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Crop Yield, Grape Quality, and Winter Injury of Eight Wine Grape Cultivars in Northern Virginia

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Abstract

'Chardonnay #4,' 'Gruner Veltliner #1,' 'Malvasia bianca #3,' 'Muscat Ottonel #1,' 'Petit Manseng,' 'Viognier,' 'Vidal' and Chardonel' were evaluated at Winchester, Virginia for components of crop yield, fruit chemistry, and dormant bud cold hardiness over eight crop seasons. 'Chardonnay' and 'Vidal' represented "standards" for comparison in that they were grown commercially and successfully in Virginia; we lacked experience with the others. All cultivars were trained to bi-lateral cordons and spur-pruned. The novel cultivars all possessed mid-winter, dormant bud cold hardiness superior to that of 'Chardonnay.' Highest crop yields were attained with 'Vidal' (11.0 kg/vine) and 'Gruner Veltliner' (10.4 kg/vine); lowest with 'Muscat Ottonel' (5.1 kg/vine) and 'Viognier' (5.1 kg/vine). High sugar accumulating cultivars were 'Chardonel' (23.4 °Brix), 'Petit Manseng' (27.6 °Brix), and 'Viognier' (23.2 °Brix), whereas 'Malvasia bianca' and 'Muscat Ottonel' were harvested at relatively low soluble solids concentration but pronounced fruit aromas. Ungrafted 'Chardonel' suffered vine loss due to phylloxera. With the exception of 'Gruner Veltliner,' all cultivars warranted general recommendation in the established grape production regions of Virginia. 'Gruner Veltliner' was susceptible to increased fruit rot severity, but was otherwise viticulturally acceptable.

Since passage of the Virginia Farm Winery bill in 1980, Virginia's wine grape production has increased from less than 120 ha to over 600 ha in 1999 (12). Cultivars planted in the early 1980s continue to dominate Virginia production, with 'Chardonnay,' 'Cabernet Sauvignon,' and 'Riesling' representing the most abundant cultivars, in descending order. Cultivars such as 'Chardonnay' are generally well suited to many sites in the state, and enjoy sustained consumer popularity. Others, such as 'Riesling,' are less well suited to Virginia's heat and humidity. Virginia's macroclimate is primarily continental, with some maritime influence on the eastern shore and Tidewater regions (4). Growing seasons are hot and humid, with 3 to 4 inches of precipitation per month at most locations (4). Non-specific fruit rots, caused by a combination of physical (e.g., berry splitting with rains near harvest) and biotic (e.g., yeasts, and bacteria) factors, can be troublesome in wet seasons. Generally mild winters can be punctuated by brief periods of injurious temperatures (e.g., < –22°C). With cultivars of *Vitis vinifera* comprising over 70% of current acreage (12), winter cold injury remains the primary threat to grape survival in the mountain and Piedmont regions of the state, where grape production is primarily centered.

Both the uniqueness of Virginia's viticultural climate, and its youth necessitated studies to evaluate grape cultivar adaptation. Accordingly, evaluations were initiated at Virginia Tech in 1989 to identify novel (for Virginia) cultivars that met the following criteria:

a) ability of fruit to ripen with flavor, aromas, pigmentation and other sensory components conducive to high quality wine production;
b) resistance to fruit rots promoted by a humid/wet growing season;
c) sufficient cold hardiness to escape winter injury at good to excellent vineyard sites in 4 out of 5 winters;

This report summarizes the significant findings of our evaluation of eight white-fruited wine grape cultivars over an eight-year period.

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Table 1. Growing season characteristics and seasonal phenology of eight wine grape cultivars grown at Winchester, Virginia.

Phenological or 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[w]	2071	1426	1752	1947	2156	1825	1721	2225	1890
Mean maximum temperature, August (°C)	32.4	27.9	32.1	28.5	31.3	28.6	29.7	31.5	30.3
Mean maximum temperature, September (°C)	25.3	21.9	24.6	22.7	25.4	23.7	26.9	30.9	25.2
Mean maximum temperature, October (°C)	23.2	17.3	16.8	14.7	20.5	19.1	18.9	19.5	18.8
Mean minimum temperature, August (°C)	18.3	14.4	17.6	16.6	19.2	16.5	15.8	18.0	17.0
Mean minimum temperature, September (°C)	11.7	12.0	13.2	11.4	12.1	13.4	11.8	16.1	12.7
Mean minimum temperature, October (°C)	10.6	6.8	5.5	3.4	7.7	9.4	8.5	8.1	7.5
Absolute minimum temperature (°C)[x]	–12	–12	–11	–24	–17	–18	–14	–12	
Number of days, bud break to harvest[y]									
– Muscat Ottonel #1 (23 April)	.[z]	148	133	149	153	141	144	139	144
– Malvasia bianca #3 (25 April)	.	151	131	148	148	143	161	139	146
– Chardonel (23 April)	.	162	136	149	156	163	158	142	152
– Viognier (20 April)	.	165	128	146	177	170	156	154	157
– Gruner Veltliner #1 (22 April)	.	162	139	174	172	154	165	161	161
– Chardonnay #4 (18 April)	.	158	159	154	167	165	176	165	163
– Vidal blanc (26 April)	.	159	187	170	178	176	165	160	171
– Petit Manseng (21 April)	.	164	167	190	191	188	177	176	179

[w]A close approximation to GDD based on °F, with 50°F base, can be achieved by dividing the values shown by 0.555.
[x]Typically in January or early February of the indicated year.
[y]Dates in parentheses are the average date of 75% bud break for that cultivar.
[z]Phenological data not collected in 1991.

Materials and Methods

Cultivars were established at the AHS Jr. Agricultural Research and Extension Center in Winchester, Virginia (39°17' N, 78°17' W) in 1989. The soil, a Frederick-Poplimento loam, was primarily limestone-derived with some contribution from sandstone deposits. The effective rooting depth was greater than 100 cm, with moderate to abundant (ca. 118 to 238 mm/m) available water capacity. Soil pH, within the top 0.5 m, ranged from 6.0 to 7.0. Selected climatological features of the study period are included in Table 1. 'Chardonnay #4,' 'Gruner Veltliner #1,' 'Malvasia bianca #3,' 'Muscat Ottonel #1,' 'Petit Manseng,' and 'Viognier' (all *V. vinifera*) were grafted to rootstock cultivar 'C-3309.' Clonal designations were those used by the Foundation Plant Materials Service, Davis, CA. 'Vidal' and 'Chardonel' (interspecific *Vitis* hybrids) were not grafted. 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 bi-lateral 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. Vineyard management was comparable to that commercially recommended in Virginia (15). Vineyard management included mowed Fescue spp. cover crop between the rows, ≈ 1.0 m wide herbicide strip under the trellis, conventional fungicide and insecticide programs, no irrigation, and 61 kg/ha of actual nitrogen fertilizer in April 1997. Vine management consisted of shoot thinning to an average of 17 shoots per m of canopy shortly after bud break, shoot positioning, shoot hedging as needed to avoid canopy shade, and annual dormant pruning. Aside from shoot thinning, no effort was made to reduce crop level. 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, incidence and severity of fruit rots at harvest, and cane pruning weights. Fruit harvest was predicated upon acceptable commercial standards for high quality wine. Harvest indices included aroma and taste of fruit for varietal character, as well as balance between fruit soluble solids concentration (SSC), pH and titratable acidity (TA). When possible, harvest was delayed until fruit attained 22 to 23 °Brix. Dormant bud cold hardiness was evaluated as described in Wolf and Cook (14), and expressed as Mean Low Temperature Exotherm (MLTE) temperatures. A MLTE temperature is essentially that temperature required to kill 50% of a population of dormant buds. 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. Bud response was evaluated shortly after the freeze event by sectioning 10 buds on 15 canes per cultivar (three canes per cultivar plot) and evaluating for primary bud viability (14). Trunks and cordons were visually evaluated for evidence of injury in late-summer 1994 by assessing shoot growth characteristics.

Results and Discussion

The continentality of the Winchester, Virginia climate is illustrated by the seasonal variation observed from 1991 through 1998 (Table 1). Mean maximum and mean minimum August temperatures during the study period averaged 30.3°C and 17.0°C, respectively. The 30-year (1951-1980) average heat unit accumulation (10°C base) for Winchester was 1970 units (4). The notable negative departure occurred in 1992 as a consequence of the dispersion of volcanic ejecta into the atmosphere from Mt. Pinatubo in The Philippines (June 1991). The warmest season 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 notable for the paucity of

precipitation (Table 1). Pronounced fluctuations in crop yields and fruit chemistry could be directly linked to seasonal extremes with most of the cultivars evaluated. For clarity, the results are discussed by cultivar.

Chardonnay:

'Chardonnay' clone #4 was used as a basis for comparison with the other white wine grapes in this study. Average date of bud break for 'Chardonnay' at Winchester was 18 April, the earliest of the cultivars evaluated (Table 1). The propensity for early budding is a potential liability with 'Chardonnay' in frost-prone sites, and was likely a contributing factor in the lower than average crop yields of 1997, a year in which bud break of 'Chardonnay' (8 April) preceded a frost event of –3.9°C on 10 April. 'Chardonnay' averaged 163 days from budbreak to harvest (Table 1). Harvested crop per vine ranged from 0.6 kg in 1994 to 12.6 kg in 1995, with an average of 8.2 kg (Table 2). Generally, 'Chardonnay #4' was among the higher yielding of the cultivars evaluated, and is reportedly (17) one of the higher yielding 'Chardonnay' clones. 'Chardonnay' cane pruning weights, 1.43 kg/vine, were mid-range of the cultivars evaluated. Given the summer pruning that 'Chardonnay' received, the specific pruning weight (0.67 kg/m of canopy) could be considered indicative of large, vigorous vines. At harvest, 'Chardonnay' clone #4 had acceptable SSC, pH and TA (Table 3). Lowest SSCs were measured in the cooi 1992 season and in the high crop year of 1995 (Table 4). 'Chardonnay' clone #4 fruit chemistry was not dissimilar to that reported by Wolpert et al. (17) for two Napa Valley locations. 'Chardonnay' was susceptible to fruit rots, primarily Botrytis bunch rot (*Botrytis cinerea*), and averaged 7.5% rotted fruit over the 8-year study period (Table 3). Other researchers (10) have reported significant clonal differences in bunch rot susceptibility of spur-pruned 'Chardonnay.' The relatively large berry and cluster size of 'Chardonnay' clone #4 (Table 3), coupled with good fruit set, impart a compact cluster, which increases the likelihood of bunch rot development. Laboratory tests of 'Chardonnay' dormant bud cold hardiness produced MLTE temperatures of –19 to –22°C, and averaged –20.5°C (Table 5). A temperature of –24°C in January 1994 caused 100% primary bud kill, a 93% reduction in expected crop, but no apparent trunk injury (Table 6).

Chardonel:

'Chardonel' was released from Cornell University (6) in 1990 as a cross of 'Seyval' x 'Chardonnay.' Average bud break date with 'Chardonel' was 23 April, approximately 5 days after 'Chardonnay,' and an average of 152 elapsed between bud break and fruit harvest (Table 1). Crop per vine (8.1 kg) was comparable to 'Chardonnay' (Table 2), while the average cane pruning weight of 1.54 kg was slightly greater than that of 'Chardonnay' (Table 3). 'Chardonel' fruit, at harvest, tended to have larger berries and fruit bunches, higher soluble solids concentrations, lower pH, and a comparable titratable acidity, compared to 'Chardonnay' (Table 3). SSC often exceeded 23° Brix, even in the cool 1992 season (Table 4). Fruit was resistant to bunch rots (Table 3). Laboratory tests of 'Chardonel' dormant bud cold hardiness produced MLTE temperatures of –20 to –24°C (Table 5). The relative cold hardiness of 'Chardonel,' 'Seyval,' and 'Chardonnay' buds is illustrated in Figure 1 for the 1994-1995 dormant period. 'Chardonel' bud cold hardiness was typically between that of 'Seyval'[2] and 'Chardonnay,' as reported in the cultivar release notes (6). A temperature of –24°C in January 1994 caused 26% primary bud kill, and produced no apparent trunk injury nor crop reduction (Table 6). 'Chardonel' was the only cultivar evaluated which lost vines during the course of evaluation. Beginning in 1996 (8th year in vineyard), one of the original 15 vines showed premature leaf yellow-

[2]Seyval was not part of the replicated cultivar evaluation; however, Seyval rows were planted immediately adjacent to the cultivar evaluation rows, and Seyval was similarly trained and otherwise managed.

ing, premature cessation of shoot elongation, advanced fruit maturity, and significantly reduced cane pruning weights and crop yield (13). That vine was removed in 1997. Three additional vines showed identical symptoms in 1997 and 1998. Upon close examination, roots of the affected vines were found to harbor numerous phylloxera, with roots showing typical nodosities (5) caused by phylloxera. Virginia Tech's plant disease clinic could isolate no fungal pathogens from affected vines, and confirmed the presence of the phylloxera. Given the parentage of 'Chardonel,' and our experience with vine attrition, the use of a phylloxera-tolerant rootstock would be warranted with 'Chardonel.'

'Viognier':

'Viognier' was once almost exclusively grown in the northern Rhône region of France, especially Condrieu, but has expanded geographically in response to consumer interest and its viticultural merits (7). On average, 'Viognier' bud break occurred 20 April, and fruit required 157 days to reach maturity (Table 1). Crop per vine ranged from 2.3 to 8.1 kg/vine, and averaged 5.1 kg/vine (Table 2). The relatively modest crops were due partly to relatively small berries and cluster weights (Table 3), but also to bud necrosis, which averaged 22 to 75% of primary buds per year (11; and our unpublished data). Cane pruning weights averaged 1.36 kg/vine, slightly lower than those of 'Chardonnay' (Table 3). Fruit was highly resistant to bunch rots and achieved relatively high soluble solids accumulation, with good acidity and acceptable pH (Table 3). 'Viognier' fruit typically exceeded 23° Brix; however, fruit pH had a tendency to be higher than optimum (Table 4). 'Viognier' primary buds appeared to be somewhat hardier than those of 'Chardonnay.' Laboratory freeze tests yielded an average MLTE temperature of –23.9°C over six dormant seasons (Table 5). The consequences –24°C exposure were not, however, as severe as with other *V. vinifera* cultivars in our evaluation. The –24°C event in January 1994 resulted in complete death of the *remaining* primary buds (Table 6). Nevertheless, vines bore an average of 5.5 kg/vine of fruit in 1994, an increase over the previous season's crop. The explanation for this conundrum appears to relate to the high proportion of primary bud necrosis with 'Viognier.' Primary bud abortion occurs at or before bloom-time, and secondary buds, which are presumably more cold hardy, are more developed, and potentially more fruitful (11). Aside from bud cold hardiness, it should be pointed out that the –24°C event caused trunk damage on 2 of 13 vines (Table 6).

'Muscat Ottonel':

'Muscat Ottonel' is one of a diverse group of grape cultivars that are noteworthy for their pronounced aromatic character (1). Bud break at Winchester averaged 23 April (Table 1). At 144 days, this was the earliest crop maturing cultivar in our collection. Crop per vine ranged from 1.9 to 8.7 kg/vine, and averaged 5.1 kg/vine over the study period (Table 2). 'Muscat Ottonel' had relatively large berries, but a small cluster weight owing to relatively few berries per cluster (Table 3). Cane pruning weights averaged 1.98 kg/vine. Even with repeated hedging, the specific pruning weight of 0.9 kg/m of canopy was indicative of an imbalance between crop and vegetation production (8). Fruit matured with reasonably high SSCs, but at an elevated pH and very low TA (Table 3). Elevation of pH was pronounced in 1991, 1994-96, and 1998 (Table 4). The cool 1992 season was associated with the lowest pH. Fruit aromas were very pronounced at 18 to 19° Brix, at which point the pH was typically less than 3.4 (data not shown). Fruit was resistant to bunch rots, averaging less than 1% (Table 3). 'Muscat Ottonel' bud cold hardiness tests produced an average MLTE temperature of –22.4°C, approaching –24°C in the relatively cold winter of 1996 (Table 5). The –24°C freeze event of January 1994 caused 74% primary bud kill, a 45% reduction in expected crop, but no trunk damage (Table 6).

Table 2. Harvested crop per vine (kg) of eight grape cultivars over eight seasons at Winchester, Virginia.

	1991[z]	1992[z]	1993[z]	1994[z]	1995[z]	1996[z]	1997[z]	1998[z]	Mean
Chardonnay #4	9.7 a	9.5 b	10.6 ab	0.6 f	12.6 b	6.4 b	6.7 cd	9.8 b	8.2
Chardonel	6.6 b	8.2 bc	8.4 bc	9.6 b	9.6 c	5.5 bc	8.1 bc	8.7 bc	8.1
Gruner Veltliner #1	11.3 a	12.9 a	9.8 b	5.0 cd	15.7 a	6.3 bc	12.0 a	9.8 b	10.4
Malvasia bianca #3	9.8 a	6.9 cd	10.9 ab	1.7 f	13.3 ab	3.6 d	10.1 ab	10.0 b	8.3
Muscat Ottonel #1	7.1 b	4.1 e	6.7 cd	3.4 e	8.7 c	1.9 e	5.5 d	3.6 d	5.1
Petit Manseng	-	-	5.1 de	3.7 de	5.8 d	4.9 c	5.7 d	6.3 cd	5.3
Vidal blanc	4.7 b	8.7 bc	12.3 a	11.9 a	14.2 ab	9.7 a	11.6 a	14.5 a	11.0
Viognier	-	5.7 de	2.7 e	5.5 c	8.1 cd	2.3 e	6.0 cd	5.6 cd	5.1

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

'Malvasia bianca':

'Malvasia bianca' is an aromatic cultivar used to produce varietal wines as well as used in blending, including red wines (e.g., Chianti of Italy) (7). Bud break averaged 25 April, about one week after 'Chardonnay' (Table 1). The period from bud break to fruit harvest averaged 146 days, comparable to that of 'Muscat Ottonel.' Crop yields averaged 8.3 kg/vine (Table 2) and Malvasia had the largest berries and greatest cluster weights among white cultivars tested (Table 3). Fruit bunch rot severity averaged 1.4%. Fruit attained a pronounced floral character at 17 to 18° Brix, and averaged 19.7° Brix at harvest (Table 3). Fruit titratable acidity was acceptable, and pH tended to be lower than that of 'Muscat Ottonel' (Table 4). Laboratory tests of 'Malvasia bianca' bud cold hardiness produced an average MLTE temperature of -23°C (Table 5). The –24°C freeze in January of 1994 caused 95% primary bud kill, an 82% reduction in expected crop, and damaged trunks on two of 14 vines (Table 6).

'Vidal':

'Vidal' was, and remains, the second most abundantly planted interspecific hy-

Table 3. Mean cane pruning weight, fruit rot severity, components of crop yield, and fruit chemistry at harvest of eight wine grape cultivars grown at Winchester, Virginia over eight seasons.

	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)[wyz]
Chardonnay #4	1.43 c	7.5 a	1.87 cd	43 c	186 b	21.6 c	3.50 cd	6.7 b
Chardonel	1.54 bc	0.7 c	2.39 b	45 c	195 b	23.4 b	3.37 d	6.5 b
Gruner Veltliner #1	1.65 b	6.4 a	1.99 c	56 b	159 bc	21.1 cd	3.76 ab	3.7 d
Malvasia bianca #3	1.97 a	1.4 c	3.53 a	23 e	336 a	19.7 e	3.46 cd	5.2 c
Muscat Ottonel #1	1.98 a	0.7 c	2.44 b	51 b	68 d	20.6 cde	3.81 a	3.5 d
Petit Manseng	1.33 cd	0.7 c	1.13 e	53 b	100 cd	27.6 a	3.41 cd	8.0 a
Vidal	1.19 d	1.8 c	1.82 cd	63 a	222 b	22.9 b	3.59 bc	6.1 bc
Viognier	1.36 cd	0.5 c	1.64 d	37 d	104 c	23.2 b	3.73 ab	5.6 bc

[w]Analyses conducted on previously frozen berry samples, with pH increased 0.1 to 0.2 pH units (Spayd et al., 1987).
[x]Analysis of variance revealed significant ($P \leq 0.001$) year, cultivar, and year*cultivar interactions for all dependent variables. Means followed by a common letter are not significantly different ($P \leq 0.05$) using Duncanís multiple range separation technique.
[y]Fruit rot 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.
[z]Titratable acidity as grams tartaric acid equivalents per liter.

Table 4. Soluble solids concentration (°Brix), pH, and titratable acidity (TA) at harvest of eight wine grape cultivars grown at Winchester, Virginia over eight seasons.

	1991			1992			1993			1994		
	° Brix	pH[w]	TA[z]	° Brix	pH[w]	TA[z]	° Brix	pH[w]	TA[z]	° Brix	pH[w]	TA[z]
Chardonnay #4	.[y]	.[y]	.[y]	20.7 c	3.24 e	5.9 a	21.6 de	3.64 a	5.4 ab	21.8 c	3.21 e	7.5 a
Chardonel	23.1 a	3.27 d	4.5 a	23.1 b	3.50 c	5.8 a	24.5 b	3.33 c	5.2 ab	23.2 b	3.15 e	7.2 a
Gruner Veltliner	21.5 a	3.63 c	2.3 c	19.5 d	3.82 a	3.8 c	22.4 cd	3.64 a	3.8 c	22.8 b	3.70 b	3.6 d
Malvasia bianca #3	16.7 c	3.68 c	3.5 b	19.5 d	3.25 e	4.8 b	20.5 e	3.24 d	5.6 ab	19.2 e	3.55 c	5.3 bc
Muscat Ottonel #1	19.3 b	4.08 a	2.2 c	20.3 cd	3.36 d	3.0 c	21.7 de	3.52 b	3.4 c	20.6 d	3.82 a	3.6 d
Petit Manseng	.[y]	.[y]	.[y]	24.5 a	3.30 de	.[y]	29.2 a	3.20 d	4.6 bc	29.0 a	3.52 c	6.2 b
Vidal blanc	22.0 a	3.87 b	3.1 bc	22.8 b	3.61 b	5.9 a	23.6 bc	3.58 ab	6.6 a	22.8 b	3.44 d	5.0 c
Viognier	.[y]	.[y]	.[y]	22.6 b	3.81 a	4.8 b	23.3 bc	3.58 ab	6.0 a	23.4 b	3.19 e	6.0 bc
	1995			1996			1997			1998		
	° Brix	pH[w]	TA[z]	° Brix	pH[w]	TA[z]	° Brix	pH[w]	TA[z]	° Brix	pH[w]	TA[z]
Chardonnay #4	20.6 cd	3.73 c	6.8 c	21.2 c	3.72 c	7.6 c	22.6 c	3.27 d	6.5 b	22.7 bc	3.65 c	8.3 a
Chardonel	24.0 b	3.37 de	8.5 a	21.9 c	3.43 e	7.5 c	24.2 b	3.50 b	5.9 c	23.2 bc	3.36 d	6.5 b
Gruner Veltliner	20.0 d	4.05 b	3.6 e	19.3 d	4.06 a	4.5 e	22.0 cd	3.36 c	3.5 e	23.0 bc	3.89 b	5.4 c
Malvasia bianca #3	20.5 cd	3.48 d	5.3 d	18.7 d	3.58 d	6.1 d	22.0 cd	3.30 d	5.0 d	19.1 e	3.69 c	5.6 c
Muscat Ottonel #1	21.7 c	4.05 b	4.0 e	19.1 d	4.01 a	4.2 e	21.3 d	3.61 a	3.5 e	21.3 d	4.10 a	4.7 d
Petit Manseng	29.0 a	3.30 e	7.4 b	25.7 a	3.70 c	11.4 a	28.6 a	3.10 e	7.4 a	27.6 a	3.78 b	7.7 a
Vidal blanc	21.5 c	3.69 c	6.4 c	24.3 b	3.68 c	9.0 b	23.4 b	3.31 cd	5.6 c	22.2 cd	3.73 bc	5.5 c
Viognier	24.7 b	4.21 a	3.8 e	21.2 c	3.90 b	6.9 c	23.7 b	3.62 a	5.7 c	24.1 b	3.90 b	6.0 bc

[w]Analyses conducted on previously frozen berry samples, with pH increased 0.1 to 0.2 pH units (Spayd et al., 1987).
[x]Analysis of variance revealed significant ($P \leq 0.001$) year, cultivar, and year*cultivar interactions for all dependent variables. Means followed by a common letter are not significantly different ($P \leq 0.05$) using Duncanís multiple range separation technique.
[y]Missing data due to insufficient plot replication, or analysis not performed.
[z]Titratable acidity as grams tartaric acid equivalents per liter.

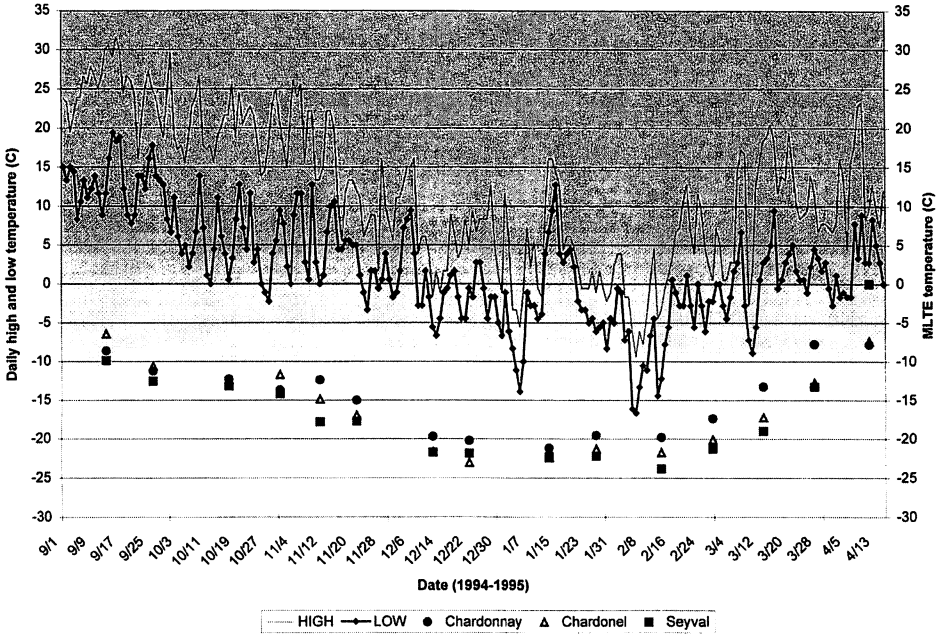

Figure 1. Mean Low Temperature Exotherm (MLTE) temperature of Chardonnay #4, Chardonel, and Seyval dormant buds in response to changes in daily air temperature during the 1994-1995 winter at Winchester, VA.

brid grape cultivar in Virginia (12); it was included in this evaluation for comparative purposes. A relatively late bud break, 26 April (Table 1), provides some measure of spring frost avoidance. In addition to dry and semi-sweet wine styles, 'Vidal' has been used commercially in Virginia for late-harvest dessert style wines. 'Vidal' had the greatest crop yields of the white cultivars, averaging 11.0 kg/vine (Table 2). Cane pruning weights averaged 1.19 kg/vine, making 'Vidal' one of the few cultivars that might be considered "balanced" (8), with a specific pruning weight of 0.55 kg/m of canopy, and a crop load (cane prunings/crop yield) average of 9.2. Fruit exhibited less than 2% bunch rot severity at harvest, and berry (1.91 g) and cluster (222 g) weights were intermediate (Table 3). Vidal fruit had excellent fruit ripening potential, averaging 23°Brix, 3.59 pH, with balanced acidity (Table 3). In contrast to Ohio (2) and Pennsylvania (3), 'Vidal' at Winchester had higher SSCs, much

Table 5. Lowest Mean Low Temperature Exotherm (MLTE) recorded in January or February of the indicated year for five cultivars at Winchester, VA.

	Lowest MLTE temperature (°C)						
Cultivar	1993	1994	1995	1996	1997	1998	Mean
Chardonnay #4			–21.1	–21.6	–19.4	–20.0	–20.5
Chardonel		–22.8	–23.0	–24.4	–20.0		–22.6
Malvasia bianca #3			–22.8		–22.8	–20.0	–21.9
Muscat Ottonel #1	–23.3		–23.3	–23.9	–21.1	–20.5	–22.4
Viognier		–24.4	–23.3	–25.0	–24.4	–22.8	–24.0

Table 6. Comparison of primary bud mortality, incidence of trunk injury, and crop yield response of eight wine grape varieties 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
Chardonnay #4	100 a	0/12	9.8 ab	0.6 f	–94
Viognier	100 a	2/13	4.2[z] e	5.5 c	+31
Malvasia bianca	95 a	2/14	9.2 bc	1.7 f	–82
Gruner Veltliner	93 a	0/14	11.0 a	5.0 cd	–55
Muscat Ottonel	74 b	0/15	6.0 d	3.3 e	–45
Vidal	60 bc	0/15	8.9 bc	11.8 a	+33
Petit Manseng	54 c	1/12	4.2[z] e	3.7 de	–12
Chardonel	26 d	0/14	7.9 c	9.5 b	+20

[x]Means followed by the same letter within each column are not significantly different using Duncanís 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.

lower TA, and higher pH, likely a function of the greater heat available in Winchester. 'Vidal' also showed good consistency of fruit chemistry at harvest among seasons that markedly differed in heat accumulation and precipitation (Table 4). Limited laboratory tests of 'Vidal' bud cold hardiness revealed an average MLTE temperature of –22.7°C (Table 5), while the –24°C freeze event caused 60% primary bud kill, no crop reduction, and no perceptible trunk damage (Table 6).

'Gruner Veltliner':

'Gruner Veltliner' represents close to 30% of Austrian grape acreage and is grown in warmer areas of Germany (7). Average bud break occurred 22 April and 161 days elapsed between bud break and harvest (Table 1). Crop yield per vine averaged 10.4 kg, among the highest of the white cultivars (Table 2). Cane pruning weights were 1.65 kg/vine (Table 3). Despite the high crops, fruit quality was very good with SSC often exceeding 22°Brix (Table 4). Fruit pH was higher than optimum in more than half of the years; however, fruit had good aroma and flavors at lower SSCs and could potentially have been harvested earlier than done here. Fruit rots were problematic and averaged 6.4% (Table 3). Berry and cluster weights were intermediate. Laboratory tests of 'Gruner Veltliner' cold hardiness were not methodically performed. Field exposure to –24°C produced a 93% primary bud kill, a 55% reduction in expected crop, but no trunk injury (Table 6).

'Petit Manseng':

Important to the Jurancon region of France (7), 'Petit Manseng' was one of the most unusual cultivars evaluated. Bud break averaged 21 April and the fruit required an average of 179 days to ripen (Table 1). Crops were relatively light, averaging 5.3 kg/vine, due in part to very small berries and low cluster weights (Table 3). Clusters were loose and generally free of rot at harvest (Table 3). Cane prunings averaged 1.33 kg/vine. The most unusual feature of 'Petit Manseng' was its ability to accumulate extremely high SSCs at a relatively high TA and low pH (Table 3). It was not unusual to harvest fruit at 29°Brix (Table 4). Ripe fruit had a pronounced flavor amalgam of honey and citrus. Laboratory bud cold hardiness tests performed in two winters produced an average MLTE temperature of –21.1°C. The –24°C field exposure caused 54% primary bud kill, reduced the expected crop by 12%, and damaged trunks on one vine (Table 6).

Conclusions

The novel cultivars provide diversity to Virginia's evolving industry. Each has certain merits and deficiencies which must be considered in making varietal decisions (16). The relative performance of these cultivars should be reproducible under similar growing conditions and management. Although not part of this report, wines were made from all cultivars in Virginia Tech's Department of Food Science. Informal evaluations of those wines reinforced the commercial recommendations. 'Petit Manseng,' however, was deemed most suitable for blending due to high potential alcohol and high TA. For "standard" cultivars such as 'Chardonnay,' our current efforts are aimed at clonal evaluations.

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