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Effect of Soil Profile Modification and Irrigation on Senescence and Bud Hardiness of Young Grapes

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Abstract. **Some aspects of senescence and bud hardiness of young 'Vidal blanc' and 'Chancellor' French-American grapevines in the following treatments were evaluated: soil profile modification plus irrigation (MI), no soil profile modification plus irrigation (CI), soil profile modification without irrigation (MN), and no soil profile modification without irrigation (CN). After a prolonged summer drought, abundant fall precipitation increased 25 Oct. chlorophyll and leaf N levels for nonirrigated vines. In contrast, leaf P and K were higher for irrigated treatments. Bud hardiness of 'Chancellor' was greater than 'Vidal blanc' for all except the CI treatment. Maximum primary bud hardiness was achieved in the CI and MN treatment for 'Vidal blanc' and 'Chancellor', respectively. Cambium damage and/or plant death occurred for only 'Vidal blanc' in the CN treatment.**

In the United States, the culture of *Vitis vinifera* grapes is restricted mainly to the Pacific coastal states. Except where Pierce's disease is a problem, the major factor limiting the geographical distribution of *V. vinifera* is minimum winter temperature. *Vitis labruscana* Bailey 'Concord' and 'Catawba' represent the majority of the grapes grown in the Midwest, although French-American hybrid wine grapes comprise most new vineyards. French-American hybrids have *V. vinifera*, V. rupestris, V. riparia, V. aestivalis, and other *Vitis* species in their parentage and vary considerably in hardiness (3, 4, 8, 10).

Bud hardiness of 'Concord' has been associated with high sunlight exposure, medium cane diameter, darkly colored periderm, a low number of lateral canes, and a consistent but moderate fruit load and vigor (5, 6). Adequate soil moisture during the spring and early summer and low soil moisture during late summer and fall facilitate cold acclimation (1, 5, 6, 14). Cultural practices must be optimized to attain maximum cold hardiness in northern limits of cultivar adaptability.

The summer of 1983 was particularly hot and dry. Soils of the nonirrigated treatments reached 1.0 MPa soil moisture tension, which resulted in a 2-fold reduction in transpiration and growth and a 6-fold reduction in total leaf area (2). Irrigation was terminated 1 Sept. 1984; however, subsequent rainfall was plentiful. Since irrigation and no irrigation were confounded by fall precipitation, a more accurate treatment comparison is summer irrigation and fall precipitation to summer drought and fall precipitation. Cold temperatures during late December (– 26° to – 20°C) provided an opportunity to evaluate the effect of treatment on bud hardiness.

The objective of this study was to determine the effect of soil profile modification/irrigation on leaf nutrient levels and chlorophyll content in the fall, and subsequent cold hardiness during an unusually cold winter.

The vineyard consisted of 48 mixed rows of 'Vidal blanc', also known as 'Vidal 256', and 'Chancellor' oriented N–S (0.42 ha) with a 5.0% south facing slope. The soil was a Lebanon silt loam with a 10–25 cm thick fragipan layer located at varying depths between 30 and 64 cm below the soil surface. Superphosphate (0-44-0) and potash (0-0-61) were broadcast (112 kg ha^{-1}) about one month prior to planting. Plant spacing was 2.4 and 3.0 m within and between rows, respectively. Two shoots were allowed to develop the first year. Shoots reaching the top wire (168 cm) were clipped 29 Aug. 1983 to initiate cordons consistent with a bilateral cordon training system.

The experimental design was a split plot with cultivars constituting the sub plots. The main plot treatments were 1) soil profile modification with irrigation (MI), 2) soil profile modification without irrigation (MN), 3) no soil profile modification with irrigation (CI), and 4) no soil profile modification without irrigation (CN). Each treatment was replicated 4 times.

Soil profile modification was accomplished by backhoeing 1 m deep and 1 m wide in-row strips of soil, mixing the soil with 10% v/v sawdust and returning it to the trench as described previously (2). Dip irrigation was applied to the irrigated treatment when soil moisture tension rose above 0.010 MPa. All irrigation was terminated 1 Sept., after which time rainfall was abundant.

Table 1. Effect of soil profile modification/irrigation and cultivar on 25 Oct. 1983 chlorophyll levels.

Treatments	Chlorophyll ($\mu g\ cm^{-2}$)
Main plot	
Control nonirrigated	33.5 a^{z}
Control irrigated	19.7 b
Modified nonirrigated	33.7 a
Modified irrigated	20.7 b
Subplot	
'Vidal blanc'	28.4 a
'Chancellor'	25.3 a
Interactions	
Control nonirrigated	
'Vidal blanc'	34.8
'Chancellor'	32.2
Control irrigated	
'Vidal blanc'	21.9
'Chancellor'	17.6
Modified nonirrigated	
'Vidal blanc'	32.7
'Chancellor'	34.7
Modified irrigated	
'Vidal blanc'	24.3
'Chancellor'	16.8
LSD 0.05 within main plot treatment interactions	8.3
LSD 0.05 across main plot treatment interactions	6.3

^{z}Mean separation within main plot and within subplot by Duncan's new multiple range test, 5% level.

Two fully expanded leaves from the midshoot area of 5 one-year-old vines per replication were collected 25 Oct. 1983, and frozen for determination of chlorophyll concentration and leaf elemental analyses.

For chlorophyll determinations, leaf disks (8 mm diameter) were thawed and ground in ethyl ether with a mortar and pestle. After grinding, the contents were transferred to a test tube, the residue was washed again with ethyl ether, and the volumes were combined. The mixture was centrifuged, brought to a 10 ml volume, and poured into a glass cuvette. Total chlorophyll was determined by measuring absorbance values at 642.5 and 660 nm obtained with a Perkin-Elmer Model 111 UV-VIS spectrophotometer. Chlorophyll concentration was calculated by the formula:

$$\mu g \text{ chlorophyll ml}^{-1} = 16.0\ A_{642.5} + 7.0\ A_{660}\ (9, 15).$$

Frozen leaves (lamina plus petioles) were thawed, oven-dried overnight at 80°C, and ground in a Wiley mill. Nitrogen was determined wtih an Antek Model 720 Nitrogen Detector. Macro and micronutrients were analyzed with an Inductively Coupled Argon Plasma Spectrophotometer (Jarrell-Ash Model 800).

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Table 2. Effect of soil profile modification/irrigation and cultivar on 25 Oct. 1983 leaf nutrient levels.

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)	Mo (ppm)
Main plot											
Control nonirrigated	2.2 a[z]	0.29 c	0.9 b	3.3 a	0.40 a	220 a	120 ab	62 a	8.2 a	21 ab	1.2 a
Control irrigated	1.8 b	0.80 a	1.7 a	2.7 b	0.28 c	130 b	90 b	34 b	7.2 c	19 b	1.2 a
Modified nonirrigated	2.3 a	0.23 c	1.0 b	3.2 a	0.35 b	210 a	140 ab	45 b	7.5 bc	21 ab	1.2 a
Modified irrigated	2.1 ab	0.52 b	1.5 a	2.8 b	0.25 c	140 b	160 a	41 b	7.9 ab	24 a	1.2 a
Subplot											
'Vidal blanc'	2.1 a	0.43 b	1.1 b	3.4 a	0.31 b	180 a	110 a	39 b	7.2 b	20 a	1.0 b
'Chancellor'	2.1 a	0.49 a	1.4 a	2.6 b	0.34 a	170 a	140 a	52 a	8.2 a	22 a	1.4 a
Interactions											
Control nonirrigated											
'Vidal blanc'	2.3	0.24	0.7	3.7	0.37	230	120	45	7.7	20	1.0
'Chancellor'	2.2	0.35	1.1	2.9	0.43	210	120	79	8.6	21	1.4
Control irrigated											
'Vidal blanc'	1.8	0.77	1.4	3.2	0.29	140	80	32	6.9	17	1.1
'Chancellor'	1.8	0.83	1.9	2.2	0.27	110	90	35	7.5	21	1.6
Modified nonirrigated											
'Vidal blanc'	2.3	0.22	0.9	3.4	0.29	200	140	40	7.4	21	1.0
'Chancellor'	2.3	0.25	1.1	3.0	0.42	220	130	49	8.3	20	1.3
Modified irrigated											
'Vidal blanc'	2.1	0.51	1.2	3.2	0.27	140	100	37	6.8	22	1.0
'Chancellor'	2.0	0.53	1.7	2.3	0.23	140	220	45	8.2	25	1.4
LSD 0.05 within main plot treatment interactions	0.3	0.05	0.2	0.3	0.06	40	80	13	0.8	5	0.3
LSD 0.05 across main plot treatment interactions	0.3	0.10	0.3	0.4	0.06	50	80	15	1.5	7	0.3

[z] Mean separation within main plot and subplots by Duncan's new multiple range test, 5% level.

Five to 10 node midcane sections of 5 vines were taken at random from each of 4 replications during March. After canes were kept at room temperature for 2–3 days, bud mortality was determined on 25 nodes per replication by the tissue browning method (10, 13). This method has been demonstrated to provide an accurate determination of grapevine bud injury (13). Primary and secondary bud mortality was recorded when the tissue in the center of the bud was brown. The percentage of underdeveloped tertiary buds also was recorded. Tertiary buds not discernible in serial sections under × 10 magnification were classified as underdeveloped. Percentage data were analyzed after conversion to a normal distribution by an arcsin square root transformation.

Chlorophyll levels in leaves sampled during late October were significantly higher for nonirrigated vines than irrigated vines (Table 1). Soil profile modification (depth of rooting) and cultivar had no appreciable effect on chlorophyll levels. Summer drought stricken vines replenished by rain in September and October apparently failed to senesce in the fall to the degree shown by summer irrigated vines.

Leaf nutrient analyses performed in the fall to help assess the degree of senescence indicated that all macronutrients were affected by treatment (Table 2). Nitrogen, the nutrient most often associated with active growth conditions, increased about 18% without irrigation. In contrast, P and K increased about 150% and 66% with irrigation. When values of N, P, and K are used to calculated a ratio (N:P and N:K) for each treatment the results are striking: CN, 7.6 and 2.5; CI, 2.3 and 1.1; MN, 9.8 and 4.3; MI, 3.9 and 1.4. Thus, N:P and N:K were reduced about 2- to 4-times for the irrigated treatments. Direct comparisons between these data and reported optimum nutrient levels of petioles at bloom or before harvest are not addressed because we analyzed entire leaves (lamina plus petioles) on young nonbearing vines in late fall.

Significant differences in Ca, Mg, and most micronutrients also occurred among treatments (Table 2). Ca and Mg were highest for the nonirrigated treatments, and the trend in Mg levels between treatments was similar to that of chlorophyll. Leaves of 'Vidal blanc' exceeded 'Chancellor' in Ca but leaves of 'Chancellor' were higher in P, K, Mg, Zn, Cu, and Mo. The remaining elements were not significantly different between cultivars.

Minimum winter temperatures in Missouri in 1983–1984 (−26°C) were appropriate for examining differential cold hardiness. Campbell and Ghosheh (3) found the greatest difference in cultivar response of canes occurred between −23° to −27° under laboratory conditions. Primary bud mortality was lowest for the MN treatment (Table 3). Primary bud mortality was not different among the CN, MI, or CI treatments. Although not significantly different, the trend in secondary bud mortality was essentially the same. The 2 treatments of moderate summer vigor (CI, MN) appear to have been most bud hardy. Tertiary buds were noticeably underdeveloped for the nonirrigated treatments, indicative of water stress the previous summer. Greatest tertiary bud development was obtained for the MI treatment.

Primary and secondary bud mortality were significantly greater for 'Vidal blanc' than 'Chancellor' (Table 3), consistent with published reports (8, 10). Primary and secondary bud hardiness was similar for the CI treatment, but 'Chancellor' was superior for the other treatments, especially MN. In a previous study, 'Vidal blanc' was shown to be more tolerant to low soil moisture conditions than 'Chancellor' (2). Largely because of this tolerance, 'Vidal blanc' in the MN treatment may not have hardened-off to the extent of 'Chancellor'. Additional evidence that 'Chancellor' of the MN treatment was more drought stressed than 'Vidal blanc' was that 97% of the tertiary buds were underdeveloped, as noted for both cultivars in the CN treatment.

Vines of the CN treatment probably accumulated the least photosynthates prior to dormancy and the hardening process. This proposition is based upon growth and stomatal conductance data measured during the summer (2) and tertiary bud development in the fall (Table 3). Vines of the MI treatment, characterized by extremely high vigor, experienced similarly high bud mortalities. The vigor for optimum bud hardiness appeared to be somewhere between these extremes (i.e., 'Vidal blanc', CI; 'Chancellor', MN).

Grape bud hardiness is favored by high soil moisture and nutrient availability during the early summer, allowing for high rate of photosynthesis and carbohydrate storage; and is reduced by high soil moisture and N fertilization during late summer and fall, conditions that delay cold acclimation (1, 5, 6, 7, 14). Fertilizers applied late in the season or those high in N have been reported to delay the hardening process, and those relatively high in P or K may promote cold hardiness (11, 12). In the present study, leaf N:P or N:K of nonirrigated vines was about 2 to 4 times higher and chlorophyll concentration was significantly greater than irrigated vines (Tables 1, 2). Also, since 'Chancellor' vines of the MN treatment were most hardy, fall nutrient status and chlorophyll levels did not reflect subsequent cold hardiness (Table 3). The fact that the leaves of nonirrigated vines abscised one week prior to irrigated vines may have reflected accelerated senescence, a reduced level of frost tolerance, and not earlier hardening.

The primary buds of grapes are more susceptible to winter injury than the secondary or tertiary buds. If the primary bud of French-American grapes is damaged by cold, the secondary buds normally will break and form fruitful shoots. The wood generally is more resistant than the buds (4), but this was not always evident in the present study. About 15% to 20% of the 'Vidal blanc' in the CN treatment (but no other treatment/cultivar combination) experienced cambium damage in the trunk region. The leaves expanded to 2 to 5 cm in diameter, then wilted and abscised. In some instances, new shoots were produced from the trunk later in the season, but, in other cases, the roots were killed as well. Roots in the nonmodified soil were restricted to the zone above the fragipan which, in some instances, was only 30 cm deep. During the Dec./Jan. cold spell in Missouri, the freeze zone extended to this level under clean cultivated areas. Because of a reduced susceptibility to winter freezes and an increased capacity of carbohydrate storage, a deep strong root system is recommended for attaining maximum cold hardiness (11).

From a viticultural and enological standpoint, late summer and fall rains are undesirable, yet fairly common throughout much of the United States. Summer drought, especially in a shallow soil, may enhance winter injury by excessively stressing vines and by delaying senescence once water becomes available during the early fall. Optimizing culture and management practices will undoubtedly expand the northern limits of profitability for marginally winter hardy grape cultivars.

Table 3. Effect of soil profile modification/irrigation and cultivar on the percentage of primary and secondary bud mortality and on the percentage of underdeveloped tertiary buds.

	Mortality				Underdeveloped tertiary bud (%)	
	Primary bud (%)		Secondary bud (%)			
Treatments	Actual	Transformed[z]	Actual	Transformed	Actual	Transformed
Main plot						
Control nonirrigated	32.0	0.59 a[y]	7.5	0.24 a	97.0	1.46 a
Control irrigated	25.5	0.52 a	5.0	0.20 a	49.0	0.77 c
Modified nonirrigated	17.5	0.38 b	2.0	0.09 a	86.0	1.26 b
Modified irrigated	29.5	0.56 a	6.5	0.21 a	31.0	0.58 d
Subplot						
'Vidal blanc'	35.6	0.63 a	8.2	0.26 a	65.5	1.00 a
'Chancellor'	16.4	0.39 b	2.2	0.11 b	66.0	1.04 a
Interactions						
Control nonirrigated						
'Vidal blanc'	45.0	0.73	11.0	0.33	96.0	1.43
'Chancellor'	19.0	0.45	4.0	0.14	98.0	1.50
Control irrigated						
'Vidal blanc'	26.0	0.53	8.0	0.24	59.0	0.89
'Chancellor'	25.0	0.52	2.0	0.15	39.0	0.66
Modified nonirrigated						
'Vidal blanc'	29.0	0.56	3.0	0.12	75.0	1.08
'Chancellor'	6.0	0.20	1.0	0.02	97.0	1.44
Modified irrigated						
'Vidal blanc'	43.0	0.71	11.0	0.32	32.0	0.59
'Chancellor'	16.0	0.40	2.0	0.10	30.0	0.56
LSD 0.05 within main plot treatment interactions		0.25		0.31		0.23
LSD 0.05 across main plot treatment interactions		0.29		0.21		0.34

[z] Actual means included for clarity. Mean separations based on arcsin square root transformed values.

[y] Mean separation within main plot and subplots by Duncan's new multiple range test, 5% level.

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