). The cultivar 'Foch', for example, often has too high a pH, even though its acid level is generally high. In a number of studies, spoilage of and low senrory scores given to 'Foch' wines have been attributed to its high pH (12, 18, 23, 42).

Significance of 1976 Morden selections: In 1976 clones fruiting at Morden were far fewer than in 1975, most likely due to the severe frost experienced on the night of May 17. Weather data from the Morden station showed a noticeable warming trend beginning May 8, 1976. Prior to the hard frost there were nine consecutive days when the mean temperature was above 50°F.

This temperature (50°F) has significance as grapevines begin growth when mean daily temperatures reach this level (78). Amdur (2) has shown that five to seven days of mean temperatures above 50° were required to produce active bud growth of 'Beta' vines. Since there were nine days of mean temperatures in excess of this threshold level and since *V. riparia* vines are known to begin growth earlier than any other native *Vitis* species (7, 54) the Morden vines were most likely in active growth by May 16.

Damage to growing vine tissue begins when the temperature drops to about 30°F (78, 81). A temperature of 26° or lower for a few hours will kill all green shoots, flower clusters and partially opened buds (78). Temperature minimum recorded on the night of May 17 were 30° (shelter value) and 26° (ground level). These minima are indicative of a radiation type frost, where the foliage temperature may be considerably colder than the air temperature (2).

Therefore, it is likely that the damage at Morden in 1976 was due to the late frost following nine days having a mean temperature above 50°F. Those clones bearing fruit in 1976 must have some mechanism for avoiding or tolerating late frosts. The characteristic of late budding would allow avoidance of late frosts and the characteristic of fruitful secondary buds (buds which will grow if the primary bud or shoot is killed) would be a

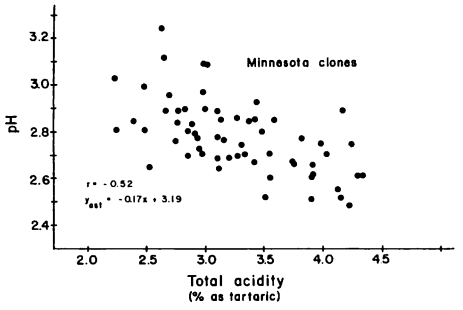

Fig. 5. Correlation of total acidity and pH in the Minnesota *Vitis riparia* clones.

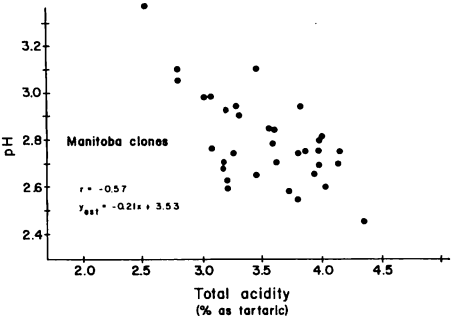

Fig. 6. Correlation of total acidity and pH in the Manitoba *Vitis riparia* clones.

frost tolerance mechanism. Either character would be desirable for breeding grapes for northern areas.

Minnesota and Manitoba populations compared: A comparison of fruit quality characteristics of the two populations reveals an interesting relationship. Table 1 shows the mean values of percent soluble solids and total acidity of the two populations. It is apparent that at the time of harvest, the fruit from the two populations was at approximately the same stage of maturity. However, the Manitoba population required fewer degree days and a shorter growing season to reach this state of maturity. Such a result is not surprising since the growing season at the site of origin of the Manitoba clones is much shorter than the growing season in Minnesota (Figs. 7, 8). The selection pressure for early ripening is much stronger in Manitoba than in Minnesota.

One complicating factor in this comparison is that the two populations were grown at different sites. The daylength during the growing season at Morden is longer than in Minnesota. The effect of increased daylength on ripening is unclear.

Such variation in photoperiodic response is not uncommon in woody plant species. Timing of growth cessation has been shown to be inversely correlated with latitude of origin and/or length of growing season in a large number of woody plant species. It has been shown that cessation of active growth is necessary for cold acclimation in the fall (39, 51, 69, 77). Therefore, it may be expected that plants from northern areas or from areas with a short growing season will be somewhat more hardy than those of the same species of more southern origin or from areas with a longer growing season. (This would be particularly true if critical temperatures occur early in the acclimation process.) This relationship has been shown in a number of woody plants including: *Acer rubrum* L. (72), *Gleditsia triacanthos* L. (19), *Fraxinus americana* L. (79), *Pinus palustris* (1), *P. strobus* (50), *P. resinosa* Ait. (11), *P. taeda* L. (52), *Quercus rubra* L. (30) and in *Pseudotsuga menziesii*, *Thuja plicata* and *Tsuga heterophylla* (65). Quamme et al. showed that native blueberry, *Vaccinium angustifolium* Ait., from northern Minnesota acclimated earlier than clones from Michigan, although both clones were equally hardy in midwinter. Smithberg and Weiser (69) found that when clones of *Cornus stolonifera*

Table 1. Comparison of Minnesota and Manitoba Clones of *V. riparia*[1].

Number of clones Source	Latitude	sampled	% Soluble solids[2]	% Acid[2]	# Days since last 0°C	(Base 50°F) Degree days[3]
33	Manitoba	49° N	18.3 ± 1.2	3.51 ± .57	123	1792
21	Minnesota	45° N	18.7 ± 2.3	3.34 ± .66	145	2341

[1]The Minnesota population is comprised of clones sampled September 12 and 13, 1975; Manitoba clones were all sampled September 15, 1975.

[2]Values of the two populations do not differ at the .99 level of significance.

[3]Manitoba climate data taken from records of the Morden, Manitoba research station; Minnesota climate data from U.S. Dept. Commerce, Environmental Data Service, Monthly Climatological Data.

Michx. from widely divergent areas were grown at one location acclimation occurred earliest in those clones originating in areas having the shortest growing season. However, as in the case of blueberry, all clones were equally hardy by midwinter.

There is more direct evidence that latitudinal variation in acclimation occurs in *V. riparia*. Dorsey (26) reported that foliage of *V. riparia* clones collected in central Iowa and northward was more resistant to fall frosts than clones of more southern origin. In his table grape breeding work Peterson (58) obtained earlier ripening progeny, and progeny of slightly greater hardiness when *V. riparia* clones from northern North Dakota instead of South Dakota were used as the hardy parent. As grown in southern Quebec, V. riparia clones of Manitoba origin ripened earlier than clones of local origin (75). Also, the leaves of the Manitoba clones naturally senesced before the first fall frost in nearly all seasons; those of local origin did not.

The genetic potential for early acclimation is a very important character for developing cold hardy cultivars (1, 5, 69, 71). Therefore, the earlier ripening Manitoba *V. riparia* ecotype would probably be the most valuable source of hardiness in developing cold hardy grape cultivars.

Mechanism and significance of ecotypic variation: The mechanism of variation between ecotypes of a species has been clearly demonstrated (21, 22, 37). In general, differences between races of a species are determined by a system of genes, each having minor but additive effects. The multiple gene nature of these characteristics allows flexibility in adapting to many small variations in habitat (21).

When different races of a species are crossed, "ecotypic heterosis" often occurs. Clausen and Hiesey (21) explained that "genes having additive, subtractive, and complementary effects on a character are frequently carried by separate races of the species and cause transgressive segregation in interracial crosses." In the case of physiological differences, such segregation may far exceed the limits found in the parental races. For example, some F_2 progeny of *Potentilla glandulosa* cross of 'Coastal x Alpine' ecotypes, surpassed the Alpine ecotype in both vigor and frost hardiness (22).

This phenomenon has horticultural as well as ecological significance. Interracial crosses have horticultural significance because the variability expressed by the progeny of such crosses may exceed that in wild populations of the species (21, 22, 36). Thus, many new recombinants not found in

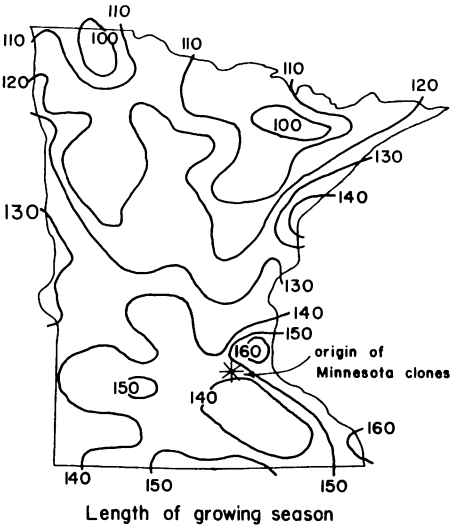

Fig. 7. Mean length of growing season in Minnesota (73) (days).

either ecotype may be selected. It has ecological significance because "in nature there is a backlog of unutilized evolutionary resources from which races capable of fitting into many new environments could be synthesized." Hybrids from such (interracial) crossings are also often superior to their parents in their ability to succeed in a wide range of environments (22).

Therefore, it would seem that instead of selecting the best individual clones in wild populations of *V. riparia* for breeding, crossing of ecotypes might yield some combinations superior to the best individuals in each population. This procedure, sometimes referred to as "semi-domestication" of the wild species, is thought to have been an early method of improvement in many of our crop plants (25). Interracial crosses occurred accidentally as early man moved from camp to camp, taking seeds of his crop with him.

Limitations of this study: When studying variations in particular traits

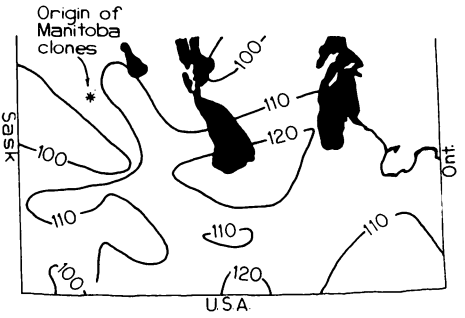

Fig. 8. Mean length of growing season in Manitoba (67) (days).

among individuals in any species, a commonly employed technique is the uniform environmental plot (11, 22, 30, 37, 52, 69, 72). In this procedure individuals from throughout a species' range are grown at one site, thereby minimizing environmental effects on the traits measured.

Due to time and space constraints the uniform environmental plot was not employed in this study. Thus the variability due to environment is a real limitation.

Those clones appearing poor in fruit quality cannot necessarily be discarded as genetically inferior, since the environmental variability could not be measured. However, some of those which appeared superior in fruit quality for their time of harvest may be expected to perform at least as well, or better when grown under standard vineyard conditions.

CONCLUSIONS

1. The *Vitis riparia* populations sampled can be characterized as moderately high to high in soluble solids and total acidity, with generally small clusters of berries.
2. There was considerable variation in percent soluble solids, total acidity, pH and cluster size in the populations sampled; however, be-

cause of the sampling methods employed the contribution of environmental variability to the total variability could not be determined. Nevertheless, those selections which were superior in their fruit quality characteristics while growing in the wild may be expected to perform at least as well under standard vineyard conditions.

3. In using *V. riparia* for breeding hardy wine grapes, juice pH should be considered an important fruit quality characteristic. Low pH clones are probably the most desirable.
4. There apparently exist in the Morden *V. riparia* population, genes for tolerance or avoidance of late spring frosts, or for productive secondary buds. Any of these characters would be valuable for breeding grapes for northern areas.
5. There may be a correlation between length of growing season at the site of origin and fruit ripening date in *V. riparia.* This variation may be useful in two ways: a) Because the northern clones ripen earliest they would be the most desirable *V. riparia* clones to use when hybridizing with the long-season European *V. vinifera* wine grapes. b) Based on work done with other species (21, 22, 36, 37) it may be expected that useful recombinant types, not found in either parental population will be obtained by crossing ecotypes of *V. riparia.* Since transgressive segregation of characters is frequent when making such crosses (21, 22) it should be possible to obtain progeny with better combinations of fruit quality characters and earliness than are found in natural populations.

Literature Cited

1. Allen, P. H. 1961. Florida longleaf fail in Virginia. *J. For.* 59:453-454.
2. Amdur, E. J. 1956. Comparatice horticultural climatology of Minnesota. National Climatology Conf., Amer. Meteorological Society.
3. Amerine, M. A. 1965. Laboratory procedures for enologists. Univ. Cal. Press, Davis.
4. Amerine, M. A. and M. A. Joslyn. 1970. Table wines—the technology of their production. Univ. Cal. Press, Berkeley, 997 p.
5. Andison, H. 1971. Early grapes for wine—how they perform in the Puget Sound region. *Canada Agric.* 16(3): 30-31.
6. Anonymous. 1975. Growing grapes for table and wine in the Puget Sound region. *Coop. Ext. Serv., Wash. State Univ. Bul.* EM 3910.
7. Bailey, L. H. 1934. The species of grapes peculiar to North Americ. Gentes Herbarum III(4):151-244.
8. Banta, E. S., G. A. Cahoon and R. G. Hill, Jr. Undated. Grape Growing *Coop. Ext. Serv., Ohio State Univ. Bul.* No. 509.
9. Barrett, H. C. 1953. A survey of black rot resistance of the foliage of wild grape species. *Proc. Amer. Soc. Hort. Sci.* 62:319-322.
10. Barrett, H. C. 1957. *Vitis cinerea* as a source of desirable charcters in grape breeding. *Proc. Amer. Soc. Hort. Sci.* 70:165-168.
11. Bates, C. G. 1930. The frost hardiness of geographic strains of Norway pine. *J. For.* 28:327-333.
12. Beelman, R. B. and M. J. McArdle. 1974. Evaluation of grape cultivars for table wine quality in Pennsylvania—1973. *Proc. 7th Penn. Wine Conf.* 96-102
13. _____, _____. 1975. Evaluation of grape varieties for table wine quality in Pennsylvania—1974. *Proc. 8th Penn. Wine Conf.* 51-55.
14. Bradt, O. A. 1968. The grape in Ontario. *Ontario Dept. Agric. & Food,* Publ. No. 487.
15. Brooks, R. M. and H. R. Olmo. 1972. Register of new fruit and nut varieties. Univ. Cal. Press, Berkeley.
16. Bryson, S. 1977. Minnesota—Grape growing frontier. Eastern Grape Grower 3(1):16-17.
17. Carroll, D. E., M. N. Hoover and W. B. Nesbitt. 1971. Sugar and organic acid concentrations in cultivars of Muscadine grapes. *J. Amer. Soc. Hort. Sci.* 96(6):737-740.

18. Carter, G. H., C. W. Nagel, J. Nelson, M. Atallah, R. Early and W. J. Clore. 1974. A summary of experimental testing of grape varieties for wine in Washington. *Amer. J. Enol. & Vitic.* 25(2): 92-98.
19. Chase, S. B. 1947. Propagation of thornless honeylocust. *J. For.* 45:715-722.
20. Chipman, G. F. 1933. Fruit growing in Manitoba, Saskatchewan and Alberta. Country Guide, Ltd., Winnipeg.
21. Clausen, J. and W. M. Hiesey. 1960. The balance between coherence and variation in evolution. *Proc. Nat. Acad. Sci.* 46:494-506.
22. Clausen, J., D. D. Keck and W. M. Hiesey. 1947. Heredity of geographically and ecologically isolated races. *Amer. Nat.* 81:114-144.
23. Clore, W. J., C. W. Nagel and G. H. Carter. 1976. Ten years of grape variety responses and winemaking trials in central Washington *College of Agric. Res. Ctr., Wash. State Univ., Pullman, Bul.* No. 823.
24. Denby, L. G. 1974. Grape and wine mission to Russia. *Proc. Wash. State Grape Soc. Ann. Meeting,* 71-76.
25. DeWet, J. M. J. and J. R. Harlan. 1975. Weeds and domesticates: Evolution in the man-made environment. *Econ. Bot.* 29:99-107.
26. Dorsey, M. J. 1918. Adaptation in relation to hardiness. *Minn. Hortic.* 46: 465-469.
27. Einset, J., K. Kimball and J. Watson. 1973. Grape varieties for New York State. *Cornell Univ., Info. Bul.* No. 61.
28. Einset, J. and C. Pratt. 1976. Grapes. *In:* Advances in Fruit Breeding, J. Janick and U. N. Moore (eds.). Purdue Univ. Press, W. Lafayette, IN., pp. 130-153.
29. Fisher, D. V. and J. Vielvoye. 1968. Grape growing in British Columbia. *Canada Dept. Agric. Res. Branch, Summerland, BC.*
30. Flint, H. L. 1972. Cold hardiness of twigs of *Quercus rubra* L. as a function of geographic origin. *Ecology* 53(6): 1163-1170.
31. Fruth, T. 1976. Grape growers report. *MN Horticulturist* 104(7):201.
32. Gallander, J. F. nd J. F. Stetson. 1976. Evaluation of grapes for Ohio wines. *Proc. Ohio Grape-Wine Short Course, Feb. 1976,* pp. 46-55.
33. Hansen, N. E. 1948. Breeding of extra-hardy plants for cold climate. Plants and Gardens 4(1):9-13.
34. Hedrick, U. P. 1907. The grapes of New York (115th Ann. Rpt., Dept. Agr., NY) Albany, J. B. Lyon, State Printer. Part II:1-564.
35. Hertz, L. B. 1975. Strawberry-raspberry-grape varieties for Minnesota. *Univ. Minn. Agr. Expt. Serv., Ext. Folder* No. 320.
36. Hiesey, W. M., J. Clausen and D. D. Keck. 1942. Relations between climate and intraspecific variation in plants. *Amer. Nat.* 76:5-22.
37. Hiesey, W. M. and H. W. Milner. 1965. Physiology of ecological races and species. *Ann. Rev. Pl. Physiol.* 16:203-216.
38. Howell, G. S., S. S. Stackhouse, M. Byrne, J. Stuurwold and T. Mansfield. 1974. *Annual report of wine grape research. Mich. State Agric. Expt. Sta., E. Lansing, MI.*
39. Howell, G. S. and C. J. Weiser. 1970. Environmental control of cold acclimation in apple. *Plant Physiol.* 45:390-394.
40. Hughes, F. A. 1973. Economics of vineyard establishment, growing and financing. *Proc. 6th Penn. Wine Conf.,* pp. 56-65.
41. Jennings, D. L. and E. Carmichael. 1972. Variation in the time of acclimation of raspberry canes in Scotland and Ireland and its significance for hardiness. *Hort. Res.* 12:187-200.
42. Johnson, T. and C. W. Nagel. 1976. Composition of central Washington grapes during maturation. *Amer. J. Enol. Viticult.* 27(1):15-20.
43. Kasckurewicz, A. and P. J. Fogg. 1967. Growing seasons of cottonwood and sycamore as related to geographic and environmental factors. *Ecology* 48:785-793.
44. Kliewer, M. M. 1976. Concentration of tartrates, malates, glucose and fructose in fruits of the genus Vitis. *Amer. J. Enol. Viticult.* 18(2):87-96.
45. Kramer, P. J. 1937. Photoperiodic stimulation of growth by artificial light as a cause of winter killing. *Plant Physiol.* 12(3):881-883.
46. Leslie, W. R. 1938. Results of experiments 1931-1937. Dominion Expt. Sta., Morden, Manitoba.
47. Levin, D. A. 1970. Developmental instability and evolution in peripheral isolates. *Amer. Nat.* 104:343-353.
48. Levitt, J. 1972. Responses of plants to environmental stresses. Academic Press, New York.
49. Lott, R. V. and H. C. Barrett. 1967. The dextrose, levulose, sucrose and acid

content of the juice from 39 grape clones. *Vitis* 6:257-268.

50. Maronek, D. M. and H. L. Flint. 1974. Cold hardiness of needles of *Pinus strogus* L. as a function of geographic origin. *For. Sci.* 20(2):135-141.
51. McKenzie, J. S., C. J. Weiser and P H. Li. 1974. Changes in water relations of *Cornus stolonifera* during cold acclimation. *J. Amer. Soc. Hort. Sci.* 99:223-228.
52. Minckler, L. S. 1951. Southern pine from different geographic sources show different responses to low temperatures. *J. For.* 49:915-916.
53. Munson, T. V. 1899. Investigation and improvement of American grapes. *Tex. Agr. Expt. Sta. Bul.*, No. 56.
54. ———. 1909. Foundations of American grape culture Orange Judd Co., New York. 252 pp.
55. New York Crop Reporting Service. 1976. New York orchard and vineyard survey for 1975. Release No. 31.
56. Obourn, T. 1974. Time distribution in the vineyard. *Proc. 7th Penn. Wine Conf.*, pp. 79-82.
57. Pauley, S. S. and T. O. Perry. 1954. Ecotypic variation in the photoperiodic response of *Populus.*. *J. Arnold Arb.* 35:167-188.
58. Peterson, R. M. 1963. Breeding grapes for the northern Great Plains. *Fr. Var. Hort. Dig.* 17(4):67-68.
59. Pfaender, W. 1912. The 'Beta' grape and its origin. *Proc. MN State Hort. Soc.* 40(1):12-14.
60. Pool, R. M., J. Einset, K. H. Kimball, J. P. Watson, W. B. Robinson and J. J. Bertino. 1976. Vineyard and cellar notes 1958-1973. *N.Y.S. Agr. Expt. Sta., Spec. Rpt. No. 22, Cornell Univ., Ithaca.*
61. Quamme, H. A., C. Stushnoff and C. J. Weiser. 1972b. Winter hardiness of several blueberry species and cultivars in Minnesota. *HortSci.* 7(5):500-502.
62. Rea, M. F. 1975. Early introduction of economic plants into New England. *Econ. Bot.* 29:333-356.
63. Rice, A. C. 1974. Chemistry of winemaking from native American grape varieties. pp. 88-115. *In:* A. D. Webb (ed.), Chemistry of Winemaking. *Advances in Chemistry Series 137. Washington: Amer. Chem. Soc.*
64. Robinson, W. B., A. W. Avens and Z. I. Kertesz. 1949. The chemical composition of Concord type grapes grown in New York in 1947. *N.Y.S. Agr. Expt. Sta., Tech. Bul.* No. 285.
65. Sakai, A. and C. J. Weiser. 1973. Freezing resistance of trees in North America with reference to tree regions. *Ecology* 54(1):118-126.
66. Shaulis, N. J., J. Einset and A. B. Pack. 1968. Growing cold-tender grape varieties in New York State. *N.Y.S. Agric. Expt. Sta., Cornell Univ. Bul. No. 821.*
67. Shaykewich, C. F. 1974. Climate of southern Manitoba as it relates to agriculture. *Manitoba Dept. Agr. Publ.* No. 546.
68. Smith, W. P. 1974 Costs and returns for Ohio grapes, 1974. *Proc. 1974 Ohio Grape-Wine Short Course*, pp. 3-13.
69. Smithberg, M. H. and C. J. Weiser. 1968. Patterns of variation among climatic races of red-osier dogwood. *Ecology* 49(3):495-505.
70. Stebbins, G. L., Jr. 1950. Variation and evolution in plants. Columbia Univ. Press, New York.
71. Stushnoff, C. 1972. Breeding and selection methods for cold hardiness in deciduous fruit crops. *HortSci.* 7(2): 10-13.
72. Townsend, A. M. 1977. Characteristics of red maple progenies from different geographic areas. *J. Amer. Soc. Hort. Sci.* 102(4):461-466.
73. U.S.D.A. 1941. Climate and Man. Yearbook of Agriculture, 1941.
74. Vaartaja, O. 1966. Ecotypic variation of photoperiodic response in trees, especially two *Populus* species. *For. Sci.* 6:200-206.
75. Vandal, J. O. 1975. Personal correspondence.
76. Wagner, P. M. 1972. A winegrower's guide. Alfred A. Knopf, New York.
77. Weiser, C. J. 1970. Cold resistance and acclimation in woody plants. *HortSci.* 5(5):403-410.
78. Winkler, A. J. 1972. General viticulture. Univ. Cal. Press, Berkeley. 633 pp.
79. Wright, J. W. 1944. Genotypic variation in white ash. *J. For.* 42:489-495.
80. Wright, J. W. 1954. Preliminary report on a study of races in black walnut. *J. For.* 52:673-675.
81. Young, F. D. 1947. Frost and the prevention of frost damage. *U.S. Dept. Commerce, Weather Bureau, Washington, D.C.*