Photoperiod Influences Growth, Bud Dormancy, and Cold Acclimation in *Vitis labruscana* and *V. riparia*

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Abstract. The grape species *Vitis labruscana* Bailey and *V. riparia* Michx. were subjected to a decreasing photoperiod at constant moderate temperatures to determine whether acclimation occurred in response to a shortening photoperiod. Cane growth, periderm development, killing temperature of the primary bud, and bud dormancy were measured in vines receiving a natural photoperiod (ND), a simulated long photoperiod of 15 hours (LD), and shorter photoperiods of 14, 13, or 12 hours (SD). The LD treatment was effective at maintaining growth and inhibiting periderm development and the onset of bud dormancy in *V. labruscana*. Cane growth rate with all SD treatments decreased as compared to the LD regime. A significant increase in periderm development occurred with the 12-hour SD treatment. Similarly, the onset of bud dormancy was promoted by the 12-hour SD in *V. labruscana*. The primary bud killing temperature was 1°C lower in *V. labruscana* under the 12-hour SD than under the LD treatment. In contrast, the LD treatment neither maintained growth nor fully inhibited periderm development and the onset of dormancy in *V. riparia*. The decrease in the cane growth rate upon exposure to SD was significantly greater in *V. labruscana* than *V. riparia*. Periderm development was observed in both the SD and its respective LD-treated *V. riparia* vines. However, the rate of periderm development was significantly greater in the SD vines than in the LD vines. The onset of bud dormancy was promoted by 13-hour SD in *V. riparia*. Similarly, the primary bud killing temperature was 2 to 3°C lower in *V. riparia* upon exposure to SD. *Vitis riparia* has a longer critical photoperiod than *V. labruscana* and appears to be more sensitive to changes in light intensity or light quality. While the change in freezing tolerance in response to short photoperiods is small, the photoperiod response at a longer critical photoperiod, when combined with lower temperatures, will promote an earlier and possibly more rapid cold acclimation in *V. riparia* than in *V. labruscana*.

The influence of a decreasing photoperiod or SD on growth and the onset of cold acclimation is documented for many woody species (Nitsch, 1957b; Vince-Prue, 1975); however, little information exists for grapes. Woody trees and shrubs manifest responses to SD in several ways—decrease in stem growth rate, decrease in cambial activity, growth cessation, terminal bud set, onset of cold acclimation, and development of bud dormancy (Nitsch, 1957b; Vince-Prue, 1975). Under SD, apples (*Malus domestica* Borkh.) and dogwood (*Cornus sericea* Michx.) cease growth, develop a terminal bud, and begin to acclimate to low temperatures (Fuchigami et al., 1971; Howell and Weiser, 1970). *Vitis vinifera* L. ‘White Reisling’ acclimates little in response to SD, but SD combined with decreasing temperatures increases acclimation or freezing tolerance (Schnabel and Wample, 1987). In *V. labruscana* ‘Concord’, vines under natural decreasing photoperiod and temperatures and those under these conditions plus an incandescent light night interruption showed little difference in acclimation (Wolpert and Howell, 1986a). However, the vines receiving the night interruption treatment had more actively growing shoots than those under the natural photoperiod.

Our field observations indicated that *V. labruscana* may not respond as quickly to the natural decreasing photoperiod in August and September as does *V. riparia*. The objectives of this study were to determine whether vines of *V. labruscana* and *V. riparia* were responsive to a SD treatment and whether the response was the same in the two species. Since grapes do not set a terminal bud, changes in growth, periderm development, killing temperature of the primary bud, and bud dormancy were used to determine changes in growth and acclimation.

Materials and Methods

Cuttings of *V. riparia* (origin, Manitoba, Canada, 52°N) were taken from dormant grapevines grown at the Univ. of Minnesota Horticulture Research Center, Chanhassen, 45°N. *Vitis labruscana* ‘Concord’ cuttings were obtained from Zilke Brothers Nursery, Baroda, Mich. All cuttings were rooted, transplanted into sand in 4-liter pots and watered daily with half-strength Hoagland solution (Lorenz and Maynard, 1980). As growth commenced, one cane was allowed to develop on each cutting. All flower clusters were removed, and the cane was trained vertically. Plants were grown in an unshaded glasshouse in St. Paul, Minn., with 600 to 1400 µmol·s⁻¹·m⁻² photosynthetic photon flux (PPF) at 25 to 30°C for 8 weeks before photoperiod treatments were started.

Photoperiod treatments. In July, 8 weeks after transplanting, 15 plants were randomly assigned to each of nine photoperiod treatments (Table 1): three ND (15, 14.3, or 13.7 h), three LD (SD plus additional hours of incandescent lighting to equal a photoperiod of 15 h), or three SD (14, 13, or 12 h). The LD and SD treatments were imposed with opaque plastic (Scrim Weave, Johnson’s Greenhouse Supply, St. Paul, Minn.). LD and SD plants were sequentially limited to 14 h, 13 h, and finally 12 h sunlight for 2 weeks each. At the end of each...

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Abbreviations: KT, killing temperature; LD, long photoperiod; ND, natural photoperiod; SD, short photoperiod.
sunlight period, LD plants received incandescent light (12 to 50 µmol·s⁻¹·m⁻² PPF from base to top of plant, respectively) under the opaque plastic to extend the photoperiod to 15 h. Day temperature was ≥ 25°C and night temperature was 25 to 30°C throughout the study. The treatments were applied sequentially as indicated in Table 1. All ND, LD, and SD plants of program A, B, and C were started with ND, LD, or SD photoperiods indicated in program A. After 2 weeks, A plants were harvested, and data collected. Those assigned to B and C received program B. Plants assigned to program B were then harvested, and C photoperiod conditions were imposed on the remaining plants that were harvested at the end of that treatment.

Results

Cane elongation was less in response to the SD treatments of 13 or 12 h, as compared to their respective LD and ND treatments in both species (Table 2). Extending the photoperiod with incandescent light (LD) had no effect on cane growth in V. labruscana when compared to the ND treatment. In V. riparia, there was a reduction of growth under the LD relative to the ND treatment. However, the growth reduction under the LD treatment in V. riparia was significantly less than that found with the SD treatment (Table 2, programs B and C). The change in node number was similar within a species for all photoperiods in treatment A. In treatment B, the change in node number was different for all three photoperiods in V. riparia, whereas in V. labruscana, there was a decrease in node number in LD and SD relative to ND. In treatment C, there was a difference in all three photoperiods for V. labruscana; however, in V. riparia, there was a decrease in node number in LD and SD compared to ND. Periderm development in response to SD was greater in V. riparia than in V. labruscana (Table 2). Periderm development did not appear in V. labruscana even after the 12-h SD treatment. Vitis riparia developed periderm in both the SD and LD treatments (Table 2, programs B and C), but not the ND treatment.

Vitis riparia acclimated in response to SD treatment, as indicated by the lower killing temperature than under ND or LD (Table 3). The SD treatments applied to V. labruscana were not as effective in inducing acclimation. KT was the same for V. labruscana and V. riparia in program A, while V. riparia showed 2 to 3°C greater freezing tolerance in response to SD vs. the LD or ND treatment (Table 3, programs B and C). Greater freezing tolerance occurred in basal than in more distal buds.

Bud dormancy was initiated by the 13-h SD treatment in V. riparia and the 12-h SD treatment in V. labruscana (Table 4). In V. riparia, the LD treatment, program C, resulted in a delayed budbreak.

Discussion

Under SD, growth cessation and terminal bud set are frequently observed in trees and woody shrubs (Fuchigami et al., 1986). However, grapevines do not set terminal buds so changes in cane elongation and periderm development were monitored in this study. In an earlier study on field-grown 'Concord' vines, Wolpert and Howell (1986a) reported more actively growing shoots on vines receiving a night interruption than those receiving natural SD, suggesting that cane growth was sensitive to changes in photoperiod. In our study, both V. labruscana and V. riparia showed a decrease in cane growth rate in response.
to SD. Cane growth rate also decreased slightly in V. riparia vines receiving extended LD when compared to those under ND, suggesting that V. riparia may require a greater light intensity to maintain growth or that an extended day merely delays but does not prevent slowing or cessation of growth (Nitsch, 1957a, 1957b; Vince-Prue, 1975).

Cane browning is associated with periderm development in the nonconducting phloem of grape canes and appears in mature ‘Concord’ vines between mid-July and mid-August in New York and in late August in Michigan (Knudson, 1916; Pratt, 1974; Wolpert and Howell, 1986 a). Native V. riparia growing in Wisconsin forms periderm in July and early August (Davis and Evert, 1970). Borger (1973) reported that several environmental factors, such as light, temperature, and water stress, influence periderm development in seedlings of various woody species and that a short photoperiod delays periderm development. In our study, the short photoperiods promoted periderm development.

Vitis labruscana did not begin to develop periderm until after it received a 12-h SD. Periderm appeared in both LD and SD V. riparia, but it progressed faster and further up the cane in the SD plants. Wolpert and Howell (1986b) suggested that tissue maturation, indicated by a change in cane color associated with periderm development and decreased water content, was correlated with the changes in freezing tolerance in V. labruscana. Our results agree with this conclusion, as the KT was lower in SD plants than in the LD plants and periderm formation coincided with the decreased KT.

Vitis labruscana in our study and in field-grown vines (Wolpert and Howell, 1986a) showed only a small change in KT in response to SD. However, reduction in shoot growth and periderm development indicate V. labruscana was responding to a SD of 12-h. The KT values reported in this study differ slightly from those in Table 2.

Table 3. Killing temperature (°C) of the primary bud in apical (nodes 12–16), middle (nodes 7–11), and basal (nodes 2–6) nodes of Vitis labruscana and V. riparia LD and SD treatments and one ND.

<table>
<thead>
<tr>
<th>Program*</th>
<th>Bud location</th>
<th>ND*</th>
<th>LD</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. labruscana</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Apical</td>
<td>-3 ± 0.3 a</td>
<td>-3 ± 0.3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>-3 ± 0.4 a</td>
<td>-3 ± 0.4 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basal</td>
<td>-4 ± 0.3 a</td>
<td>-4 ± 0.3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V. riparia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Apical</td>
<td>-3 ± 0.3 a</td>
<td>-3 ± 0.3 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>-3 ± 0.4 a</td>
<td>-3 ± 0.4 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basal</td>
<td>-4 ± 0.3 a</td>
<td>-4 ± 0.3 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Mean separation in rows by Student–Newman–Keuls test at P = 0.05. Values are mean ± se for 10 plants.

Table 4. Days to budbreak of the primary bud in apical (nodes 12–16), middle (nodes 7–11), and basal (nodes 2–6) nodes of Vitis labruscana and V. riparia after LD and SD treatments.

<table>
<thead>
<tr>
<th>Program*</th>
<th>Bud location</th>
<th>V. labruscana</th>
<th>V. riparia</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Apical</td>
<td>14 ± 2.4</td>
<td>18 ± 1.3</td>
<td>18 ± 4.0</td>
</tr>
<tr>
<td>Middle</td>
<td>19 ± 1.2</td>
<td>18 ± 1.3</td>
<td>12 ± 0.9</td>
</tr>
<tr>
<td>Basal</td>
<td>16 ± 2.9</td>
<td>18 ± 1.3</td>
<td>12 ± 1.0</td>
</tr>
<tr>
<td>B Apical</td>
<td>20 ± 1.2</td>
<td>21 ± 0.1</td>
<td>16 ± 1.2</td>
</tr>
<tr>
<td>Middle</td>
<td>20 ± 3.2</td>
<td>21 ± 0.0</td>
<td>16 ± 1.2</td>
</tr>
<tr>
<td>Basal</td>
<td>24 ± 2.7</td>
<td>21 ± 1.2</td>
<td>16 ± 1.2</td>
</tr>
<tr>
<td>C Apical</td>
<td>22 ± 1.7</td>
<td>24 ± 4.4</td>
<td>20 ± 1.6</td>
</tr>
<tr>
<td>Middle</td>
<td>25 ± 5.0</td>
<td>48 ± 8.3</td>
<td>47 ± 12.6</td>
</tr>
<tr>
<td>Basal</td>
<td>43 ± 8.3</td>
<td>&gt;120</td>
<td>47 ± 12.7</td>
</tr>
</tbody>
</table>

*Photoperiod treatments for programs A, B, and C are described in Table 1. Values are means of three plants ± se.

† >120: Buds were alive, but did not break in 100 days of daily observation. The buds for >120 began to break after 120 days.

to SD. Cane growth rate also decreased slightly in V. riparia vines receiving extended LD when compared to those under ND, suggesting that V. riparia may require a greater light intensity to maintain growth or that an extended day merely delays but does not prevent slowing or cessation of growth (Nitsch, 1957a, 1957b; Vince-Prue, 1975).
from the bud Tm values reported by Wolpert and Howell (1986a, 1986b) for two reasons: we used KT (temperature causing 90% to 100% death) instead of a Tm (temperature causing 50% tissue death), and the vines used in this study were grown in the greenhouse with moderate day and night temperatures, whereas the 2-year-old and mature vines in Wolpert and Howell’s studies were grown under natural field conditions.

Fuchigami et al. (1986) described several stages of tissue maturation in a growth stage and acclimation model. In the first stage, bud growth is not inhibited by short days. In the second stage, i.e., maturity induction, plants become responsive to photoperiod or other environmental factors promoting maturity. The critical daylength for this photoperiod response varies with species, latitude, and altitude of origin (Heide, 1974; Hummel et al., 1982; Nitsch, 1957a, 1957b; Vince-Prue, 1975). At the third stage, i.e., vegetative maturity, removal of leaves will not stimulate bud growth. The results of our bud dormancy test suggest that V. riparia reaches the maturity-induction stage sooner or that it has a longer critical daylength than V. labruscana. The 13-h SD treatment promoted vegetative maturity in V. riparia, as indicated by the onset of bud dormancy. However, bud dormancy was not noted in V. labruscana until the 12-h SD was reached. This response difference to the 13- and 12-h SD maybe attributed to requirements for adaptation in the contrasting latitudes of origin of the V. riparia clone and V. labruscana.

Vitis riparia and V. labruscana both showed reductions in growth, greater periderm development, and onset of bud dormancy in response to short photoperiods. In V. riparia, the 13-h photoperiod induced slower growth and promoted periderm development, onset of bud dormancy, and greater freezing tolerance. In V. labruscana, the 13-h photoperiod caused a decrease in cane growth, and the 12-h photoperiod promoted periderm development and initiation of bud dormancy. There was little cold acclimation in response to the short photoperiods. In V. riparia, there was a 2 to 3C greater freezing tolerance in short photoperiod plants and only a 1C change in V. labruscana. The use of white incandescent lights to extend daylength maintained growth and inhibited periderm development and bud dormancy more in V. labruscana than in V. riparia. These results suggest that in addition to critical photoperiod, the influence of light intensity, light quality, and time of photoperiod extension (midnight, predawn, or sunset) should be considered in future studies of initiation of acclimation and dormancy in V. riparia.

**Literature Cited**


