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Crop Yield, Fruit Quality, and Winter Injury of 12 Red-fruited Wine Grape Cultivars in Northern Virginia

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Abstract

'Charbono', 'Fer', 'Limberger', 'Mourvèdre', 'Nebbiolo', 'Petit Verdot', 'Refosco', 'Sangiovese', 'Syrah', 'Tannat', 'Valdepeñasí, and clones FPMS #6 and #7 of 'Cabernet Sauvignon' were evaluated at Winchester, Virginia for components of crop yield, fruit chemistry, and dormant bud cold hardiness over seven crop years. All cultivars were trained to bi-lateral cordons and spur-pruned, except that spur-pruning and cane-pruning were compared with 'Nebbiolo' in the last four years. Based on consistent, high fruit quality, and on cold hardiness at least comparable to 'Cabernet Sauvignon' the cultivars 'Fer', 'Mourvèdre', 'Petit Verdot', and 'Tannat' were recommended for commercial consideration in Virginia. Very high crops (± 10 kg/vine, or 12.8 t/ha) were achieved with 'Charbono', 'Limberger', 'Refosco', and 'Sangiovese', all of which were associated with large (> 2.0 g/berry) berries, and relatively dilute soluble solids concentration (SSC) and flavors. 'Nebbiolo' fruit averaged 23 °Brix, but fruit color intensity and flavors were mediocre. 'Syrah' and 'Valdepeñas' fruit quality were occasionally good, but not consistently so. All cultivars produced more vegetative growth (> 0.5 kg cane prunings per m of canopy) than desirable, and all would be considered cold-tender in northern Virginia.

Wine grape production in the mid-Atlantic US is based primarily upon *Vitis vinifera* cultivars and inter-specific hybrids of *V. vinifera* and American grape species. Typical of the region, Virginia's grape acreage is dominated by 'Chardonnay', 'Cabernet Sauvignon', 'Cabernet franc', and 'White Riesling'; however, commercial plantings of more obscure cultivars have occurred in the last 10 years as experience, research, and consumer interest in such cultivars have increased.

Wine grape cultivar evaluations were initiated at Virginia Tech in 1989. Our objectives were to evaluate a range of novel or untested vinifera and hybrid grapes that had commercial potential in Virginia's hot, humid growing season, and that were adapted to the occasional harsh winters experienced in the region. The minimal criteria upon which cultivars were evaluated were:

- ability to ripen fruit with flavor, aroma, pigmentation and other sensory properties conducive to high quality wine production;
- resistance to fruit cracking and fruit rots during wet growing seasons
- sufficient cold hardiness to escape winter injury at good to excellent vineyard sites in at least 4 out of 5 winters.

An earlier report summarized the performance of eight white-fruited cultivars (13). The performance of 12 red-fruited cultivars from the same evaluation is presented here.

Materials and Methods

Vines were grown at the AHS Jr. Agricultural Research and Extension Center in Winchester, Virginia (39°17′ N, 78°17′ W). Cultivars were those listed in Table 2, which also provides specific clone designations, where known, as used by the Foundation Plant Materials Service (FPMS), Davis, CA. Budwood was obtained from a combination of the FPMS, the New York State Agricultural Experiment Station in Geneva, NY, Agriculture Canada, Summerland, BC, and Sonoma Grapevines, Fulton, CA (12). With the exception of 'Syrah', 'Fer', 'Mourvèdre' and

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'Petit Verdot' all vines were planted in 1989. 'Syrah' was planted in 1993, 'Fer' and 'Petit Verdot' in 1990, and 'Mourvèdre' in 1991. Site details were given in the previous report (13). All vines were grafted to rootstock cultivar 'C-3309'. Each cultivar was planted in three-vine plots, replicated five times, in a completely randomized design. The vines were spaced 2.1 m apart in north-south oriented rows that were 3.7 m wide. Training was to bilateral cordons 1.1 m above ground. Cordons were spur-pruned each year and shoots were positioned vertically upright with the aid of trellis foliage wires. An exception to the spur-pruning occurred with 'Nebbiolo', for which a comparison of spur-pruning and cane-pruning was made in the 1995-1998 growing seasons. One half of each 'Nebbiolo' vine was trained to a cordon, and spur-pruned, while the other half was head-trained and cane-pruned. Crop yield components were separately collected from either side. Vineyard management was comparable to that commercially recommended in Virginia (11). Other aspects of vine and vineyard management were provided in Wolf and Warren (13). Data collected each season included dates of significant vine phenological stages, fruit chemistry and berry weights (50-berry samples) at harvest, cluster counts and crop weight per vine, fruit rots at harvest, and cane pruning weights. Fruit rot was rated as both incidence and severity on a vine by vine basis. Incidence was counted as the percentage of clusters that exhibited more than five berries with symptoms or signs of Botrytis bunch rot or non-specific (e.g., sour rot) fruit rots at harvest. Rot severity was visually judged for harvested fruit using a 0 to 100% rating scale. Typically, two judges independently judged rot severity, and the average was recorded. Rot incidence and rot severity were closely correlated, however only the severity data are presented. Harvest time was primarily based upon fruit soluble solids concentration (SSC), pH and titratable acidity (TA). When possible, harvest was delayed until fruit attained 22 to 23 °Brix. In addition to the basic fruit chemistry, harvest decisions were also based on juice aroma and taste. Fruit chemistry was usually determined on previously frozen berry samples, and our pH values tend to be increased 0.1 to 0.2 units as a result of potassium bitartrate precipitation (8). Dormant bud cold hardiness was evaluated as described in Wolf and Cook (10), and expressed as Mean Low Temperature Exotherm (MLTE) temperatures. In addition to laboratory measures of bud cold hardiness, a damaging freeze of -24°C on 19 January 1994 permitted a field assessment of bud and trunk injury (10,13).

Results and Discussion

Mean maximum and mean minimum August temperatures during the study period averaged 30.3°C and 17.0°C, respectively (Table 1). The 30-year (1951-1980) average heat unit accumulation (10°C base) for Winchester was 1970 units (4). The coolest season was 1996, whereas the warmest was 1998, with 2225 heat units and a mean maximum September temperature of 30.9°C. Winter minima were generally benign, with the exception of 1994, when a minimum of -24°C was recorded on 19 January (Table 1). Precipitation was generally adequate during growing seasons; however, 1996 was noteworthy for both the frequency and high amount of rainfall, while 1991 was relatively dry (Table 1). As with the preceding report (13), seasonal variations in crop quality and quantity could often be related to gross seasonal climate differences. For clarity, results are discussed by cultivar.

'Cabernet Sauvignon': 'Cabernet Sauvignon' was Virginiaís second most abundant cultivated grape in 1987, a rank maintained today with close to 100 planted ha (9). As such, it was included here as a basis for comparison with other red cultivars. Two 'Cabernet Sauvignon' clones were evaluated on the basis of reported yield differences between the two (14). The two 'Cabernet Sauvignon' clones, FPMS #7 (syn. Clone #8) and FPMS #6, were phenologically similar; both aver-

aged a 26 April bud break and required approximately 174 days to mature their crop (Table 2), despite a 58% difference in average crop yield per vine (Table 3). The greater crop yield of clone #7 was due principally to greater berry weight, which resulted in greater average cluster weight (Table 4), although berries per cluster also differed between the two clones (data not shown). The magnitude of the crop yield difference observed between clones #7 and #6 was similar to the yield difference between the same clones in a California trial (14). Cane pruning weights were comparable between the two 'Cabernet Sauvignon' clones (Table 4), and were among the heaviest of the red cultivars. Because shoot density (*ca.* 15 shoots per m of canopy) and the degree of shoot hedging (retention of *ca.* 17 primary nodes) was similar for all cultivars, the greater pruning weight of 'Cabernet Sauvignon' was due to differences in individual cane features, including specific mass, diameter, and degree of persistent lateral development. It is worth noting that the vine size of both 'Cabernet Sauvignon' clones was much greater than the 0.6 kg per m of canopy generally considered as the upper limit of desirable vine size (7). 'Cabernet Sauvignon' fruit was resistant to splitting and rot, and fruit ripened to acceptable maturity, with SSC averaging 22°Brix for clone #6, and 21.3°Brix from clone #7 (Table 4). Despite a 0.7° Brix average difference in SSC at harvest, there were no significant differences in SSC, pH, or TA between the two clones (Table 4). Differences were, however, occasionally observed within specific years, with clone #6 occasionally having a greater SSC (data not shown). Laboratory freeze tests yielded an average MLTE temperature of -21.1°C for clone #6 and -21.7°C for clone #7 over six winters (Table 5). As such, both 'Cabernet Sauvignon' clones were extremely cold-tender (12) under Virginia conditions. Primary bud survival was greater for clone #6 than for #7 following a -24°C event in January 1994 (Table 6). That same cold episode caused obvious trunk damage to 2 of 15 clone #6 vines, with no trunk injury observed with clone #7 vines.

'Charbono': 'Charbono' bud break averaged three days prior to 'Cabernet Sauvignon' (Table 2). An average of 183 days, the longest of the cultivars evaluated, was required for fruit maturation, a function of the very high cropping potential of the cultivar (Table 3). Cane pruning weights averaged 0.65 kg per m of canopy and, as with other cultivars evaluated, summer shoot hedging was required to prevent elongating shoots from shading the canopy. 'Charbono' had the greatest berry weights of all red cultivars evaluated in this trial (Table 4), a contributing factor to the large clusters (Table 4) and high (excessive) crop per vine. Not surprisingly, 'Charbono' fruit quality at harvest was poor, with SSC averaging only 18.2 (Brix (Table 4). 'Charbono' was an extreme contributor of an inverse relationship observed between individual berry weight and SSC across all cultivars in the eight years of cropping. Specifically, individual berry weights at harvest and fruit SSC values had significant, inverse correlation coefficients in all years, except 1995, when evaluated across all cultivars. Correlation coefficients were as great as -0.71 ($P > |r| = 0.0001$) in 1992, more typically around -0.50. In effect, large-berried cultivars were associated with dilute SSC and flavors. Fruit rots were not particularly troublesome with 'Charbono' (Table 4). While fruit quality was mediocre, potential improvements would be possible if crops were more rigorously limited. In 1998, a hot season with average precipitation (Table 1), SSC was 19.4 °Brix at harvest (our unpublished data). We conducted insufficient laboratory testing of 'Charbono' cold hardiness to evaluate MLTE temperatures; however, the -24 °C cold episode on 19 January 1994 resulted in trunk injury to 8 of 15 vines, 100% primary bud kill, and a 89% crop reduction in the subsequent year (Table 6).

Fer: 'Fer' (syn. 'Fer Servadou', 'Pinenc') has traditionally contributed to the blended

Table 1. Selected climatological characteristics at Winchester, Virginia for the eight cropping seasons in which cultivars were evaluated.

Climatological parameter	Year								
	1991	1992	1993	1994	1995	1996	1997	1998	Mean
Precipitation, April - October (mm)	289	563	493	445	748	799	391	554	**535**
Heat units (10°C base), April - October [Y]	2071	1426	1752	1947	2156	1825	1721	2225	**1890**
Average maximum temperature, September (°C)	25.3	21.9	24.6	22.7	25.4	23.7	26.9	30.9	**25.2**
Average minimum temperature, September (°C)	11.7	12.0	13.2	11.4	12.1	13.4	11.8	16.1	**12.7**
Absolute minimum temperature (°C) [Z]	-12	-12	-11	-24	-17	-18	-14	-12	

[Y]A close approximation to GDD based on °F, with 50°F base, can be achieved by dividing the values shown by 0.555.
[Z]Typically in January or early February on the indicated year.

Table 3. Harvested crop per vine (kg) of 12 grape cultivars and two clones over eight seasons at Winchester Virginia.

Cultivar	1991[Z]	1992[Z]	1993[Z]	1994[Z]	1995[Z]	1996[Z]	1997[Z]	1998[Z]	Mean
'Cabernet Sauvignon #6'	4.9 cd	4.6 e	5.1 ef	3.2 cd	6.7 ef	4.4 d	5.6 g	5.2 f	**5.0**
'Cabernet Sauvignon #7'	7.8 bc	8.2 bc	9.5 cd	3.1 cde	9.3 c	8.7 a	9.9 def	7.0 def	**7.9**
'Charbono'	12.9 a	11.6 a	13.0 ab	1.4 de	10.3 bc	5.9 cd	17.2 a	8.5 cdef	**10.3**
'Fer'	.	6.8 cde	4.8 ef	1.1 de	6.6 f	2.8 e	8.9 ef	6.4 def	**5.3**
Limberger'	10.4 ab	10.4 ab	12.9 ab	5.0 bc	11.7 ab	7.6 ab	12.5 bcd	6.0 ef	**10.1**
'Mourvèdre'	.	.	.	2.7 cde	10.0 bc	.	8.6 f	9.5 bcd	**7.1**
'Nebbiolo'	7.5 bc	5.0 de	3.4 f	1.6+ de	7.1 def	0.9 f	2.8 h	8.1 cdef	**4.5**
'Petit Verdot'	.	7.7 dcd	9.3 cd	6.3 ab	9.8 bc	7.6 ab	10.8 cdef	9.2 bcde	**8.7**
'Refosco'	5.0 cd	11.0 a	7.4 de	8.6 a	12.3 a	6.4 bc	13.4 bc	12.4 ab	**9.6**
'Sangiovese'	11.1 a	13.0 a	14.9 a	0.5 e	9.0 cd	6.5 bc	14.1 b	10.8 abc	**10.0**
'Syrah'	.	.	.	.	.	5.4 cd	9.0 ef	6.0 ef	**7.2**
'Tannat'	10.7 ab	7.6 bcd	15.8 a	1.6 de	6.6 ef	5.2 cd	11.7 bcde	13.1 a	**9.1**
'Valdepeñas'	2.7 d	7.2 cde	10.9 bc	1.3 de	8.7 cde	4.6 d	8.8 f	7.7 cdef	**6.5**

[Z]Means followed by the same letter within each column are not significantly different using Duncan's multiple range test ($P \leq 0.05$).

Table 2. Average date of bud break, days from bud to harvest, and days from bloom to harvest for 12 cultivars and two clones.

Cultivar	Average bud break	Average days from bud break to harvest	Average days from bloom to harvest
'Cabernet Sauvignon #6'	26 April	174	124
'Cabernet Sauvignon #7'	26 April	173	124
'Charbono #3'	23 April	183	128
'Fer'	22 April	172	127
'Limberger'	21 April	164	114
'Mourvèdre'	7 May	177	129
'Nebbiolo #1'	22 April	164	113
'Petit Verdot'	24 April	177	130
'Refosco'	21 April	181	132
'Sangiovese #2 (grosso)'	22 April	182	133
'Syrah #6'	20 April	178	126
'Tannat #1'	8 May	167	114
'Valedpeñas'	23 April	170	120

wines of Aveyron, Gaillac, and Madiran in southwest France (6). Bud break averaged 22 April, 4 days earlier than 'Cabernet Sauvignon' and 172 days elapsed, on average, between bud break and harvest. 'Fer' crops were comparable to 'Cabernet Sauvignon' clone #6 and, as such, were among the highest of the red cultivars evaluated (Table 3). Berry and cluster weights were intermediate (Table 4). 'Fer' was very much an "average" cultivar among the red cultivars evaluated. That is, pruning weights, berry weights, cluster weights, and SSC were all among the middle of the range (Table 4). Fruit rots were inconsequential. Laboratory freeze tests in two winters yielded an average MLTE temperature of -21.7°C (Table 5), while a -24 °C cold episode caused 99% primary bud kill, trunk damage to 8 of 15 vines, and resulted in an 80% crop reduction the ensuing season (Table 6).

Limberger: Also known as 'Blaufränkish' in Austria (6), 'Limberger' (syn. 'Lemberger') has gained a quality reputation in Washington State and is recommended for limited trial in other regions with cold winters, such as Michigan (1), due to its purported cold hardiness. 'Limberger' broke bud early (21 April) and ripened crops, on average, 164 days after bud break (Table 3). Like 'Charbono', 'Limberger' fruit quality suffered from excessive crops (Table 3), leading to relatively low SSC (19.9°Brix) at harvest (Table 4). Vines were vigorous, averaging 0.9 kg of cane prunings per m of canopy. Individual berries and clusters were both large (Table 4). MLTE data were not systematically gathered for 'Limberger'; however, -24 °C field exposure caused 84% primary bud kill, a 56% crop reduction, but no obvious trunk injury (Table 6). While inferior in cold hardiness to some of the white-fruited cultivars (13), 'Limberger' was one of the more cold hardy red cultivars evaluated, at least in terms of absence of trunk injury.

Mourvèdre: 'Mourvèdre' (syn. 'Mataro' in California) is widely grown in the south of France, in its native Spain, and in Australia, and was selected for comparison on the basis of that association with other warm/hot growing season regions. One of the latest budding cultivars evaluated, 'Mourvèdre' required an average of 177 days to ripen crops. Thus, while the threat of spring frost is lessened, 'Mourvèdre' demands a very long growing season with abundant heat in the post-veraison period

Table 4. Annual cane pruning weight, fruit rot severity, components of crop yield, and fruit chemistry at harvest of 12 grape cultivars and two clones, averaged over the 1991-1998 growing seasons.

Cultivar	Cane pruning wt per vine (kg)[W]	Fruit rot severity (%)[WX]	Berry wt. (g)[W]	Clusters per vine[W]	Cluster wt. (g)[W]	Soluble solids (°Brix)[W]	pH[WY]	Titratable acidity (g/L)[WXY]
'Cabernet Sauvignon'	2.91 a	0.0 d	1.18 g	69 ab	71 f	22.0 bc	3.65 bc	0.51 cd
'Cabernet Sauvignon #7'	2.60 ab	0.1 d	1.48 f	62 bc	127 def	21.3 bcd	3.68 bc	0.53 cd
'Charbono'	1.37 de	1.4 bcd	2.73 a	39 de	259.ab	18.2 f	3.79 ab	0.48 cd
'Fer'	1.96 cd	0.2 d	1.95 cde	32 de	161 cde	21.4 bcd	3.71 abc	0.56 cd
'Limberger'	1.89 cd	2.4 bc	2.08 cd	49 cd	202 bc	19.9 de	3.62 bc	0.50 cd
'Mourvèdre	2.13 bc	0.5 d	2.15 c	25 e	277 a	21.6 bc	3.79 ab	0.62 bcd
'Nebbiolo'	1.67 cde	0.1 d	1.81 e	20 e	210 bc	23.0 ab	3.44 c	0.74 ab
'Petit Verdot'	1.45 de	0.4 d	1.30 fg	84 a	108 ef	23.8 a	3.61 bc	0.67 abc
'Refosco'	1.17 e	2.7 b	2.14 cd	40 de	246 ab	18.6 ef	3.85 ab	0.46 d
'Sangiovese'	1.84 cd	4.6 a	2.48 b	34 de	284 a	20.9 cd	3.66 bc	0.49 cd
'Syrah'	1.43 de	1.4 bcd	1.77 e	41 de	181 cd	21.5 bcd	3.99 a	0.52 cd
'Tannat'	1.76 cde	1.2 cd	1.79 e	35 de	263 ab	22.8 ab	3.61 bc	0.83 a
'Valdepeñas'	2.31 abc	0.9 d	1.89 de	35 de	179 cd	21.3 bcd	3.79 ab	0.53 cd

[W]Analysis of variance revealed significant ($P \leq 0.001$) year, cultivar, and year*cultivar interactions for all dependent variables. The figures presented are averages of six to 8 years' data: means followed by a common letter are not significantly different ($P \leq 0.05$) using Duncan's multiple range separation technique.

[X]Fruit rot severity estimated at harvest on 0 to 100% scale. Percentage data were arcsin-transformed prior to ANOVA, but are shown as non-transformed data here. Rating precision was to whole number, but means are presented in tenths because 0% rot was rarely observed..

[Y]Analyses conducted on previously frozen berry samples, with pH increased 0.1 to 0.2 pH units (8).

[Z]Titratable acidity as grams tartaric acid equivalents per liter.

(2). 'Mourvèdre' crops averaged 7.1 kg/vine (Table 3). The 1996 crop was significantly delayed in maturity due to the cool, wet season (Table 1) and, ultimately, was lost to bird depredation. Vines were vigorous, averaging 1.0 kg of prunings per m of canopy (Table 4). Berry and cluster weights were large and, despite cluster thinning, 'Mourvèdre' crops were probably greater than optimal in most years. Fruit was resistant to rots and had acceptable SSC, pH and titratable acidity (Table 4). MLTE data were not systematically gathered for 'Mourvèdre'. The -24 °C field exposure caused 97% primary bud kill (Table 6) but vines were too young that year to adequately rate trunk damage or the percent crop reduction from previous years. 'Mourvèdre' is reportedly very sensitive to potassium deficiency (2), which may have accounted for our annual observation of post-veraison leaf discoloration.

Nebbiolo: 'Nebbiolo' reigns as a principal component of Barolo and other Piedmont wines and has received attention in the US

Table 5. Lowest Mean Low Temperature Exotherm (MLTE) recorded in January or February of the indicated year for dormant buds of selected cultivars at Winchester, Virginia. Only those cultivars with two or more years' data were included.

	Lowest MLTE temperature (°C)						
Cultivar	1993	1994	1995	1996	1997	1998	Mean
'Cabernet Sauvignon #6'		-22.2	-20.0	-20.6	-21.7	-21.1	**-21.1**
'Cabernet Sauvignon #7'	-21.7	-23.3	-21.7	-21.1	-22.8	-19.4	**-21.7**
"Fer'		-21.1			-22.2		**-21.7**
'Nebbiolo'					-22.8	-20.0	**-21.4**
'Petit Verdot'		-22.2	-22.2	-23.3	-20.0	-20.6	**-21.7**
'Refosco'	-24.4				-22.2		**-23.3**
'Sangiovese'	-20.0				-20.0	-18.3	**-19.4**
'Syrah'					-20.6	-20.6	**-20.6**
'Tannat'	-21.1				-22.2		**-21.7**

as a varietal wine. April 22 was the average bud break and, on average, 164 days followed before fruit harvest (Table 2). Crops averaged only 4.5 kg per vine (Table 3), a reflection of the cordon-training and spur-pruning. The years with greater than average yields were years in which most bearing units were canes as a function of early training (1991) or re-training after winter injury (1995). Cane-pruned 'Nebbiolo' had a clear crop superiority to spur-pruned vine sides. Our 1998 data illustrated that pattern, with an average of 4.3 kg of crop from cane-pruned vine sides and 1.8 kg of crop from spur-pruned sides ($P \leq 0.0006$). Average cluster weights did not vary significantly as a function of pruning, illustrating that the affected yield component was a reduced cluster number with spurs. Basal bud infertility is a recognized feature of 'Nebbiolo' (3). Arguably, the relatively small crops of 'Nebbiolo' contributed to the relatively high SSC of harvested fruit (Table 4). Fruit was free of rot, and had good pH, although TA was somewhat high, and fruit did not always exhibit uniformly dark pigmentation. Vine size was supra-optimal (Table 4). Laboratory freeze tests in two winters yielded an average MLTE temperature of -21.4 °C (Table 5), while a -24 °C cold episode caused 96% primary bud kill, trunk damage to 2 of 15 vines, and resulted in a 69% crop reduction (Table 6). As with most of the other red cultivars evaluated, 'Nebbiolo' was considered cold-tender. Better clones on excellent sites might have greater potential than borne out by our experience.

Petit Verdot: 'Petit Verdot' is one of the five principal Bordeaux red cultivars and the variety has gained some favor in blended wines in California and South America (6). Bud break at Winchester was slightly advanced of 'Cabernet Sauvignon', whereas fruit harvest was slightly delayed (Table 2). Vines averaged 8.7 kg of crop, consistently producing greater than 6 kg of crop per vine, even in the year following -24°C (Table 3). Vines were vigorous, but cane prunings (1.45 kg/vine) were less than those of either 'Cabernet Sauvignon' clone (Table 4). Fruit quality was excellent, with SSC averaging 23.8° Brix, good pH and titratable acidity, and general freedom from fruit rots (Table 4). Laboratory freeze tests yielded an average MLTE temperature of -21.7 °C (Table 5), while a -24 °C cold episode caused 95% primary bud kill, trunk damage to 1 of 12 vines, but reduced the subsequent season's crop by only 27% (Table 6).

Refosco: Also known as 'Mondeuse noire' in the Savoy region of France, 'Refosco' is planted in small quantities in California, Australia, Argentina, the Friuli region of Italy, and in the Federal Republic

Table 6. Comparison of primary bud mortality, incidence of trunk injury, and crop yield response of 12 wine grape cultivars and two clones following -24°C exposure on 19 January 1994.

Cultivar	Percent primary bud kill[X]	Incidence of trunk damage[Y]	Crop yield/vine (kg) Average 1991-1993	1994	Percent yield change
'Cabernet Sauvignon #6'	76 c	2/15	4.9	3.2	- 35
'Cabernet Sauvignon #7'	90 ab	0/15	8.5	3.1	- 64
'Charbono'	100 a	8/15	12.5	1.4	- 89
'Fer'	99 a	8/15	5.6[Z]	1.1	- 80
'Limberger'	84 bc	0/15	11.3	5.0	- 56
'Mourvèdre'	97 ab	.	.	2.7	.
"Nebbiolo'	96 ab	2/15	5.2	1.6	- 69
'Petit Verdot'	95 ab	1/12	8.6 [Z]	6.3	- 27
'Refosco'	95 ab	0/13	7.7	8.6	+ 10
'Sangiovese'	100 a	13/15	13.0	0.5	- 96
'Syrah'	.	.	.	.	.
'Tannat'	100 a	9/10	11.2	0.0	- 100
'Valdepeñas	100 a	4/15	7.0	1.3	- 83

[X]Means folloed by the same letter within each column are not significantly different using Duncan's multiple range test ($P \leq 0.05$) on arcsin-transformed data (non-transformed means shown).
[Y]Trunk damage shown as number of visibly affected vines out of total present for that cultivar. Damage judged at end of 1994 growing season as poor shoot development or lack of shoots on affected cordons or trunks.
[Z]Figures based only on 1993 data.

of Yugoslavia, where it is known as 'Terrano' (6). Bud break averaged 21 April at Winchester and the fruit required an average of 181 days from bud break to ripen (Table 2). Crops averaged 9.6 kg/vine, and frequently exceeded 10 kg/vine (Table 3). Vines were vigorous, but produced the lightest pruning weights of the red cultivars evaluated (Table 4). Fruit SSC averaged 8.6 °Brix (Table 4) and only reached 20 °Brix in two years (our unpublished data). Relatively large berries and large clusters contributed to the high crops and, probably, the low SSC (Table 4). Fruit pH tended to be high and TA low, relative to other reds. Laboratory freeze tests over two winters yielded an average MLTE temperature of -23.3 °C (Table 5), while a -24 °C cold episode caused 95% primary bud kill, but no visible trunk injury, and no reduction in crop during the subsequent season (Table 6). Despite the apparently acceptable cold hardiness, the mediocre fruit quality provided no compelling reason to recommend 'Refosco' for general consideration in Virginia (12).

Sangiovese: 'Sangiovese' is a highly aromatic cultivar grown as the major component of Chianti wines, and making significant inroads as a varietal wine in the US, including Virginia. At Winchester, 'Sangiovese' bud break averaged 22 April and fruit required an average of 182 days to mature (Table 2). Crops averaged 10 kg per vine (Table 3), and we found it difficult to adequately regulate crop level, even with additional "green cluster thinning" at veraison. Berries and clusters were among the largest of the red cultivars evaluated (Table 4). The combination of large berries and excessive crop levels contributed to the relatively low, average SSC of 20.9 °Brix. While not formally evaluated, fruit and wine color was inferior to that of all other red cultivars evaluated at Winchester. The propensity for excessive cropping is a feature of the 'grosso' bio-type 'Sangiovese' clones (5), of which clone #2 used here is a member. In addition to the low SSC and poor color, 'Sangiovese' fruit had a greater rot potential than all other cultivars (Table 4). Laboratory freeze tests yielded an average MLTE temperature of -

19.4 °C (Table 5), while a -24 °C cold episode caused 100% primary bud kill, trunk damage to 13 of 15 vines, and resulted in an 96% crop reduction (Table 6). As such, the cultivar was considered extremely cold-tender. While we cannot recommend 'Sangiovese' clone #2 for commercial planting in Virginia, other, lower yielding clones may merit trial.

Syrah: Planted worldwide, 'Syrah' has probably achieved most attention for its contribution to the Rhone wines of France and to the concentrated wines of South Australia, where it is referred to as 'Shiraz'. 'Syrah' was early budding (20 April) at Winchester and required 178 days, on average, to ripen fruit (Table 2). Crops averaged 7.2 kg per vine (Table 3) and vine size was supra-optimal at 0.68 kg per m of canopy (Table 4). Fruit was resistant to cracking and rots, but varied considerably in quality. Soluble solids concentration averaged 21.5°Brix (Table 4), but was as low as 18.6° Brix in the cool, wet 1996 season, and as high as 22.9 °Brix in 1995. In addition to variable SSC levels, 'Syrah' fruit tended to exhibit elevated pH values prior to harvest. Our evaluation of 'Syrah' cold hardiness was limited to laboratory freeze evaluations in two winters, which consistently produced a MLTE temperature of -20.6(C (Table 5), inferring cold-tenderness. Given the variable fruit quality and the apparent lack of cold hardiness, 'Syrah' was not generally recommended for commercial planting in Virginia (12). As with other cultivars evaluated, superior clones grown in excellent sites, might fare better.

Tannat: 'Tannat' (syn. 'Moustrou', 'Madiran') contributes 40 to 60% of the volume to Madiran and certain other southwest France blended wines, adding tannins, firm structure, and alcohol (6). Bud break at Winchester averaged 8 May, nearly two weeks later than 'Cabernet Sauvignon', while fruit was harvested, on average, 167 days after bud break. Crops could be excessive, such as the 15.8 kg/vine attained in 1993. Overall, 'Tannat' crops were among the largest of the red cultivars evaluated. Despite those large crops, fruit quality was very good, showing little rot, relatively small berries, excellent SSC, acceptable pH, and intense pigmentation (12). Titratable acidity, however, was often higher than desired (12). Laboratory freezing tests produced a MLTE of -21.7°C, comparable to 'Cabernet Sauvignon' clone #7 (Table 5), but the -24°C field exposure killed 100% of primary buds, eliminated crop, and caused obvious trunk damage to 9 of 10 vines in 1994 (Table 6). As such, 'Tannat' was considered extremely cold-tender, reserved for excellent vineyard sites.

Valdepeñas: If not identical, 'Valdepeñas' is apparently quite closely related phenologically and enologically to the 'Tempranillo' of the Rioja region of Spain (6). Bud break at Winchester averaged 23 April and fruit required an average of 170 days from bud break to ripen (Table 2). Crop per vine averaged 6.5 kg (Table 3) and vines were very vigorous with 1.1 kg of prunings per m of canopy (Table 4). Fruit quality was mediocre, occasionally good, with very little rot, and fruit chemistry similar to 'Cabernet Sauvignon' clone #7 at harvest (Table 4). Laboratory tests of cold hardiness produced a MLTE temperature of -22.5°C (Table 5), while field exposure to -24°C killed 100% of primary buds, reduced crop by 83% and caused damage to 4 of 15 trunks (Table 6).

Conclusions

Each of the cultivars evaluated here had certain merits and deficiencies which must be considered in making varietal decisions (12). Based primarily upon high fruit quality and, to a lesser extent, cold hardiness comparable to or superior to that of 'Cabernet Sauvignon' clone #7, the cultivars 'Fer', 'Mourvèdre', 'Petit Verdot', and 'Tannat' were generally recommended for commercial consideration in Virginia. Although not part of this report, wines

were made from all cultivars in Virginia Tech's Department of Food Science and Technology. In addition to their favorable viticultural performance, wines made from the above cultivars exhibited the qualities outlined in the objectives to warrant recommendation for production in either general, or site-specific situations (Wolf et al., 1999). Cultivars with relatively small berries generally had higher fruit quality than did those with large (e.g., >2.0 g/berry) berries, and that feature might be a useful trait to consider for further cultivar and clone evaluations. All vines produced more vegetative growth than the 2.1-m vine spacing and non-divided canopy training system could accommodate. The major weakness with all of the red-fruited cultivars was their apparent cold-tenderness. The results obtained at Winchester should be applicable to other sites in the eastern US that have comparable climates and soils.

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Apple Multiple Harvest - Fruit Size

Although 'Gala' fruit size was not used directly in harvest selection, authors found that larger fruit still tended to be picked first, with the odds of a fruit being selected approximately doubling for each 20 g increase in size. The mean harvest fruit size is largest for the first harvest and decreases in later harvests despite ongoing fruit growth. Because the smaller fruit left on the tree continues to grow, the standard deviation of overall size distribution from multiple harvests is smaller than when fruit are harvested in a single picking. Authors developed a model to predict size distribution. From Hall et al 2001 J.Hort.Sci.Biotech. 76(4):424-430.