Physiological Response of Rhododendron Cuttings to Different Light Levels During Rooting

Tim D. Davis

Department of Horticulture, Oregon State University, Corvallis, OR 97331

John R. Potter

Agricultural Research Service, U.S. Department of Agriculture, Horticultural Crops Research Laboratory, 3420 Northwest Orchard Ave., Corvallis, OR 97330

Abstract. Leafy cuttings of Rhododendron catawbiense Michx. ‘Roseum Elegans’ were rooted under 0%, 55%, or 95% shade in a greenhouse. Compared to the low-light treatment, higher light induced high photosynthetic rates, high sucrose and starch levels, and low leaf water potential, but these differences only persisted for the initial part of the 23-week rooting period and did not influence subsequent rooting percentage. However, in cuttings receiving 95% shade, dry weights of leaves and stems and rootball size were relatively small after 23 weeks, suggesting that growth was reduced by lack of photosynthate. The reduced size of cuttings rooted under 95% shade apparently did not affect vigor because the size of the above-ground portion of all plants was equal after 2 months of growth in a greenhouse.

Numerous investigators have studied the effect of light on adventitious root formation by leafy cuttings. Considerable evidence indicates that incident light on leaves of cuttings promotes rooting because it energizes photosynthesis, thereby causing synthesis of carbohydrates, which in turn stimulate rooting (4, 5, 8, 9, 12, 14, 18). Also, enrichment of the atmosphere with CO₂ stimulates rooting in some species or cultivars (6, 15, 19), presumably by accelerating photosynthesis. However, even moderate light levels (<20% of full sun) can affect rooting of leafy cuttings adversely (4, 9, 10, 15, 17), perhaps by the desiccating effect of light (16, 17) or by inducing inhibitory levels of solutes (11). Because of the conflicting data concerning the role of light, photosynthetic rate, carbohydrate content, and water status in rooting, this study was initiated using a slow-rooting cultivar to determine if any of these parameters are associated with rooting of leafy cuttings under widely different light levels.

Materials and Methods

Vegetative stem-tip cuttings (12 cm long with 6 to 8 leaves) of Rhododendron catawbiense Michx. ‘Roseum Elegans’ were excised on 13 Aug. from 15 stock plants growing in a lathhouse (50% shade). Immediately after excision, the basal ends of the cuttings were wounded (7), dipped in 0.3% 1º-indole-3-butyric acid (IBA) in an inert powder (Hormodin 2) and inserted in a rooting medium of 1 spaghnum peat:1 perlite (v/v). Cuttings were rooted in a glasshouse under intermittent mist at either 0%, 55%, or 95% shade with day/night temperatures of 25°/18°C. Shade was provided by a single layer of black polyethylene shade cloth on cubic frames 1.2 m on a side, with all cuttings from each light treatment rooted under a single frame in a completely randomized design. The entire experiment was enclosed in a clear polyethylene tent. Light was measured as the photosynthetic photon flux (PPF) at the top of the cuttings in the unshaded treatment on several clear days during the experiment. From 13 Aug. to 24 Sept., the sun was the sole light source, but thereafter light was supplemented by high-pressure sodium vapor lamps giving 160 μmol·s⁻¹·m⁻² PPF from 0600 to 2200 h. The maximum daily unshaded PPF under the polyethylene tent was 500 and 340 μmol·s⁻¹·m⁻² at the beginning and end, respectively, of the rooting period.

For net photosynthesis (Pn) and respiration measurements, cuttings were removed from the propagation bench and their bases were inserted into 5-cm pots filled with moist rooting medium. The pots were sealed to prevent escape of CO₂ from the rooting environment and placed in an assimilation chamber (2) with the following environment: temperature, 23°C; relative humidity >85%; PPF—500, 250 and 30 μmol·s⁻¹·m⁻² for the 0%, 55%, and 95% shade treatments, respectively, through week 4; 400, 180, and 25 μmol·s⁻¹·m⁻² for the three shade treatments during weeks 5 through 14; 340, 150, and 20 μmol·s⁻¹·m⁻² for the three shade treatments for week 18. The light levels in the assimilation chamber were chosen because they approximated the maximum daily light levels for each treatment during the respective weeks of the rooting period. Dark respiration measurements were made by turning off the lights and reducing the temperature to 20°. The cuttings remained in the chamber until a steady state Pn or dark respiration rate was obtained (about 1 hr for Pn and 0.5 hr for dark respiration), and both rates were expressed on a leaf area basis.

The leaf water potential (ψw) of the cuttings was measured by thermocouple psychrometry using 4.1-cm² leaf disks obtained at mid-day from leaves that had been washed with water
to remove surface solutes and then blotted dry. Starch, sucrose, and glucose analyses were made on fresh basal 2-cm stem sections. To express carbohydrate data on a dry weight basis, the ratio of fresh to dry weight of each of the above cuttings was determined on 1-cm stem sections immediately apical to the sections sampled for carbohydrate. Drying was done at 70°C until constant weight was achieved.

The percentage of rooted cuttings and rootball diameter and depth were determined after 18 weeks and again after 23 weeks in the rooting medium. Rootball diameter and depth were the horizontal and vertical dimensions of the rootball. In addition, the number of leaves per cutting and the dry weight of the leaves and stems were determined after 23 weeks.

After rooting was evaluated, 11 or more rooted cuttings from each treatment were planted in 15-cm pots containing 3 bark : 1 soil : 1 sphagnum peat (by volume) adjusted to pH 5.5 with dolomitic limestone. The rooted cuttings were placed in a greenhouse for 2 months, after which time growth was evaluated by measuring the height and the number of leaves and branches per plant. Approximate greenhouse day/night temperatures were 25°/19°C, the maximum PPF was about 1200 μmol·s⁻¹·m⁻² (sunlight supplemented with high-pressure sodium vapor lamps), and the photoperiod was 16 hr.

Cuttings were removed from the shade frames for analysis at random at times indicated in the figures and in Table 1. Once a cutting was used for carbohydrate and ψw determination, it was discarded, but cuttings used for photosynthesis and respiration determinations were returned to the cutting bench. For each sampling time and treatment, the following number of cuttings was measured individually for the corresponding determination: carbohydrate analysis, 4; ψw, 3; Pn and respiration, 3; rooting, 60; and dry weight after rooting, 30. The rooting percentage means were evaluated using a confidence interval procedure (22), while all other means were evaluated using the least significant difference.

Results

Leaves exposed to 95% shade had significantly higher ψw values than those of the other treatments for one or two observations during the first 3 weeks of the rooting period. Thereafter, ψw did not differ consistently among treatments (Fig. 1). In all treatments, ψw dropped to a minimum value of −1.0 to −1.2 MPa between the 4th and 12th week of the rooting period. By the 14th week of the rooting period, ψw had increased to −0.6 to −0.8 MPa in all treatments.

Initially, Pn under 95% shade was significantly lower than that under higher light, but, during the first week, Pn under 0% shade declined to the low rate of that under 95% shade (Fig. 2). Under 55% shade, during the first 2 weeks, Pn declined to less than one-half its initial value, but, thereafter, it generally stayed higher than that of the other two treatments for the first 8 weeks. For all treatments, Pn remained relatively low for the latter half of the rooting period. The dark respiration pattern was similar for all treatments and remained relatively constant.

During the first 6 weeks of the rooting period, the sucrose concentration increased in the base of cuttings under 0% and 55% shade, while sucrose in cuttings under 95% shade did not (Fig. 3). By 18 weeks, cuttings under all treatments lost significant amounts of sucrose compared to their peak concentrations. Glucose concentrations did not differ among treatments during the rooting period and fluctuated inconsistently with time (Fig. 3). Starch increased substantially during the rooting period regardless of treatment, the increase being 8-fold under the higher light levels and 4-fold under the lowest light; but, by week 18, starch concentrations were not greater than initial values (Fig. 3).

Rooting percentage, rootball diameter, and rootball depth did not differ among shade treatments after 18 weeks in the rooting medium (Table 1). During the subsequent 5 weeks, rooting percentage increased, but still did not differ among treatments. However, after 23 weeks, rootball diameter and depth were higher in the 0% and 55% shade treatments compared to 95% shade. Also, cuttings in 95% shade lost leaves and weighed less than cuttings rooted under the other treatments (Table 1).

After 2 months of post-propagation growth, there were no differences among plants grown from cuttings rooted under the three treatments. All plants were about 14 cm tall, had about 17 leaves, and had two or three branches regardless of the shade treatment during rooting (data not shown).

Discussion

It is difficult to compare results from different studies because experimental conditions vary greatly. One useful approach is to
compare studies based on estimated daily irradiance (400–700 nm) (17), although this method does not account for maximum short-term irradiance, photoperiod, or infrared irradiance—omissions that could be important. On clear days, at the midpoint for our rooting period, irradiance was 3.5, 1.6, and 0.18 MJ-m⁻²-day⁻¹ for 0%, 55%, and 95% shade levels, respectively (conversions based on ref. 23; light values integrated over the photoperiod). Because 54% of this irradiance was from electric lamps, clouds would have a limited effect on irradiance. As with French (10), who also worked with misted rhododendron, we did not detect a light effect on rooting percentage, although our range of light was considerably greater than that of French (0.45 to 2.0 MJ-m⁻²-day⁻¹). Our results differ from those of Loach and Gay (17), who found that rooting percentage of two woody species was best at 1.2 or 2.3 MJ-m⁻²-day⁻¹, and that 3.5 MJ-m⁻²-day⁻¹ inhibited rooting. Apparently Loach and Gay (17) did not use mist, which could account for the rooting difference between our studies. In a more recent study with mist, Grange and Loach (11) reported that rooting of one of three species was best at 1.4 to 3.0 MJ-m⁻²-day⁻¹, but that the other species rooted best at 1.2 to 1.6 MJ-m⁻²-day⁻¹. In a study without mist, Eliasson and Brunes (9) found that rooting percentage of two woody species was inhibited at high vs. low irradiance (≠2.2 MJ-m⁻²-day⁻¹ compared to ≤0.66 MJ-m⁻²-day⁻¹). Carpenter et al. (4) reported that in several herbaceous species rooted with mist, supplementing greenhouse light with 2.5 MJ-m⁻²-day⁻¹ (based on their photometric data) produced more roots per cutting than did either no supplemental light or 3.5 MJ-m⁻²-day⁻¹ supplemental light. Their study indicates that too much light can inhibit rooting even with mist, but that normal autumn greenhouse light at temperature latitudes (2 MJ-m⁻²-day⁻¹) can be so low that it limits rooting of some species. Unlike our rhododendron study, several of these studies used species that rooted relatively quickly (4, 9, 17), a potentially significant difference. Working with woody cuttings, Lin and Molnar (15) supplemented greenhouse light with 0.5 MJ-m⁻²-day⁻¹ under mist. This relatively low level of supplementary light had no effect on the rooting percentage of eight cultivars or species, inhibited two, and promoted one. Taken together, these experiments suggest that, under greenhouse conditions with mist, light beyond 1.5 MJ-m⁻²-day⁻¹ does not increase the rooting percentage of woody cuttings and, for some species, considerably less light results in maximum rooting.

In our experiments, a 20-fold light level difference failed to affect rooting percentage despite significant differences in leaf $\psi_w$, $\text{Pn}$, and sucrose and starch concentrations in the cutting bases. Therefore, rooting percentage in this cultivar was relatively insensitive to significant changes in these parameters, a finding in contrast to the work of investigators using other species (9, 17). The following are possibilities why this is so.

First, the low $\psi_w$ elicited by higher light may have been counterbalanced by higher $\text{Pn}$ and, hence, higher carbohydrate at higher light. The potential interaction of these four parameters has been recognized (12, 17), where the model states that high

![Fig. 3. Time course of sucrose, glucose, and starch concentrations in the base of 'Roseum Elegans' cuttings rooted under three shade levels (0%, 55%, and 95%). Bars indicate LSD values at the 5% level of probability. Each point is a mean of four cuttings.](image-url)

Table 1. Effects of three shade levels (0%, 55%, and 95%) on the rooting of 'Roseum Elegans' cuttings measured at two dates (weeks 18 and 23).

<table>
<thead>
<tr>
<th>Shade level during the rooting period (%)</th>
<th>Rooting (%)</th>
<th>Rootball diam (cm)</th>
<th>Rootball depth (cm)</th>
<th>No. leaves per cutting</th>
<th>Dry wt of leaves + stems (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>63 a</td>
<td>1.5 a</td>
<td>1.2 a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>55</td>
<td>73 a</td>
<td>1.7 a</td>
<td>1.4 a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>95</td>
<td>63 a</td>
<td>1.4 a</td>
<td>1.1 a</td>
<td>-</td>
<td>-</td>
</tr>
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<td>Week 23</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>71 a</td>
<td>3.1 a</td>
<td>2.2 a</td>
<td>7.4 a</td>
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<tr>
<td>55</td>
<td>79 a</td>
<td>3.8 a</td>
<td>2.5 a</td>
<td>7.6 a</td>
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</tr>
<tr>
<td>95</td>
<td>80 a</td>
<td>2.0 b</td>
<td>1.8 b</td>
<td>6.0 b</td>
<td>2.8 b</td>
</tr>
</tbody>
</table>

$^a$Means of rooting percentages for a date separated by confidence intervals, $P = 5\%$.

$^b$Mean of rootball diameter and depth, number of leaves/cutting, and dry weight of leaves and stems separated by LSD, $P = 5\%$.

Rootball diameter and depth were calculated considering only rooted cuttings. Means for rooting percentage, n = 60; for rootball size, n < 60 as above; for size of tops, n = 30.
light depresses the other three parameters, but the present data indicate that changes in $\psi_w$ were not necessarily paralleled by changes in either $Pn$ or carbohydrate concentrations. Under 95% shade one would not expect parallel changes because light limited $Pn$, at least initially when all treatments had the same $\psi_w$. The presence of mist did not prevent a decrease in $\psi_w$ during the first several weeks of the rooting period regardless of light. In addition, high light may act on other rooting factors, such as auxin content (1), further complicating the role of light.

Second, while it is conceivable that changes in $\psi_w$, $Pn$, or the carbohydrate economy of cuttings do not affect rooting, it is more likely that the light-elicted differences were too small or too brief in our study to affect rooting percentage. Previous investigators found large differences in one or more of these parameters to have no affect on rooting, while others have associated small differences with rooting effects (3, 5, 9, 14, 16, 17, 20). The lack of agreement between these studies is probably due to numerous differences in experimental protocols.

Because carbohydrate differences disappeared by 18 weeks (at which time rootball sizes were equal), the larger rootballs at 23 weeks under high light were not due to these carbohydrate differences. Cuttings typically increase $Pn$ after roots have formed (5, 9, 20), but, under 95% shade, $Pn$ would be light-limited (see initial values in Fig. 2); hence, growth would be slow. The absence of an increase in $Pn$ at 18 weeks is probably due to the extremely small root size. The loss of leaves, due to abscission, under 95% shade suggests an extremely unfavorable environment, but the dry weight of these leaves (0.2 g) did not account for the weight difference in Table 1.

Plant size 2 months after the rooting period was unaffected by light level during rooting, in contrast to work with chrysanthemum (13), where a high irradiance- (5.9 vs. 1.5 MJ m$^{-2}$day$^{-1}$) induced size advantage at the end of the rooting period persisted long afterwards. The observation that our 95% shade-rooted cuttings overcame their size disadvantage indicates that they adapted to the relatively high light during post-propagation growth.

Literature Cited
