Literature Cited

1. Beattie, D.J. 1986. Principles, practices, and comparative costs of overwintering container-grown landscape plants. South. Coop. Series Bull. 313.

2. Bing, A., G.L. Good, J. Gruttadaurio, R.G. Mower, J.C. Neal, T.C. Weiler, M. Doughtrey, and M. Semel. 1987. Cornell perennial guidelines for New York state - 1987. Cornell Univ., Ithaca, NY.

3. Boyer, J.S. 1982. Plant productivity and environment. Science 218:443–448.

4. Gouin, F.R. and C.B. Link. 1979. Temperature measurements, survival, and growth of container-grown ornamentals, overwintered unprotected, in nursery shelters, and under microfoam thermo-blankets. J. Amer. Soc. Hort. Sci. 104:655–658.

5. Green, J.L. and L.H. Fuchigami. 1985. Overwintering container-grown plants: Principles and practices. Ornamental Northwest Newsl. 9:10–17.

6. McNiel, R.E. and G.A. Duncan. 1983. Foam tops poly for overwintering container stock. Amer. Nursery. 158:94–101.

7. Pellett, N.E., D. Dippre and A. Hazelrigg. 1985. Coverings for overwintering container-grown plants in northern regions. J. Environ. Hort. 3:4–7.

8. Perry, L.P. 1990. Overwintering container-grown herbaceous perennials in northern regions. J. Environ. Hort. 8:135–138.

9. Rieger, M. 1989. Freeze protection for horticultural crops. Hort. Rev. 11:45–109.

10. Smith, G. 1984. A practical method of cold protection for container nursery stock. Georgia Nursery Notes, Aug.–Sept., pp. 4–9.

11. Still, S.M., T. DiSabato-Aust and G. Brenneman. 1987. Cold hardiness of herbaceous perennials. Proc. Intern. Plant Prop. Soc. 37:386–392.

12. Still, S.M., T. DiSabato-Aust and T. Rhodus. 1989. Overwintering systems for herbaceous perennials. Proc. Perennial Plant Symp., pp. 24–35.

13. Taylor, R.D., D.T. Gillette and E.M. Smith. 1984. Comparative costs of overwintering plants in nurseries differentiated by system for Ohio–1984. Ohio Agr. Res. Dev. Center Res. Cir. 283, pp. 38–48.

14. van de Werken, H. 1987. Nursery container design for improved root environments. J. Environ. Hort. 5:146–148.

15. Whitcomb, C.E. 1984. Plant Production in Containers. Lacebark Publ., Stillwater, OK., pp. 472–494.

Seed Germination of *Rhododendron carolinianum*: Influence of Light and Temperature[1]

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Abstract

Seeds of *Rhododendron carolinianum* Rehd. (Carolina rhododendron) were germinated at 25°C (77°F) or an 8/16 hr thermoperiod of 25°/15°C (77°/59°F) with daily photoperiods of 0, 1/2, 1/2 twice daily, 1, 2, 4, 8, 12, or 24 hr. For both temperatures, no germination occurred during a 30-day period for seeds not subjected to light. At 25°C (77°F) increasing photoperiods increased germination with germination of 26 and 39% occurring by day 30 for the 12 and 24 hr photoperiods, respectively. The alternating temperature of 25°/15°C (77°/59°F) enhanced germination when light was limiting. At this temperature germination ≥58% occurred by day 30 for photoperiods ≥ 4 hr. For photoperiods ≥ 8 hr, 30-day germination ≥ 70% was realized.

Index words: seeds, sexual propagation, Carolina rhododendron, Ericaceae, native plants.

Significance to the Nursery Industry

Quantitative data are presented concerning the influence of light and temperatures of 25°C (77°F) and 25°/15°C (77°/59°F) on seed germination of *R. carolinianum*, an indigenous species with desirable landscape characteristics. Regardless of temperature, seeds required light for germination. However, the photoperiod which maximized germination varied, depending on the temperature. Seeds should not be covered during propagation because of their extremely small size [approximately 825,000 pure seeds per 28 g (1 oz)] and light requirement.

[1]Received for publication October 22, 1992; in revised form February 8, 1993. This research was funded by the North Carolina Agricultural Research Service (NCARS), Raleigh, NC 27695-7643. Assistance of the staff of the Southeastern Plant Environment Laboratory (Phytotron) is gratefully acknowledged.

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Introduction

Carolina rhododendron (*Rhododendron carolinianum* Rehd.) is a native evergreen, lepidote (scaly) rhododendron of the southeastern United States. Although the taxonomic treatment of *R. carolinianum* and related taxa is problematical (4,7,9), it occurs at high elevations in the mountains of North and South Carolina and Tennessee (4).

Rhododendron carolinianum is a cold hardy, compact shrub reaching a height of 1 to 2.5 m (4). Flowering occurs in May through June with attractive blooms ranging from pale pink to rose-purple (4). Leaves are dark to paler green in the summer (4) and develop a purplish tinge in winter (5). All of these characteristics have contributed to *R. carolinianum* being a highly desirable landscape plant. Additionally, because of its compact growth habit, outstanding floral display and cold hardiness, it has been used as a parent in many crosses (controlled pollinations). Hybrid selections include Wilson rhododendron (*Rhododendron* X *laetevirens* Rehd.) and the *Rhododendron* 'Peter J. Mezitt' ('P.J.M.') hybrid complex (5).

Propagation of *R. carolinianum* can be accomplished sexually (by seeds) or asexually (vegetatively) by stem cuttings. Both techniques can be and are used by nurserymen in North Carolina and surrounding states, particularly those individuals who specialize in native plants. However, more propagators have commented on difficulties associated with rooting stem cuttings than germinating seeds. Thus, sexual propagation appears to be a more reliable approach to propagation. Despite the greater chances of success when using sexual propagation, little quantitative information has been reported on the influence of various environmental factors (e.g. light and temperature) on seed germination of *R. carolinianum*. Preliminary data by Gensel and Blazich (8) indicated a light requirement for germination and depending on the photoperiod, greater germination was achieved at an alternating temperature than a constant temperature. Unfortunately, lack of sufficient replication limits definitive conclusions to be made from those data (8). Therefore, the objective of this study was to investigate in greater detail the influence of varying photoperiods and a constant versus an alternating temperature on seed germination of *R. carolinianum*.

Materials and Methods

On November 6, 1989, mature seed capsules were collected from a native population of open-pollinated plants of *R. carolinianum* growing in Henderson County, North Carolina at an elevation of 700 m (2300 ft). Capsules were stored in a paper bag at 20°C (68°F) for 30 days. Seeds were then removed from the capsules and stored at a moisture content of 6% in a sealed glass bottle at 4°C (39°F). Moisture content of the seeds was determined by calculating the mean moisture content of six, 200-seed samples following drying at 105°C (221°F) for 24 hr.

In July and October 1990, seeds were removed from storage and graded by manual removal of abnormal, damaged, and undersized seeds. Graded seeds [approximately 825,000 pure seeds per 28 g (1 oz)] were sown in covered 9-cm (3.5 in) glass petri dishes, each containing two prewashed germination blotters moistened with tap water. Following placement of seeds in the dishes, half were designated for germination at 25°C (77°F) and the other half for germination at an 8/16 hr thermoperiod of 25°/15°C (77°/59°F). All dishes were placed in black sateen cloth bags and the seeds allowed to imbibe overnight at 21°C (70°F). The next day, bags were randomized within two growth chambers [C- chambers (6)] set at the appropriate temperatures. Chamber temperatures varied within ±0.5°C (0.9°F) of the set point.

Within each temperature regime, seeds were subjected daily to the following nine photoperiods: total darkness, 1/2, two 1/2 hr photoperiods separated by 7 1/2 hr of darkness, 1, 2, 4, 8, 12, or 24 hr. Regardless of temperature, photoperiod treatments were administered the same time each day and for the alternating temperature of 25°/15°C (77°/59°F), all photoperiod treatments with the exception of total darkness and 24 hr irradiation began with the transition to the high temperature portion of the cycle.

Growth chambers were equipped with cool-white fluorescent lamps that provided a photosynthetic photon flux (400-700 nm) of 69 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (5.3 klx) as measured at dish level with a cosine corrected LI-COR LI-185 quantum/radiometer/photometer (LI-COR, Lincoln, Neb.). All photoperiod treatments, except total darkness and the 24 hr irradiation, were regulated by removal and placement of the petri dishes in black sateen cloth bags. For the 24 hr photoperiod treatment, the petri dishes remained continuously unbagged in open chamber conditions. Regardless of the photoperiod, temperatures within the petri dishes never exceeded ambient by more than 1°C (2°F). Petri dishes representing the total darkness treatment remained in black cloth bags throughout the experiment and all watering and germination counts were performed under a green safelight. Germination blotters were kept moist with tap water throughout the experiment. Seeds showing signs of decay were immediately removed from the dishes.

Each photoperiod was replicated four times within a temperature regime with a replication consisting of a petri dish containing 100 seeds. Germination counts were recorded every 3 days for 30 days. A seed was considered germinated when the emerging radicle was ≥ 1 mm (0.04 in). The experiment was conducted two times (July and October 1990).

For each experiment, percent germination was calculated as a mean of four replications per treatment. Data were subjected to analysis of variance procedures and regression analysis. Since there were no significant differences between the two experiments, only data from the October 1990 study are presented.

Results and Discussion

Seeds of *R. carolinianum* required light for germination whether germinated at 25°C (77°F) or 25°/15°C (77°/59°F) (Fig. 1). With the exception of the split photoperiod (1/2 + 1/2 hr), germination at 25°C (77°F) was a function of photoperiod with 30-day germination being greater with each increase in photoperiod (Fig. 1A). The highest ger-

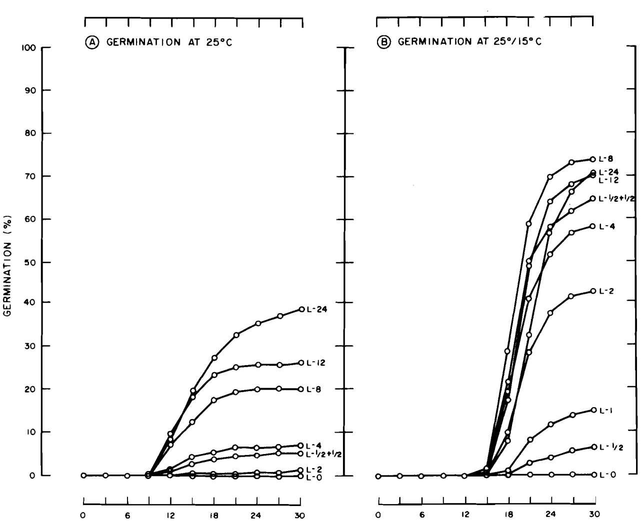

Fig. 1. Influence of light and temperature on seed germination of *R carolinianum*. (A) germinated at 25°C (77°F) with daily photoperiods (L) ranging from total darkness (L-0) to 24 hr (L-24). Data for photoperiods of 1/2 and 1 hr were omitted since they were similar to seeds maintained in constant darkness (L-0). (B) germinated at 25°/15°C (77°/59°F) utilizing the same photoperiods as in A.

mination (39%) at the constant temperature was realized for seeds subjected to continuous light.

At 25°/15°C (77°/59°F) the germination response was different than at 25°C (77°F) as the alternating temperature partially compensated for the light requirement (Fig. 1B). This is best illustrated by comparing 30 day germination at 25°C (77°F) and 25°/15°C (77°/59°F) for photoperiods of 1/2, 1 and 2 hr. At 25°C (77°F) 30-day germination for photoperiods of 1/2, 1 and 2 hr was 0, 0, and 1%, respectively, in comparison to 6, 15, and 43%, respectively, for identical photoperiods at 25°/15°C (77°/59°F). The stimulatory influence of the alternating temperature was so great that germination ≥ 70% was achieved with photoperiods ≥ 8 hr whereas at 25°C (77°F) maximum germination of 39% occurred for seeds receiving a 24-hr photoperiod. Partial substitution of a light requirement by an alternating temperature has also been demonstrated with other ericaceous species such as *Kalmia latifolia* L. [mountain laurel (11)], *Rhododendron calendulaceum* (Michx.) Torr. [flame azalea (10)], *Rhododendron maximum* L. [rosebay rhododendron (1)], and *Leucothoe fontanesiana* (Steud.) Sleum [drooping leucothoe (2)].

Analysis of variance showed that for each temperature, photoperiod, time (days) and their interactions were highly significant. Thus, regression analysis was conducted on cumulative germination within each temperature (Fig. 2) for each 3-day interval (Table 1). The analysis did not include data for total darkness or the split photoperiod.

At 25°C (77°F) a highly significant linear and quadratic response to photoperiod was noted beginning at day 12 and continuing to day 30 (Table 1, Fig. 2A). Identical responses were noted at 25°/15°C (77°/59°F) beginning at day 18 (Table 1, Fig. 2B).

Although light was essential for germination at both temperatures, photoperiods of 12 and 24 hr appeared to inhibit germination at 25°/15°C (77°/59°F) (Fig. 2B). This was not noted at 25°C (77°F). Beginning at day 18 and continuing to day 30, germination under an 8 hr photoperiod was always greater than photoperiods of 12 and 24 hr. An identical

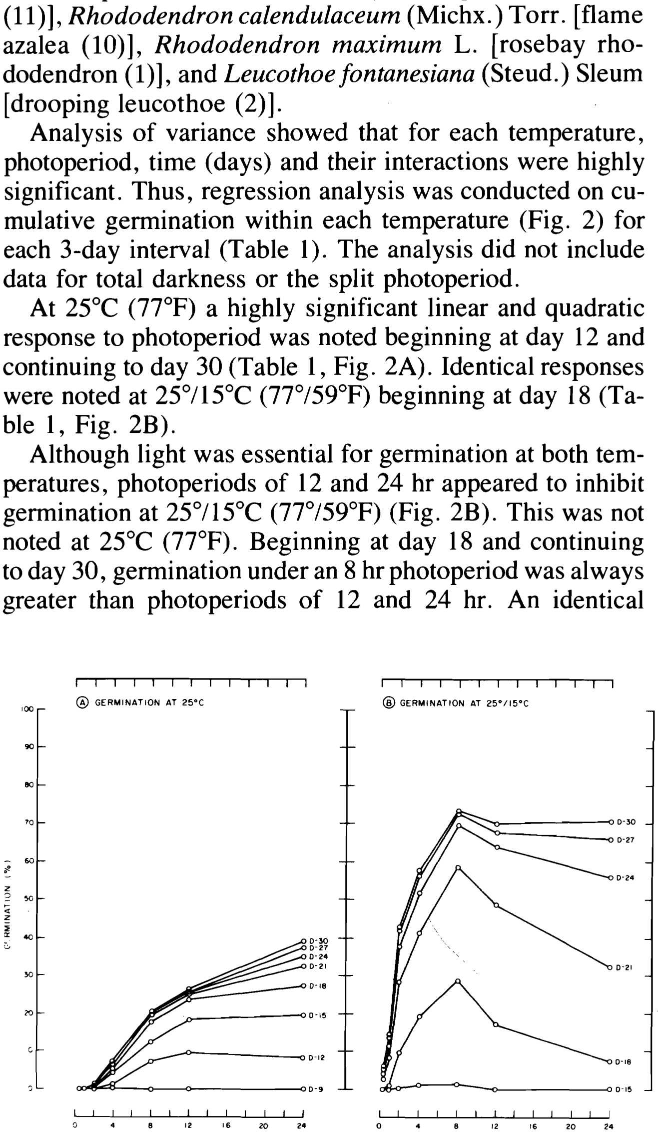

Fig. 2. Cumulative seed germination of *R. carolinianum* as influenced by photoperiod at days (D) 9 to 30. Data for seeds germinated in total darkness and the 1/2 + 1/2 hr photoperiod were omitted. (A) germinated at 25°C (77°F). (B) germinated at 25°/15°C (77°/59°F). Data for days 9 and 12 were omitted since no seeds germinated.

Table 1. Influence of photoperiod on cumulative seed germination of *Rhododendron carolinianum* for days 9 to 30.

Temp. (°C)	Photo-period	Time (days)[z] 9	12	15	18	21	24	27	30
25°	L	NS	**	**	**	**	**	**	**
	Q	NS	**	**	**	**	**	**	**
25°/15°	L	—	—[y]	NS	**	**	**	**	**
	Q	—	—	NS	**	**	**	**	**

[z]NS, **, indicates nonsignificant and highly significant ($p \leq 0.01$) linear (L) or quadratic (Q) response, respectively.

[y]No germination occurred by day 12.

response was reported by Blazich et al. (2) for seeds of *Leucothoe fontanesiana* whether germinated at 25°C (77°F) or 25°/15°C (77°/59°F).

Depending on the photoperiod, germination commenced earlier at 25°C (77°F) in comparison to 25°/15°C (77°/59°F). Despite the delay in germination with the alternating temperature, 30-day germination at 25°/15°C (77°/59°F) for all photoperiods except total darkness was always greater than equivalent photoperiods at 25°C (77°F). However, the magnitude of the differences was striking, e.g., 71% cumulative germination at 25/15/°C (77/59°F) with a 24 hr photoperiod in comparison to 39% cumulative germination at 25°C (77°F) with an identical photoperiod. These data suggest that 25°/15°C (77°/59°F) is more desirable to maximize germination. Subsequent experiments by the senior author have shown that although the alternating temperature generally results in greater cumulative germination than the constant temperature for equivalent photoperiods, the absolute differences can vary depending on the seed lot.

Since 1989, germination studies similar to the research reported herein have been published by the senior author and coworkers dealing with the following ericaceous species indigenous to the southeastern United States: *R. calendulaceum* (10), *Kalmia latifolia* (11), *Rhododendron catawbiense* Michx. [catawba rhododendron (1)], *R. maximum* (1), *Leucothoe fontanesiana* (2), and *Pieris floribunda* (Pursh ex Sims) Benth. and Hook. [mountain andromeda (12)]. From this work and results for *R. carolinianum*, the following generalizations are applicable for all these species with the exception of *R. catawbiense* and *Pieris floribunda*.

Whether seeds are germinated at 25°C (77°F) or 25°/15°C (77°/59°F), light is necessary for germination. For seeds placed at 25°C (77°F) germination is a function of photoperiod and the longer the photoperiod the greater the germination. When seeds are germinated at 25°/15°C (77°/59°F) the alternating temperature will partially compensate for the light requirement when photoperiod is limiting. For example, greater germination will be achieved at 25°/15°C (77°/59°F) with a 1 hr photoperiod in comparison to 25°C (77°F) with an equivalent photoperiod. Despite greater total germination at 25°/15°C (77°/59°F) in comparison to 25°C (77°F) with identical photoperiods, germination begins faster at 25°C (77°F).

Rhododendron catawbiense and *Pieris floribunda* respond differently than the above species since they have no light requirement regardless of germination temperature (1,12). For seeds not exposed to light, greater germination will occur at 25°/15°C (77°/59°F) than 25°C (77°F). Daily photoperiods as short as 1/2 hr will permit maximum germination of these species.

All the seed germination studies conducted and published by Blazich and coworkers (1,2,10,11,12) have included a split photoperiod of two 1/2 hr photoperiods separated by 7 1/2 hr of darkness. When this treatment results in greater germination than a continuous 1 hr photoperiod, the data strongly suggest that light stimulation of seed germination is phytochrome mediated (3). Thus, seed germination of *R. carolinianum* appears to be phytochrome mediated (Fig. 1). Other species responding in a similar manner include *R. calendulaceum* (10), *Kalmia latifolia* (11), *R. maximum* (1), and *Leucothoe fontanesiana* (2).

Despite variation in seed size among the aforementioned species, including *R. carolinianum*, seeds of all species are very small. Small seed size plus the requirement or stimulation of germination by light should caution nurserymen not to cover the seeds during propagation.

Literature Cited

1. Blazich, F.A., S.L.Warren, J.R. Acedo, and W.M. Reece. 1991. Seed germination of *Rhododendron catawbiense* and *Rhododendron maximum*: Influence of light and temperature. J. Environ. Hort. 9:5–8.

2. Blazich, F.A., S.L. Warren, J.R. Acedo, and R.O. Whitehead. 1991. Seed germination of *Leucothoe fontanesiana* as influenced by light and temperature. J. Environ. Hort. 9:72–75.

3. Borthwick, H.A., E.H. Toole, and V.K. Toole. 1964. Phytochrome control of *Paulownia* seed germination. Israel J. Bot. 13:122–133.

4. Davidian, H.H. 1982. The Rhododendron Species. vol. I. Lepidotes. Timber Press, Portland, Ore.

5. Dirr, M.A. 1990. Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses. 4th ed. Stipes Publishing Co., Champaign, Ill.

6. Downs, R.J. and J.F. Thomas. 1983. Phytotron procedural manual for controlled environment research at the Southeastern Plant Environment Laboratory. N.C. Agr. Res. Serv. Tech. Bul. 244 (Revised).

7. Duncan, W.H. and T.M. Pullen. 1962. Lepidote rhododendrons of the southeastern United States. Brittonia 14:290–298.

8. Gensel, W.H. and F.A. Blazich. 1983. Seed germination studies of the lepidote rhododendrons of the southeastern United States. N.C. State Univ. Phytotron Rpt. p. 48.

9. Hardin, J.W. and W.H. Gensel. 1982. Atlas of foliar surface features in woody plants, IV. Rhododendrons (Ericaceae) of eastern North America. Bul. Torrey Bot. Club 109:189–198.

10. Malek, A.A., F.A. Blazich, S.L. Warren, and J.E. Shelton. 1989. Influence of light and temperature on seed germination of flame azalea. J. Environ. Hort. 7:109–111.

11. Malek, A.A., F.A. Blazich, S.L. Warren, and J.E. Shelton. 1989. Influence of light and temperature on seed germination of mountain laurel. J. Environ. Hort. 7:161–162.

12. Starrett, M.C., F.A. Blazich, and S.L. Warren. 1992. Seed germination of *Pieris floribunda*: Influence of light and temperature. J. Environ. Hort. 10:121–124.