growth.

The cummulative loss of leachate N from IBDU-treated medium was less than that from the U + NI treatment for the first 28 days and from U for the entire 87 days of the study (Table 3). The U + NI treatment demonstrated less cumulative loss of N than did the IBDU and U treatments for the last 31 and 59 days of the study, respectively. In both the U and U + NI treatments, 25% of the total N had leached by day 14, whereas, only 12% had leached in the IBDU treatment. After 56 days, U, IBDU, and U + NI treatments resulted in cumulative losses of 47%, 40%, and 35% N, respectively.

Nitrate and nitrite accounted for 46.5% and 69.6% of the total cumulative N loss from the U and IBDU, but only 5.2% from the U + NI treatment (Table 2). Between days 14 and 67, the concentration of NO_2^- + NO_3^--N from U and IBDU exceeded 10 mg·liter^{-1}, the level considered safe for human consumption of water, indicating the high potential for NO_3^- pollution from these two materials. Essentially all of the N leached from the medium treated with U + UI was NH_4^+.

Azaleas fertilized with IBDU were of higher quality than those fertilized with U on days 77, 84, and 87, and higher quality than the U + NI treated plants on days 70 and 77 (Table 4), which is a result of its lower cumulative N loss (Table 3). Despite these differences, all plants were marketable (rating of 5 or above) by the end of the investigation suggesting that minimum N requirements were met regardless of leachate losses. No differences in shoot dry weight or N content of leaf or stem tissue were found (data not shown). The reduced quality of plants treated with U + NI during the latter sampling dates may be due to use of carbohydrates to detoxify NH_4^+ at the expense of plant growth. This diversion of carbohydrates would explain the slightly reduced vigor of azaleas in this treatment (6). Plants fertilized with U were beginning to show early symptoms of N deficiency, which explains the reduced quality ratings relative to the IBDU treatment (Table 4).

Some benefit in terms of plant quality can be expected from plants fertilized with IBDU relative to U during a 3-month growing season. The lower cumulative loss of N in leachate from the IBDU-treated medium for the first 28 days is the contributing factor to the increased quality plants in the IBDU treatment. Use of NI reduced cumulative N losses in leachate compared to other treatments, increasing fertilizer efficiency and reducing the potential for NO_3^- contamination of groundwater. Since only trace amounts of NO_2^- + NO_3^- were leached from NI-treated medium, it is questionable whether the rate of NI used would allow adequate NO_3^- for balanced carbohydrate metabolisms or growth of plants that did not assimilate NH_4^+ directly (6, 7). However, low rates of NI may reduce N leachate losses while allowing release of sufficient NO_3^- for plant growth.

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Effect of Pre-force Storage Conditions on Early Flowering of *Rhododendron*

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Abstract. **The effects of two cold storage treatments (natural temperatures vs. 5°C) and durations (6 vs. 8 weeks) on subsequent forced flowering were investigated in four *Rhododendron* cultivars. Natural temperatures were: day (0600–1800 HR), mean 6.8°, range −1.0° to 15°; night (1800–0600 HR), mean 4.8°, range −1.0 to 13°. There were marked differences among cultivars in the chilling requirements to break flower bud dormancy. An early flowering cultivar (R. 'Christmas Cheer'; *R. caucasicum* x), required less pre-force chilling than the late-flowering R. 'Vulcan' ('Mars' x *R. griersonianum*). Mid-season flowering 'Unique' (*R. campylocarpum* x) and 'Pink Bountiful' (*R. williamsianum* x 'Linswegeanum') had intermediate cold requirements. 'Christmas Cheer' was forced into flower for the Christmas period in 3 weeks without artificial pre-force cold storage.**

Rhododendrons offer great potential as pot plants when forced into bloom early, and commercial production used to be widely practiced in Europe. Wide ranges of colors, flower shapes, and sizes are accessible, many of which are not available in current traditional pot plants such as azaleas. In addition, there is the added advantage, in mild climates, of a plant that subsequently can make an attractive addition to the landscape after forced flowering.

Previous work (2) concentrated on condensing production time (rooted liner-flowering plant) into a 1-year period, using information on the cultivars' response to various growth regulators (1). There are also reports on the forcing period required to bring various cultivars into flower for such holidays as Valentine's Day and Mother's Day, using a low-temperature (13°C) forcing regime (6).

In preliminary work at Saanichton, B.C., it was found that increasing the temperature to 21° day/18°C night during the forcing period greatly reduced time to flower. In addition, plants produced in two growing seasons showed the structure and bud set required for a quality product, without the necessity for either growth regulators or green house space during the pre-force production period (4).

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Table 1. Mean day/night temperatures and number of hours below 10°C during pre-force storage under natural conditions.

Pre-force period	Day temp[z] (0600–1800 HR)	Range (°C) Max	Min	Night temp (1800–0600 HR)	Range (°C) Max	Min	Hours below 10°C
13–19 Oct.	9.8 ± 2.6	15	3	5.3 ± 1.9	10	3	124
20–26 Oct.	10.4 ± 3.2	15	3	7.1 ± 3.7	13	3	88
27 Oct.–2 Nov.	9.1 ± 2.4	14	3	7.4 ± 2.3	12	3	127
3–9 Nov.	5.7 ± 2.8	13	0	4.7 ± 2.5	10	0	162
10–16 Nov.	4.6 ± 2.0	8	0	3.4 ± 1.8	7	−1	168
17–23 Nov.	6.6 ± 2.1	11	−1	5.5 ± 1.9	9	0	163
24–30 Nov.	4.8 ± 1.8	11	−1	3.1 ± 1.4	6	0	165
1–7 Dec.	3.0 ± 1.1	7	0	2.1 ± 1.2	5	−1	168

[z]Mean ± SD.

Table 2. Effects of storage conditions and duration on forcing time of four cultivars of Rhododendron.

Flowering response	Forcing time (days): Cold storage[z] 6 weeks	Cold storage[z] 8 weeks	Natural storage[y] 6 weeks	Natural storage[y] 8 weeks	Date of natural flowering[x]
			Christmas Cheer		9–25 Mar.
First open flower	23.3	NA[w]	21.0	NA	
Full flower	28.7	NA	26.5	NA	
First flower to full	5.4	NA	5.5	NA	
			Pink Bountiful		11–22 Apr.
First open flower	38.0	28.6	---[v]	39.8	
Full flower	---[u]	37.6	---[u]	---[u]	
First flower to full	NA	9.0	NA	NA	
			Unique		12–25 Apr.
First open flower	39.0	36.0	48.2	40.2	
Full flower	48.0	43.0	57.2	47.4	
First flower to full	9.0	7.0	9.0	7.2	
			Vulcan		15–24 May
First open flower	47.2	46.8	67.0	56.3	
Full flower	55.3	54.0	72.7	63.3	
First flower to full	8.1	7.2	5.7	7.0	

[z]Cold storage at 5° ± 2°C.
[y]Storage at natural outside temperature.
[x]Flowering date range of field plants in coastal southwestern British Columbia.
[w]No experimental data.
[v]No flowering.
[u]Did not reach full flowering.

Table 3. Significance of main effects and interactions of cultivar, storage, and duration on flowering response.

Source of variation	Flowering response: First flower	Full flower	First flower to full
Cultivar (CV)	**	**	*
Storage (STOR)	**	**	NS
Duration (DUR)	**	**	NS
CV × STOR	**	**	NS
CV × DUR	NS	NS	NS
STOR × DUR	**	*	NS
CV × STOR × DUR	NS	NS	NS

*,**,NSSignificant at the 5% or 1% levels or not significant, respectively.

Previous workers suggested that *Rhododendron* requires a prolonged (8 to 10-week) cold period with temperatures < 10°C to break flower bud dormancy and allow early flowering (2). The present study was conducted with four *Rhododendron* cultivars, each differing in flowering date under natural field conditions, to determine: a) temperature (cold) requirements during the pre-force period; b) the effect of duration of pre-force cold storage; c) the relationship between chilling requirements for flower forcing and natural flowering dates for the different cultivars; and d) using cold storage, whether certain cultivars can be forced successfully for the Christmas holiday period.

The four cultivars were 'Christmas Cheer', forced color, light pink fading to white; 'Unique', forced color, white; 'Pink Bountiful', forced color, pink; and 'Vulcan', forced color, red.

Experimental plants were rooted from cuttings under mist as previously described (3). In Spring 1985, rooted cuttings were potted into 2.8-liter containers in a 3 bark : 1 sand : 1 sawdust : 1 peat (by volume) mix containing the following amendments (per cubic meter) 2.25 kg dolomite limestone, 1.8 kg superphosphate (0N–8.8P–0K), 0.15 kg FTE 503, and 4.75 kg Nutricote (Plant Products Co. Bramalea, Ont. Canada) (16N–10P–10K), slow-release formulation Type 40 and Type 180 (1:3 by weight). In Spring 1986, plants were top-dressed at a rate of 9 g/2.8 liter container with the same slow-release formulation fertilizer. An unheated shadehouse (50% light transmission) was used throughout the production schedule. 'Christmas Cheer' was acquired from a local nursery in 6-liter containers in Spring 1986 and top-dressed with 16N–10P–10K at a rate of 22 g/container.

Pre-force storage of plants was either under natural temperatures in the shadehouse (Table 1) or in a temperature-controlled cold room under the following conditions: temperature 5° ± 2°C, light; photoperiod 12 hr (0600–1800 HR), irradiance at plant level from incandescent lamps, 6.8 ± 1.6 $\mu mol \cdot s^{-1} \cdot m^{-2}$.

Forcing was in a glass greenhouse (50% light transmission) and temperatures of 21° (day)/18°C (night), without supplementary lighting. Actual temperatures ranged from 16° to 20° (night) and 20° to 29° (day). Relative humidity varied between 60% and 80%. Environmental conditions in the greenhouse were essentially constant throughout the experimental forcing period from 25 Nov. to 15 Feb. Since previous work (4) had shown that K deficiency could occur during and following the forcing period, the plants received a weekly liquid feed from a commercial fertilizer (20N–8.8P–16.6K) at 0.5 $g \cdot liter^{-1}$ throughout the forcing period.

Flowering was measured by the number of days to the first open flower and days to full flowering, defined as the date when all flower buds were in bloom, i.e., the maximum floral effect.

The experiment comprised a 4 × 2 × 2 factorial design consisting of four cultivars, two pre-force storage conditions (cold storage vs. natural chilling), and two pre-force periods (6 vs. 8 weeks). Replication varied from three to six plants per treatment, with one plant as an experimental unit. Pre-force storage began on 13 Oct. Forcing began either on 25 Nov. (6-week storage) or 8 Dec. (8-week storage) in a heated greenhouse section. Plants were randomly distributed both during cold storage and during the forcing period. Data were subjected to analysis of variance.

There were significant differences in the response of the various cultivars to storage conditions and duration (Tables 2 and 3). Interactions between cultivars and pre-forcing storage conditions and between storage conditions and storage duration also were evident. Therefore, the cultivar's flowering responses to pre-force storage conditions are described on an individual basis.

'Christmas Cheer' forced in the shortest period (21 to 23 days) and apparently required no artificial chilling to achieve full flowering during the forcing period. This cultivar also reached full flowering in the shortest period following the opening of the first flower. An 8-week pre-force treatment was not conducted for this cultivar. Plants were in full bloom by 21 Dec. and were of excellent quality.

'Unique' forced in an average of 37.5 days following cold storage. There was little difference between plants stored for 6 or 8 weeks at 5°C. However, the plants stored under natural temperatures for 8 weeks forced faster than those stored 6 weeks under similar conditions. Plants stored for 8 weeks under natural pre-force temperatures flowered in a similar period to that of plants receiving 6 weeks of artificial cold storage. Quality of the forced flowers was excellent in all treatments.

'Vulcan' forced in 47 days (cold storage). As for 'Unique', there was no difference in forcing behavior following the two artificial cold-storage treatments. The 8-week naturally stored plants flowered 11 days earlier than the 6-week plants under equivalent conditions. In this cultivar, plants stored under natural pre-force conditions for 8 weeks required at least 9 extra forcing days to achieve the same degree of flowering as the artificially stored plants. Quality of the forced plants was very good, independent of pre-force conditions.

'Pink Bountiful' displayed different behavior during the forcing period, dependent on pre-force treatment. Plants artificially cold-stored for 8 weeks required 29 days to the first open stage. Plants stored under natural temperatures for 8 weeks were equivalent to 6-week cold-stored plants. Plants stored under natural temperatures for 6 weeks failed to flower; flower buds on these plants turned brown and eventually aborted. In only one treatment (8-week cold-storage) did full flowering occur. In the other three treatments, <20% of the buds opened.

Cold temperature storage below 10°C is stated to be required to break flower bud dormancy in *Rhododendron* (2). However, both the critical temperature and duration for effective cold treatment may vary between cultivars. For 'Unique' and 'Pink Bountiful', plants from 6 weeks of artificial cold storage were equivalent in forcing behavior to plants from 8 weeks of storage under natural temperatures. This response suggests that temperatures in the initial 2-week period under natural conditions were insufficiently low to produce effective vernalization in these two cultivars. Forced flowering responses were similar to those obtained in previous experiments, when forcing began in mid- or late-January (4), following a prolonged chilling period under natural conditions. Therefore, it can be concluded that the cold requirement to break flower bud dormancy can be fully met by 6 weeks and 8 weeks of storage at 5°C for 'Unique' and 'Pink Bountiful', respectively.

In the case of 'Vulcan', 8-week naturally chilled plants flowered 9 days later than 6 or 8 weeks of cold-stored plants, and forcing times for all treatments were considerably longer when compared to forcing from mid- or late-January (47 vs. 31 days) (4). This difference implies that 'Vulcan' has either a longer cold storage requirement than the other cultivars or that 5°C is insufficient to saturate the cold requirement. These chilling requirements could be related to the late flowering behavior of 'Vulcan' under natural field conditions.

'Christmas Cheer' clearly has a modest cold requirement (not longer than 4 weeks below 10°C); this condition can be met by natural temperatures, even in coastal southwestern British Columbia. It is possible that this characteristic may also be found in other related cultivars derived from *R. caucasicum*, such as 'Rosamundi', 'Dr. Stocker', and 'Cunningham's Sulphur', which flower early under local field conditions (5).

Since there is considerable variation in the chilling requirement to break flower bud dormancy between cultivars, further work is necessary to determine individual cold storage requirements. However, from the previous discussion, there appears to be an approximate relationship between natural flowering dates and cold-storage requirements for forcing and, therefore, future efforts to develop cultivars suitable for forcing should focus on early flowering types.

Forcing rhododendrons for the Christmas period seems commercially feasible, especially for cultivars such as 'Christmas Cheer', which have a short forcing period and a modest cold requirement to break flower bud dormancy. For cultivars such as 'Unique', artificial cold storage appears necessary for early forcing in coastal Southwestern British Columbia, but, in cooler climates, plants would normally receive sufficient chilling under natural conditions by mid-November, when the forcing period would begin. Cultivars such as 'Vulcan' would require an extensive period of cold treatment to achieve Christmas forcing. However, it should be noted that 'Vulcan' is easy to force for Valentine's Day, starting in mid-January (4), and is one of the few red *Rhododendron* cultivars that has been identified as suitable for pot plant production.

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