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J. Amer. Soc. Hort. Sci. 111(1):16–20. 1986.

Effect of Night Interruption on Cold Acclimation of Potted 'Concord' Grapevines

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Additional index words. hardiness, *Vitis labruscana*, root conductance

Abstract. **Two photoperiod regimes, natural daylength (ND) and night interruption (NI) of ND with a white light source, were used to test the importance of photoperiod on growth parameters, cold acclimation, and root conductance of potted 'Concord' grapevines (*Vitis labruscana* Bailey). By 3 Sept., NI-treated plants had a greater percentage of shoots with actively growing apices and a greater number of nodes per shoot than those untreated. No differences were seen in effect of light treatment on the extent of shoot maturation, as evidenced by shoot color change from green to brown. No consistent differences in hardiness of primary buds or canes of the first 12 nodes could be attributed to light regime. Apical tissues were less hardy than basal tissues for all regimes early in the acclimation period (10 Sept.). Root conductance, measured as suction-induced water flow, decreased throughout the acclimation period but did not differ between light treatments. Results are discussed in light of current hypotheses and of evidence of interrelationships among photoperiod, shoot growth cessation, shoot maturation, and cold acclimation.**

Reports on dogwood and other woody plants have suggested strongly that the first stage of cold acclimation is initiated by short days (SD) (6, 20) and mediated by phytochrome (13, 22). Leaves are the site of reception (6, 9) and must be present to facilitate full hardening (6). SD leaves produce a hardiness promoter (5) and long day (LD) leaves produce a hardiness inhibitor (11). Plants split between the inductive (SD) and noninductive (LD) photoperiods are intermediate in hardiness (8), suggesting an interaction of regulators rather than a single override control mechanism.

An important aspect of cold acclimation appears to be the SD-induced decline in tissue water content (14), a portion of which results from pith senescence and dehydration (3, 14). McKenzie et al. (14) and Parsons (15) claim overall plant water decline may be facilitated, or even controlled, by increased root resistance and decreased stomatal resistance. If root suberization is the cause of increased resistance to water flow, then it may account for observations that plants acclimate regardless of the amount of water present in the root environment (16, 21). This is likely a too simplistic explanation in view of reports that water stress can promote (4) and inhibit (19) cold acclimation.

Previous research on cold acclimation of 'Concord' grapevines has detailed the close relationship of acclimation to tissue maturation and loss of water (24), but whether SD photoperiod can trigger the initiation of these events is not known. Shoot growth cessation in grapevines is not brought about by the formation of a terminal bud, as in other woody plants, thus the need for growth cessation as a prerequisite for cold acclimation has not been shown. Although tissue water loss is related closely to the first stage of acclimation in grapevines, the involvement of roots and their resistance to water uptake has not been investigated.

The objectives of this study were to investigate whether night interruption would delay the importance of photoperiod cold acclimation of grapevines and to determine if root resistance plays a role in the process.

Materials and Methods

'Concord' plants were used in this study. They were purchased in 1980 from a commercial nursery as 1-year-old rooted cuttings and planted singly into 11 liter plastic pots containing a steam sterilized medium of 1 loam soil : 1 sand : 1 peat (by volume). Plants were thinned to 2 shoots per pot, tied to bamboo stakes, and grown without treatment throughout the year. After fall frost, plants were transferred to a protected lathhouse and mulched over winter. In spring of 1981, 55 vines were assigned at random to each of 2 blocks and equally spaced on a 5 m × 15 m flat concrete area. Plants were trained to 2 shoots, 1 on each of the 2 branches which grew the previous year, tied to

Received for publication 7 May 1984. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Effect of night interruption on growth and maturation of shoots of potted 'Concord' grapevines. Observations taken on 3 Sept. 1981.

Light treatment[z]	Actively growing shoots: No. actively growing shoots	Actively growing shoots: Total shoots observed	Actively growing shoots: Percent	Total nodes/shoot: Overall avg	Total nodes/shoot: Avg of shoots actively growing	Total mature nodes/shoot: Overall average	Total mature nodes/shoot: Avg of shoots actively growing	Percent mature nodes/shoot: Overall average	Percent mature nodes/shoot: Avg of shoots actively growing
ND	0	40	0 a[y]	20.1 b[x]	---	14.8 a[x]	---	73.9 a[x]	---
ND-SP	1	15	6.7 ab	19.6 b	23.0	14.3 a	13.0	73.2 a	56.5
NI-SP	3	15	20.0 b	20.7 b	24.3	13.6 a	12.6	66.7 b	50.8
NI	11	40	27.5 b	22.8 a	25.5	13.8 a	13.0	61.8 b	51.0

[z]Light treatment abbreviations: ND = natural daylength; NI = night interruption (one-half hr incandescent light, 2.4 ± .8 μcm^{-2}) in the middle of the dark period; SP = designation of split plant; 1 shoot trained into natural daylength (ND-SP) and 1 shoot trained into night-interrupted photoperiod (NI-SP).

[y]Mean separation within column by χ^2 test, $P = 0.05$.

[x]Mean separation within column by Duncan's multiple range test, $P = 0.05$.

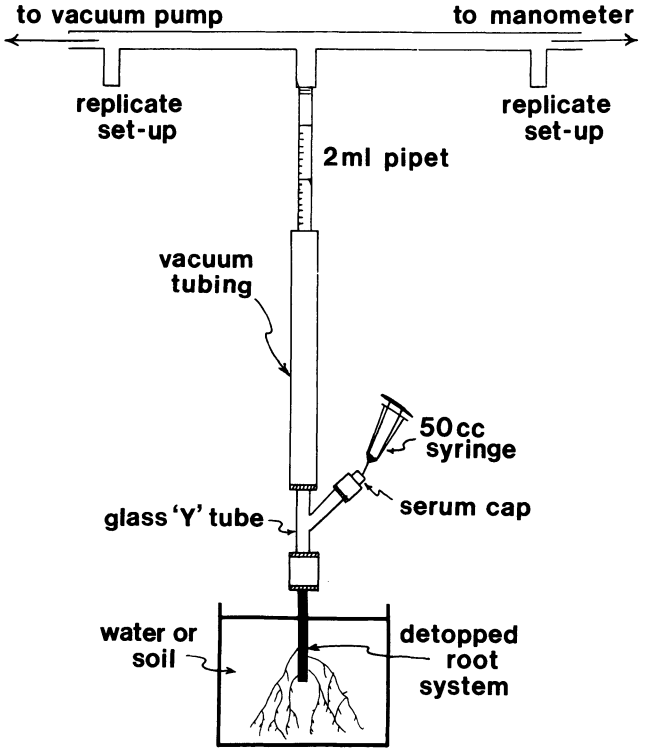

Fig. 1. Schematic diagram of apparatus used to measure root conductance by suction-induced water flow through detopped root systems.

bamboo stakes, and trained, when growth permitted, to an overhead trellis (1.7 m) constructed of a grid of wire and twine. Lateral shoots were removed on a regular basis.

A light barrier consisting of a black plastic wall (2 m high) was placed in the middle of each block (in a N-S orientation). Light treatments were the following: natural daylength (ND), in which plants were exposed to naturally decreasing daylengths; night-interruption (NI), in which plants were exposed to natural daylength plus one-half hr of white incandescent light (2.4 ± 0.8 $\mu mol\ cm^{-2}$) in the middle of the night period; and split plants (SP), in which 1 of the 2 shoots was trained through the light barrier and exposed to natural daylengths (ND-SP) and the other shoot exposed to night-interruption (NI-SP). Eighty plants were used in the ND and NI treatments and 30 in the SP treatments. Night interruption was begun on 27 July when daylengths were 14.5 hr and continued until 30 Oct., after leaves were killed by frost.

Measurements of shoot growth (total numbers of nodes), shoot maturation (extent of change in shoot color, green to brown), and percentage of shoots with actively growing apices were taken on 27 July and again after 5 weeks (3 Sept.). Shoot tips which had young leaves with a fresh appearance were considered to be actively growing.

On 4 sampling dates (10 and 24 Sept. and 10 and 29 Oct.) throughout the acclimation period, random plants from all treatments were assessed for cold hardiness and root resistance. Tissue water content was measured on Sept. 10 and 24.

The freezing technique has been described previously in detail (24). Representative samples from each treatment were frozen to several test temperatures, removed, and allowed to thaw slowly overnight at 2°C. Samples were incubated in humid chambers for 7 to 10 days, after which tissues were sectioned and rated as alive or dead by tissue browning (18). Hardiness was expressed as T_{50} (the temperature at which 50% of tissues theoretically would be killed), which was calculated by the Spearman-Karber equation as modified by Bittenbender and Howell (1). Values were separated statistically by chi-square (12).

Tissue water content was determined by placing 2 to 4 bud or cane pieces into air-tight glass weighing vials fitted with ground-glass stoppers. Tissues were oven-dried for 36 hr at 70°C (vials open) and reweighed. Water content was calculated by difference after correction for vial weight and expressed as grams water per grams tissue dry weight.

Root conductance was measured as described by McKenzie et al. (14). After collection of shoot material for hardiness and water content measurements, vines were removed from pots, and the soil was removed by gentle agitation in a basin of water. Roots then were transferred to 7-liter buckets of fresh, room temperature tap water. Just prior to being attached to the root conductance apparatus, the stem was cut about 8 to 10 cm above the soil line, loose bark was removed, and the outer surface of the stem was coated with vacuum grease to prevent entry of water or air.

The apparatus used in measuring root conductance consisted of an upright 2 ml (2 × 0.01) glass pipet, vacuum tubing, and a glass "Y" tube (Fig. 1). The bottom end of the glass "Y" was connected to the cut stem by vacuum tubing and secured by a tightened hose clamp. One arm of the "Y" was connected to the pipet by vacuum tubing while the other arm was fitted with a short piece of vacuum tubing and a serum stopper. This

Table 2. Effect of night interruption on cold acclimation (T_{50}) of primary bud and cane tissues of potted 'Concord' grapevines and the response of plants split between the 2 photoperiods.[z]

Date	Tissue	Node position	Light treatment[y] ND	ND-SP	NI-SP	NI
10 Sept.	Primary bud	Basal	−12.4 a[x]	−13.0 a	−14.2 a	−13.6 a
		Middle	−13.0 a	−13.0 a	−13.0 a	−14.5 a
		Apical	−11.2 bA[y]	−10.7 bAB	−8.3 bB	−9.5 bB
	Cane	Basal	−11.8	−13.6 a	−13.6 a	−13.6 a
		Middle	−11.8	−13.0 ab	−11.3 a	−13.0 a
		Apical	−11.2 A	−10.1 bAB	−8.3 bB	−8.3 bB
24 Sept.	Primary bud	Basal	−15.5 A	−14.5 BC	−15.0 aAB	−13.9 aC
		Middle	−15.0 A	−15.5 A	−13.2 abB	−13.2 aB
		Apical	−14.5 A	−14.0 AB	−12.5 bB	−12.5 bB
	Cane	Basal	−15.3 aA	−15.5 aA	−15.0 aA	−14.0 aB
		Middle	−15.5 a	−15.5 a	−15.0 a	−13.0 ab
		Apical	−13.0 b	−12.5 b	−12.0 b	−12.0 b
10 Oct.	Primary bud	Basal	−15.5 a	−15.2	−15.8 a	−15.4 a
		Middle	−14.9 b	−15.3	−14.5 a	−14.7 a
		Apical	−14.8 bA	−15.3 A	−13.2 bB	−13.2 bB
	Cane	Basal	−16.2	−16.6	−15.8	−15.8 a
		Middle	−15.8	−15.8	−15.8	−15.8 a
		Apical	−15.8	−15.8	−15.3	−14.9 b
29 Oct.	Primary bud	Basal	−19.5 a	−19.5	−17.0	−17.4 a
		Middle	−18.5 a	−19.0	−17.5	−18.5 a
		Apical	−16.2 b	−17.9	−16.0	−15.7 b
	Cane	Basal	−21.3 aA	−21.5 aA	−20.0 aAB	−19.3 aB
		Middle	−21.3 a	−20.5 ab	−20.5 a	−19.8 a
		Apical	−19.0 b	−19.0 b	−17.5 b	−17.5 b

[z]T_{50} calculated by means of Spearman-Karber equation.
[y]Light treatment, abbreviations: ND = natural daylength, NI = night interruption, ND-SP = shoot of split-plant exposed to natural daylength, NI-SP = shoot of split-plant exposed to interrupted nights.
[x]Mean separation by χ^2 test, $P = 0.05$. Lowercase letters indicate significance within columns for an individual tissue for a single date. Uppercase letters indicate significance within rows for a single node position. The absence of letters indicates no statistical significance.

assembly formed a single unit which was connected to 5 other units by means of a manifold constructed of vacuum tubing and glass "T" tubes. The manifold was connected to a manometer at one end and to a vacuum pump at the other end. All connections were secured by hose clamps or were wrapped with parafilm and checked regularly for leaks.

Measurement of root conductance was done as follows. With roots in water, the vacuum tubing was attached, secured, and filled partially with water. The pressure was reduced to 150 torr for 5 min to clear the root system of air bubbles, to prevent air bubbles from lodging in the pipet in later measurement. The vacuum was then released and a treatment at reduced pressure of 500 torr was applied. The water level at each position was adjusted individually to the lower end of the pipets by introducing water from a 50 ml syringe through the serum cap on the arm of the glass "Y". An initial reading of each pipet was taken followed by a final reading after 15 to 30 min.

After measurement of 3 to 6 replicates, root systems were oven-dried and weighed. (Only the fibrous portion was weighed, excluding the stem portion of the original cutting.) Water flow was expressed as ml H_2O per hr per 100 g of dry roots.

Results

The influence of light treatments on growth cessation, total shoot growth, and extent of shoot maturation is shown in Table 1. NI plants and NI-SP shoots had a greater percentage of actively growing shoots than ND plants (Table 1). Data on total nodes per shoot, mature nodes per shoot, and percentage of mature nodes per shoot are presented as overall averages of plants in the treatment and as averages for actively growing shoots for comparison purposes (Table 1).

NI plants averaged 2 to 3 more nodes than other treatments. Shoots actively growing on 3 Sept. had about 3 to 4 nodes more than the overall average; however, no differences in numbers of mature nodes were found among treatments. Actively growing shoots also had an average of 1 less mature node per shoot. On 10 Sept., cane and primary bud tissues were hardy to −8° to −14°C (Table 2). In general, hardiness increases were small (2° to 4°) for late sampling dates.

Hardiness differences due to treatments or node positions on the cane were sporadic due to variability. Although few significant differences were observed, NI plants generally were less hardy than ND plants. Shoot hardiness of split plants showed no clear relationship to treatment. Differences in hardiness due to node position were most prominent on the first and last sampling dates when apical nodes were less hardy than basal nodes.

Water content measurements (Table 3) were taken on the first 2 sampling dates (data presented only for 24 Sept.). No consistent differences were seen due to treatment. Differences due to node position were seen only on the 2nd sampling date.

Table 3. Effect of night interruption on water content of primary bud and cane tissues of potted 'Concord' grapevines, 24 Sept. 1981.

Tissue	Node[y] number	Light treatment[z] ND	ND-SP	NI-SP	NI
		Water content (g H_2O/g dry wt)			
Primary bud	1	0.82 a[x]	0.90 a	0.80 a	0.78 a
	5	0.84	0.90 a	9.89 a	0.88 ab
	9	0.90 a	0.99 a	0.93 b	0.96 b
	13	1.17 bA[x]	1.24 bA	1.44 cB	1.25 cA
Cane	1	0.89 aB	0.79 A	0.83 aB	0.84 AB
	5	0.86 ab	0.84	0.84 a	0.87
	9	0.85 ab	0.85	0.85 a	0.85
	13	0.81 bA	0.83 A	0.92 bB	0.90 B

[z]Light treatment abbreviations: ND = natural daylength, NI = night interruption, ND-SP = shoot of split plant exposed to natural daylength, NI-SP = shoot of split plant exposed to interrupted night.
[y]Nodes numbered from the base of the shoot.
[x]Mean separation by Duncan's multiple range test, $P = 0.05$. Lowercase letters following values indicate significance within columns for a single tissue, and uppercase letters indicate significance within rows for a given node number. Values without letters were not statistically significant.

Treatments had no effect on root conductance of vines as measured by suction-induced water flow (Fig. 2). However, root conductance decreased during the experiment as indicated by a decrease in water flow from 2.5 to 0.9 ml per hr per 100 g of dry roots.

Discussion

Night interruption significantly delays cessation of shoot growth as evidenced by the increased number of nodes per shoot and the percentage of shoots with actively growing tips (Table 1). Previously, grapevines were not known to be responsive to photoperiod (23). Although growth cessation in grapevines is not accompanied by the formation of a terminal bud, the process does seem to be under photoperiodic control. Why only 17% of the NI plants had actively growing tips is unknown, but one might speculate that the intensity of the night interruption was insufficent. Although the intensity used here is comparable to that used in studies of other species (6, 8), the light intensity threshold for photoperiodic response in grapevines is not known. Cool night temperatures also may have played a role; night temperatures were below 10°C several times in August (Fig. 3) and low temperatures override a photoperiodic signal in acclimation of apple stems (8).

Brown cane color (shoot maturation) (7), is associated with periderm development and death of epidermal and cortical tissues exterior to its origin (17). Periderm development in young seedlings of woody plants is affected by many environmental parameters (2), including photoperiod, but factors affecting periderm development in grapevines are unknown. Neither night interruption nor presence of an actively growing shoot tip affected shoot maturation (Table 1).

Although light treatments yielded minor (1° to 3°C) differences in hardiness, night interruption did not prevent acclimation (Table 2), which agrees with data reported for *Cornus* (13), apple (8), and *Viburnum* (10). Consequently, without a clear distinction between hardiness of ND and NI plants, it is impossible to draw conclusions about split plants as was done for *Cornus* (6).

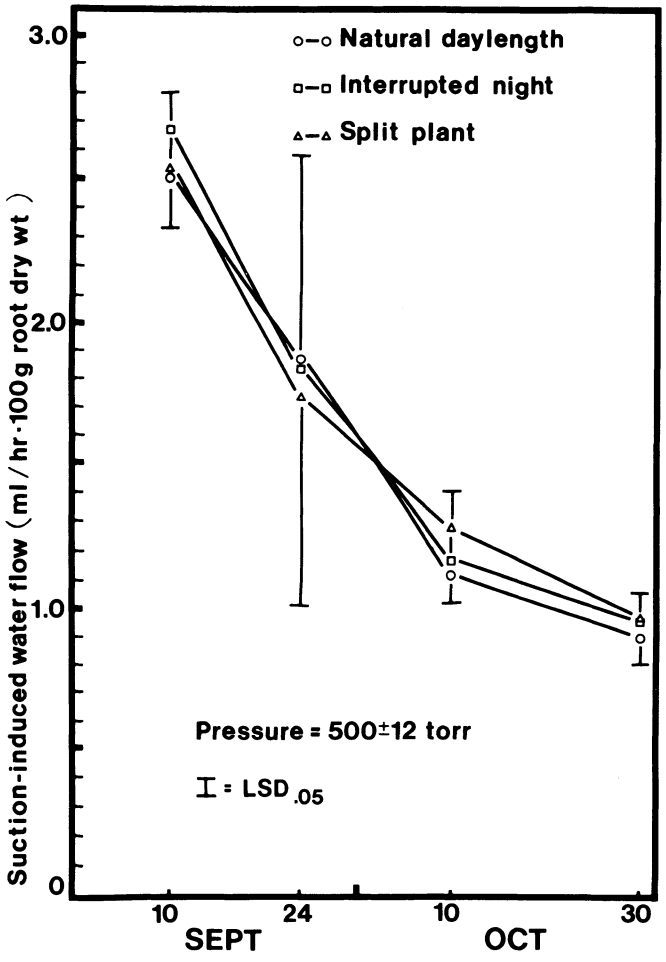

Fig. 2. Root conductance of detopped, potted 'Concord' grapevines in response to natural and night-interrupted photoperiods and the response of plants split between the 2 photoperiods (split plants). Root conductance measured as suction-induced water flow (pressure = 500 ± 12 torr).

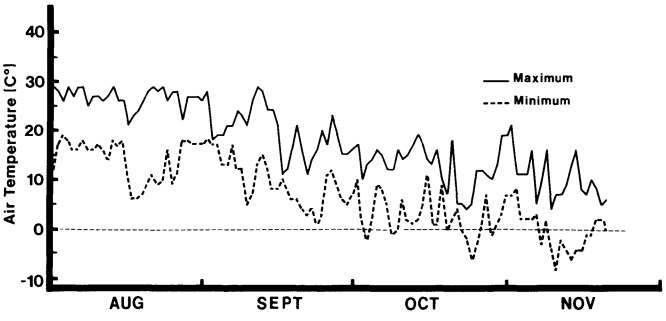

Fig. 3. Maximum and minimum air temperatures (°C) during late summer and fall, 1981, at the Horticulture Research Center, East Lansing, Mich.

In view of the lack of photoperiodic effect on acclimation, it is not surprising that root conductance (Fig. 2) was not affected by light treatment. The decrease in root conductance over the course of the experiment (Fig. 2) may reflect increased root suberization. McKenzie et al. (14) found reduced water flow into roots of SD plants and used this observation as an explanation of water loss in dogwood stems.

Further research is needed to understand which environmental parameters affect shoot maturation and hardiness. If photoperiod is not critical to acclimation, as suggested in this study, tem-

perature would be the most likely parameter to investigate next. A study of low temperature or of temperature-photoperiod interactions may provide clues as to how cold acclimation in grapevine is controlled.

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