florida or of *C. nuttallii* × *C. kousa*. Many of the plants have been found to be more vigorous than those of either *C. florida* or *C. kousa* and have been found to be highly resistant to attack by the dogwood borer. Vegetatively, these hybrids are fully winter-hardy at New Brunswick, NJ although the floral bracts may show injury following a severe winter, as is true with most cultivars of *C. florida*.

Advanced generation interspecific hybrids resulting from hybridization among plants of *C. florida*, *C. kousa*, and *C. nuttallii* are currently under test at Rutgers University and new hybrids are being generated each year. At present, the five F_1 interspecific hybrids of *C. kousa* × *C. florida* described above are being increased prior to introduction to commerce as Rutgers University's answer to dogwood decline.

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PROPAGATING RHODODENDRON CUTTINGS WITH FLEXWATT IN POLY TUNNELS

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Abstract. The effectiveness of rooting rhododendron cuttings in poly-tunnels heated with Flexwatt electric heating mats during late winter and early spring was examined. Mats maintained root-zone temperatures above 20.0°C (69.0°F) even when night temperatures dropped to −20.4°C (−4.7°F). Placing a Microfoam insulating blanket over the rooting medium and sticking cuttings through it reduced energy consumption by about 20%, but also reduced rooting and complicated removal of rooted cuttings. Time when cuttings were stuck, as well as length of the rooting period, influenced rooting percentage, root quality, and subsequent growth.

INTRODUCTION

Rhododendrons are usually propagated by cuttings stuck in September through December in bottom-heated greenhouse

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benches (4). While greenhouse propagation is effective, alternative methods using minimum structures may be equally effective and less costly (3) and especially useful where greenhouse space is unavailable. The objectives of this study were to determine: 1) if adequate rooting temperatures could be maintained in electrically heated poly-tunnels; 2) how well rhododendron rooted in electrically heated medium in poly-tunnels; and 3) how much energy use could be reduced by placing an insulating blanket over the rooting medium.

MATERIALS AND METHODS

Four outdoor poly-tunnels were assembled during the winter of 1983-84. The structures, oriented in a north-south direction, were 1.5 m (5 ft) wide, 4.5 m (15 ft) long, and 1.2 m (4 ft) tall. Bed sides were constructed of copper naphthenate treated lumber and were 25.4 cm (10 in.) high and anchored to the ground by 61 cm (2 ft) sections of 1.3 cm (½ in.) galvanized water pipe spaced at 91.4 cm (3 ft) intervals. Steel reinforcing rods; 1.3 cm (½ in.) in diameter and 3 m (10 ft) long were bent into a semi-circular hoops, inserted into the water pipe attached to the sides of the beds and covered with 6 mil white copolymer.

The bottom of each bed was lined with about 5.2 cm (2 in.) of fine gravel, providing a uniform base for the Flexwatt Agritape[1], a thin, flexible electric resistance heating mat in which copper strips are bonded into Mylar plastic. Four 28 cm (11 in.) wide mats rated at 17 watts per linear foot were placed across the bottom of each bed and covered with a single layer of aluminum screening. Bed sides were lined with 3.2 cm (1¼ in.) thick Thermax sheating[2]. Each bed was partitioned the width of the tunnel into four equal sections with Thermax sheating and filled to a depth of 20.3 cm (8 in.) with a sphagnum peatmoss:horticultural perlite 1:1 (v/v) propagating medium. Only the two center sections were used in the study. Shaded-pole blowers[3] ($^1/_{50}$) horsepower and set to activate when air temperatures exceeded 4.4°C (40°F) were installed at one end of each tunnel and the structure vented at the opposite end. Plastic irrigation pipe 2.5 cm (1 in.) in diameter, equipped with mist nozzles spaced 1.2 m (4 ft) apart, was suspended from the ridge for the length of each tunnel to provide overhead watering as necessary to maintain a moist medium. Bed thermostats were placed 7.6 cm (3 in.) deep and

[1] Ken-Bar Company, Division of Flexwatt Corp., Reading, MA.
[2] The Celotex Corp., Tampa, FL.
[3] Dayton Electric Manufacturing Co., Chicago, IL.

set to maintain a 21°C (70°F) medium temperature at 7.6 cm (3 in.), the depth of the base of the cutting. Air temperatures were monitored throughout the experiment by thermocouples inserted into silver-painted ping-pong balls (13). Medium tempertures were monitored with thermocouples.

In two of the four poly-tunnels, 6.3 mm (¼ in.) thickness Microfoam[4] was installed over the rooting medium, and cuttings inserted directly through the perforations. Beds in the other two tunnels were not covered with Microfoam. Energy usage for heating and ventilating in each tunnel was monitored continuously as kilowatt hour day^{-1} sq. $ft.^{-1}$ and the sum recorded daily.

Cuttings of *Rhododendron maximum* 'Pink' were collected the week of February 12 and again just before bud swell the week of April 7, 1984. Cuttings were stored in a refrigerator at 4.4°C (40°F) between the time of collecting and sticking. Cuttings were 10.2 to 15.2 cm (4 to 6 in.) long, with flower buds removed. The three to four leaves on each cutting were cut in half transversly.

All cuttings were wounded and treated with a solution containing Dip-N-Grow[5] root-promoting compound which contains 1.0% IBA and 0.5% NAA. Cuttings were wounded by removing two thin slices of tissue approximately 1.3 cm (½ in.) long from the basal side of each cutting using a sharp potato peeler. Cuttings were dipped to a depth of approximately ½ inch (1.25 cm) for 5 seconds in a Dip-N-Grow solution diluted with distilled water to contain 2000 ppm IBA and 1000 ppm NAA. One-half of the cuttings stuck in February were lifted six weeks later (in April) and evaluated. The remaining cuttings were left in place and evaluated in late May, 12 weeks after sticking. Another set of cuttings was stuck in April and evaluated in May.

A completely randomized experimental design with two replications was used with a split-split plot treatment arrangement. The main plot Microfoam treatment was randomized among the four poly-tunnels. Each main plot accommodated the sub-plots which were the different sticking and lifting dates. Each split contained 45 cuttings. Two border rows were stuck around the perimeter of each bed. In addition, data were taken in order to monitor uniformity of rooting across the bed. Differences among means were analyzed using Duncan's New Multiple Range Test.

[4] Whitemarsh Paper and Specialties, Philadelphia, PA.
[5] Alpkem Corp., Clackama, OR.

When cuttings were lifted in April or May, the number of rooted cuttings was recorded. In addition, each cutting was rated qualitatively using a numerical scale of 1 (no roots) to 5 (excellent rooting) (5,8,16). Five randomly chosen representatives of each rating number from each treatment (total of 10 rooted cuttings) were potted in a sphagnum peatmoss-horticultural vermiculite 1:1 (v:v) potting mix and grown on for the remainder of the season. In early August 1984, potted plants were rated qualitatively using a numerical scale of 1 (dead) to 3 (actively growing).

RESULTS AND DISCUSSION

Throughout the experiment, Flexwatt Agritape heating mats maintained root-zone temperatures near 21° (70°F) in all poly-tunnels (Table 1). During the coldest 24-hour period, when the daytime outside high temperature was −5°C (23°F) and the low was −20.4°C (−4.7°F), root-zone temperatures in Microfoam covered beds ranged from 17.2 to 22.8°C (63 to 74°F), while the beds without Microfoam ranged from 15.6 to 22.8°C (60 to 73°F). Temperatures in the center of the beds were only 1 to 2°C (2 to 3°F) higher than at the edge. Average medium temperatures in all tunnels reflected changes in ambient outside air temperature, dipping below 21°C (70°F) on very cold nights and climbing above 21°C (70°F) on warm days.

Average air temperatures (Table 1) in all structures were warmer than ambient outside air temperatures at night and considerably warmer during the day, especially on sunny days. Air temperature fluctuated the most in poly-tunnels equipped with Microfoam (Table 1); temperatures were higher during the day due mostly to trapped solar radiation, and cooler at night as Microfoam restricted heat loss from the medium. Daytime air temperatures were lower in structures without Microfoam due to the absorptive capacity of the dark colored medium, but were warmer at night due to heat escaping from the medium. Although average air temperatures in poly-tunnels with and without Microfoam were practically the same (Table 1), the greater daily air temperature fluctuations in tunnels with Microfoam may have been responsible for the reduction in rooting.

On cold, cloudy days air temperature differences between tunnels varied only between 1 to 2°C (2 to 3°F). When temperatures warmed in the spring and fans were used to ventilate the structures, temperature differences were less than 1°C (2°F).

Poly-tunnels without Microfoam required about 25% more energy to maintain root-zone temperatures near 21°C (70°F)

Table 1. Low and high poly-tunnel air and root-zone temperatures (°C,°F) on selected days. Root-zone temperatures represent an average of 3 readings/bed over 2 poly-tunnels. Air temperatures represent 1 reading/bed averaged over 2 poly-tunnels.

	Coldest day[z] Low −20.4°C (−4.7°F) High −5.0°C (23.0°F) Ave. −11.8°C (10.9°F)		Cold/cloudy day[y] Low −7.3°C (18.8°F) High −2.3°C (27.8°F) Ave. −4.9°C (23.2°F)		Cold/sunny day[x] Low −5.6°C (22.0°F) High 1.1°C (34.1°F) Ave. −1.1°C (30.0°F)	
Treatment	Low	High	Low	High	Low	· High
Air[w]	−14.2°C (6.5°F)	18.3° (65.0°F)	−0.3°C (44.0°F)	6.7°C (35.9°F)	−5.6°C (68.5°F)	20.3°C (38.0°F)
With microfoam						
Root-zone[v]	17.8°C (64.0°F)	22.8°C (73.0°F)	20.6°C (69.0°F)	23.0°C (73.5°F)	20.0°C (68.0°F)	22.8°C (73.0°F)
Air	−9.7°C (14.5°F)	15.3° (59.5°F)	−0.6°C (33.0°F)	5.3°C (41.5°F)	−3.0°C (26.5°F)	17.5°C (63.5°F)
Without microfoam						
Root-zone	16.9°C (62.5°F)	23.0°C (73.5°F)	20.3°C (68.5°F)	23.3°C (74.0°F)	19.4°C (67.0°F)	23.3°C (74.0°F)

[z] March 10, 1984
[y] March 13, 1984
[x] February 28, 1984
[w] 1 thermocouple reading/tunnel in the center of bed at cutting canopy height.
[v] 3 thermocouple readings/tunnel taken at cutting base depth (3 in) across the bed at equal intervals.

Table 2. Kilowatt hour usage (KWH) for poly-tunnel heating between February 27 and May 29, 1984

Poly-tunnel	Average 24 hour usage (KWH) March	April	May	Total usage[z] (KWH)
With microfoam				
Bed #1	12.30	11.50	9:30	1030
Bed #3	11.00	10.20	7.50	896
Mean	11.60	10.80	8.30	963
Without microfoam				
Bed #2	13.20	12.00	9:90	1096
Bed #4	11.90	15.10	14.90	1320
Mean	13.10	13.60	12.40	1208

z Poly-tunnel area = 75 sq. ft.

than tunnels with Microfoam (Table 3). This difference was partly due to equipment failure. A heating mat in poly-tunnel 4 malfunctioned during the experiment and caused higher energy use. If the energy use results from poly-tunnel 4 is ignored, differences in energy useage between tunnels with and without microfoam become considerably less. Lower energy use in tunnels with Microfoam was also due to its insulating properties and the higher medium moisture levels under the microfoam. This would improve heat retention, conduction and distribution throughout the medium (11) and reduce energy to heat the medium.

During this experiment poly-tunnels without Microfoam used 1208 KWH (16.1 kilowatt hours square foot^{-1}) while those with Microfoam used 963 (12.8 kilowatt hours square foot^{-1}) (Table 2). If energy use for this experiment is considered to be about 25% of the yearly total (7), then heating costs for these beds would be unacceptably high. However, the capital investment in these beds is much lower than for a larger structure, and combined with the ease of installation, could be considered an acceptable alternative. Dramatic reductions in energy use could probably be realized if these tunnels were installed inside a standard overwintering house.

Table 3. Effect of root rating and time of propagation on survival (%)[z] and vigor rating[y] of *Rhododendron* 'Pink Pink'.

	Survival (%)			Vigor rating[x]		
Root rating	Feb-Apr[w]	Apr-May[w]	Feb-May[v]	Feb-Apr[w]	Apr-May[v]	Feb-May[v]
1	0	0	0	1.0	1.0	1.0
2	100	62	0	2.1	1.6	1.0
3	85	83	100	2.2	1.5	2.0
4	100	100	100	2.7	2.5	2.3
5	100	–	100	3.0	–	3.0

[z] % survival at each rooting sequence based upon 10 observations; 5 from each root rating for each microfoam treatment.
[y] Vigor rating based on 10 observations; 5 from each root rating for each microfoam treatment.
[x] 1 = dead; 2 = 1 flush growth; 3 = 2 or more flushes of growth.
[w] 6 week propagation period.
[z] 12 week propagation period.

There was no significant interaction between time cuttings were stuck and the use of Microfoam. Therefore, rooting data with and without Microfoam were averaged for all sticking times for each of these two rooting replications. Rhododendron cuttings rooted significantly better without Microfoam as 74% of the cuttings rooted (Figure 1) with an average root rating of 2.7 (Figure 1). Only 31% of the cuttings rooted under Microfoam, and they had an average root rating of 1.8.

The thickness of the insulating blanket combined with areas where this blanket may not have been in direct contact with the medium may have prevented the shorter (10.2 cm. 4 in.) cuttings from being stuck deep enough into the medium. If the cuttings were not stuck as deep as in the uncovered beds, their bases may not have been maintained at a high enough temperature for rooting.

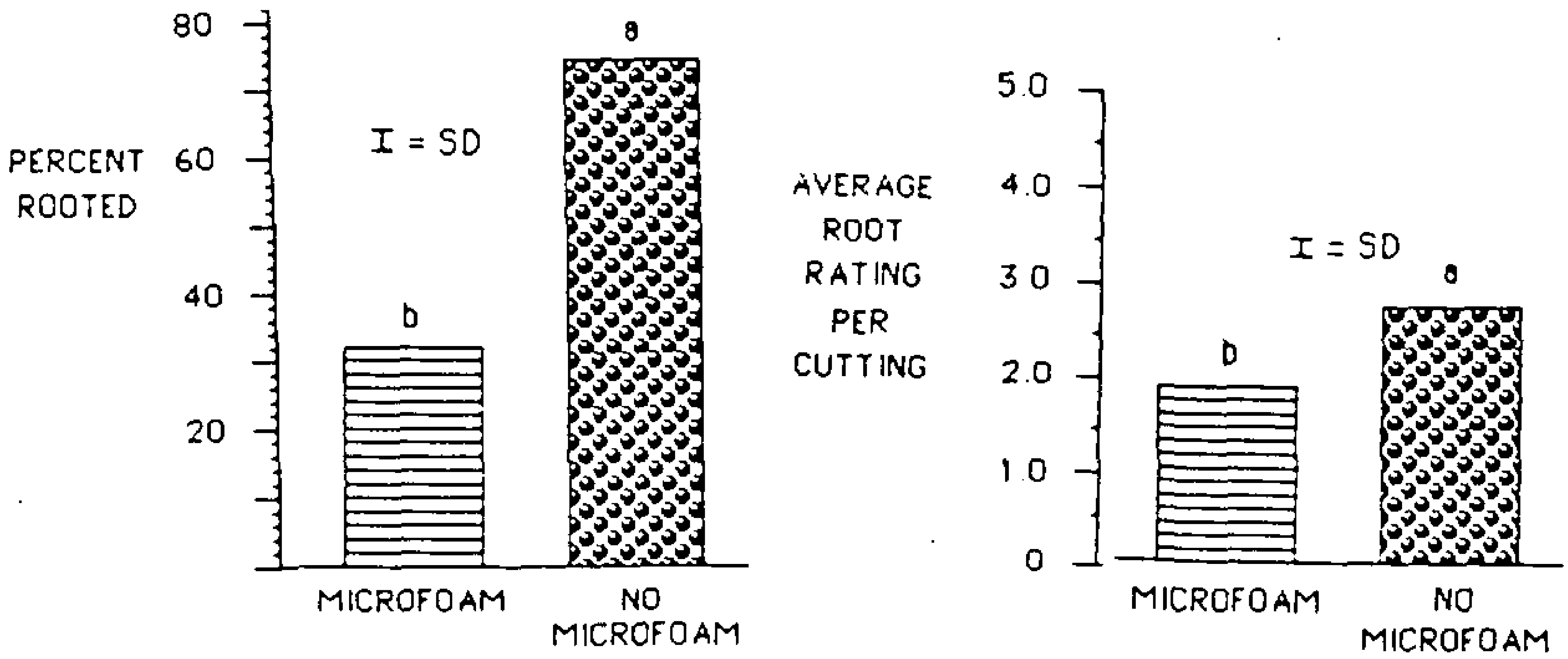

Figure 1. Effect of Microfoam on rooting percentage and average root rating per cutting of *Rhododendron maximum* 'Pink'.

Rhododendron rooting was significantly poorer in the April/May sequence than the February/April or February/May sequence (Fig. 2). Many plant species propagated by cuttings have optimal times where physiological condition of the cutting may be modified by environmental factors (1,14). Those stuck in April apparently missed the optimal rooting time.

Rhododendron cuttings are commonly rooted in June through early December (15). However, moderate success was achieved in this study when rooting cuttings in February. There was no statistical difference in number of cuttings rooted between the February/April sequence (61%) and the February/May sequence (68%) (Figure 2). However, cuttings left in the bed from February to May had a significantly higher average root rating than those left in from February to April (Figure 2). Most propagators believe that three months in the propagating bench is required to form a substantial root system on rhododendron cuttings (4,6). Cuttings stuck in April and lifted in May had significantly lower rooting percentages and root ratings than the other times (Figure 2). This was probably because the buds were swelling and cambial activity had already begun, and leaves were ready to develop.

The propagation structure, location of cuttings in the bed, and Microfoam had no effect upon survival and vigor of potted cuttings. Cutting survivability was between 80 to 100%. All of the cuttings rated 4 or above survived (Table 3). Of the cuttings with a root rating of 3, 80% of those that were in the propagation bed for 6 weeks survived, while 100% of those that were in the bed 12 weeks survived. Of the cuttings with a root rating of 2, 100% of those that were in the propagation bed from February to April survived, but survival of cuttings from the other sequences was poor. None of the cuttings with

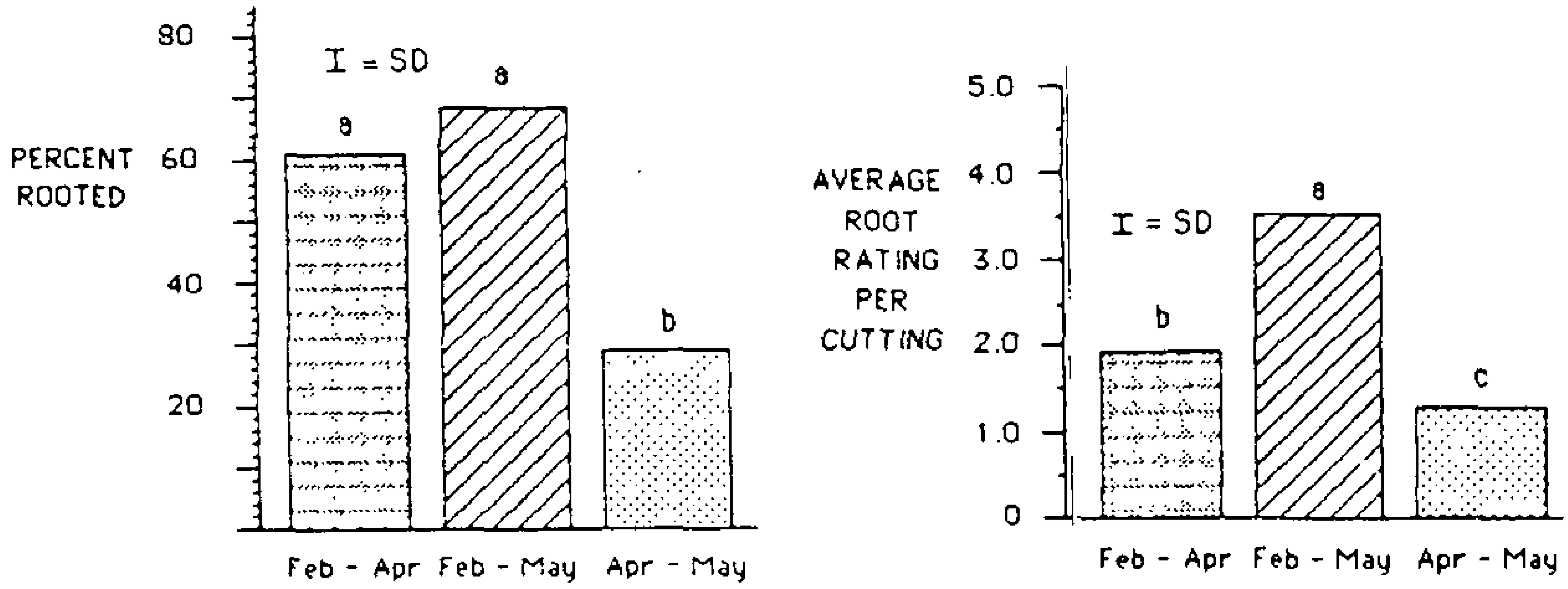

Figure 2. Effect of sticking and lifting dates on rooting percentage and average root rating per cutting of *Rhododendron maximum* 'Pink'.

a root rating or 1 survived.

During the first growing season, the plants rooted in the February-April sequence exhibited the most vigorous growth (Table 3). Cuttings that remained in the propagation beds from February to May did not grow as well, unless they had a root rating of 4 or 5 when planted. Cuttings from the April-May sequence grew poorly unless they had a root rating of 4 when they were planted.

Survivability and vigor were enhanced when cuttings were taken in February and potted 6 weeks later in April. Although larger root systems developed, there appeared to be no advantage to leaving cuttings in the bed for 12 weeks at that time of the year. The sooner plants were rooted, potted, and placed outdoors, the better the growth that season. Subjecting potted cuttings to cool early spring temperatures where transpiration was reduced, but conditions for root growth were favorable, enabled these plants to begin vigorous growth earlier. Many plants pass through alternative periods of active root growth followed by active shoot growth (12). This cycle is apparently controlled by the photoperiod, temperature, and the water and nutrient status of the plant. The plants potted in April probably developed the first flush of root growth in the containers, while those potted in May probably had their first flush of root growth in the propagation bed. This would account for the higher root ratings for the plants lifted in May. Disturbing the roots after the roots had their first main flush of growth would be expected to reduce the vigor of top growth. Cuttings potted in May, subjected to early heat stress, grew less. Based on these results, two crops could be produced if the sticking date in February was preceded by a rooting period initiated in late December or early January.

Although Microfoam does conserve energy, the additional material expense, labor required to install and harvest cuttings stuck through this blanket, and the reduced rooting, makes its use questionable. A better way to reduce costs would be to shorten the time cuttings remain in the propagation bed. These experiments show that rhododendron cuttings can be successfully rooted if left in the medium for only 6 weeks and will grow vigorously when lifted and potted.

Propagators who want to root rhododendron cuttings in the winter no longer need expensive greenhouses but can use easy-to-assemble, low-cost poly-tunnel structures. Cuttings rooted during the winter allow a more even distribution of the work load, improving efficiency and increasing profits. Root-zone heating directs heat to the root zone for efficient rooting, has a relatively low initial cost, and is easy to install. A rooting period of 6 to 8 weeks is sufficient to develop adequate rooting. This short rooting period lowers production costs and allows time for two crops to be rooted during the winter. Finally, better disease control might be obtained in the propagation bed because of the low temperatures around the foliage and the short time cuttings remain in the bed.

In the future, cuttings may be stuck directly into containers (2,9) within the poly-tunnel. Direct sticking eliminates one transplanting step possibly lowering production costs. Without transplant shock, rooted cuttings develop into larger plants by season's end. In addition, because the cuttings would be more widely spaced, larger cuttings or multiple cuttings per pot could be stuck. This would result in the production of salable plants sooner (10).

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