foliar spray to runoff 1 week after application of BA treatments. The number of lateral shoots was counted 6 months after GA_3 treatment.

A maintenance program of fertilizers (1600 $kg \cdot ha^{-1} \cdot year^{-1}$ of 14N–6.1P–11.6K) and pesticides was followed for both experiments. Data were analyzed by single degrees of freedom analysis of variance.

In the first experiment, an interaction between topping and levels of GA_3 was observed ($P < 0.01$) (Fig. 1). A slight linear decrease in the number of shoots produced by untopped plants occurred with increased GA_3 concentration. However, a linear increase in number of shoots produced in topped plants was evident with increasing GA_3 concentration.

Topped plants in the second experiment produced more lateral shoots (4.5) per plant than did intact plants (1.8) ($P < 0.01$). The number of shoots produced increased linearly with increasing BA concentration (Fig. 2) and was not affected by topping ($P < 0.01$). As in the first experiment, an interaction between topping and GA_3 application was observed ($P < 0.01$). However, application of 500 ppm GA_3 increased shoot number for both topped and intact plants (Table 1). No significant interaction was observed between BA and GA_3 treatments or among the three factors.

BA application increased the number of lateral buds developing on juvenile plants, irrespective of topping. This response is consistent with observations by Higaki and Rasmussen on mature plants (3). Concentrations of BA >1000 ppm may be more effective on juvenile plants (Fig. 2); however, a few plants treated with the various levels of BA produced some abnormal white leaves, which did not develop fully. In addition, some shoots that developed after BA treatment died back after several weeks.

Similar undesirable effects were not observed on GA_3 treated plants. The conflicting results obtained in the two experiments on the effect of GA_3 on intact juvenile plants may have been due to the use of different cultivars; the tendency for sucker production in mature as well as juvenile anthuriums has been noted to be highly cultivar-dependent. As with *Hedera helix* (5), once apical dominance was removed through topping, GA_3 enhanced development of lateral buds of anthuriums. Plants topped and sprayed with 500 ppm GA_3 produced the greatest number of shoots of all treatments. Use of GA_3 at concentrations >500 ppm may be more effective than lower concentrations, as evidenced by the linear trend in Fig. 1; this warrants further investigation.

BA on intact plants and topping treatments and the same effect on promotion of shoot development. Although GA_3 application enhanced growth of shoots apparently stimulated by topping, this effect was not observed on plants treated with BA, which may be due to the fact that the GA_3 may not have been applied at the optimal time after BA treatment.

Results showed that both BA and GA_3 applications increased shoot development of juvenile anthurium plants and may be used for anthurium clonal propagation.

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Growth and Quality of Hinodegiri Azalea as Influenced by Isobutylidene Diurea, Urea, and Nitrapyrin

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Additional index words. Nitrification inhibitor, container media, leachate, nitrogen, controlled-release fertilizer, *Rhododendron obtusum*

Abstract. **Extensive losses in N applied to container-grown woody ornamental plants prompted this investigation to determine a) leaching of N from urea (U) and isobutylidene diurea (IBDU); b) influence of nitrapyrin (NI), a nitrification inhibitor, on N leaching losses from U; and c) to evaluate influences of these materials on growth, quality, and N uptake by *Rhododendron obtusum* Lindl. cv. Hinodegiri. In root medium composed of 60 pine bark : 30 sand : 10 soil (by volume), 48.8% of applied N from U was leached after 87 days, whereas leachate losses of N from IBDU and U + NI were 42.3% and 37.2%, respectively. All plants attained marketable quality by the end of the study. Azaleas fertilized with IBDU were of significantly higher quality on days 70 and 77 than those treated with U + NI and higher quality on days 77, 84, and 87 than those treated with U. No differences were found in shoot dry weight or N content in shoot tissues.**

Nitrogen is the mineral nurtrient used by plants in greatest amounts and is often limiting for plant growth due, in part, to the various mechanisms by which it is removed from the rhizosphere. Mills and Pokorny (7) stated that 50% of applied N may be leached from highly organic growing media. Leachate losses of NO_3^--N in excess of 10 $mg \cdot liter^{-1}$ pose an environmental hazard (4, 12). Retention of NH_4^+-N by bark also reduces plant available N (7).

Considerable losses of N from container media as leachate not only result in the inefficient use of soluble N fertilizer, but prompt the use of controlled-release N fertilizers such as urea-formaldehyde, sulfur-coated urea,

Table 1. Particle size distribution by percent weight of pine bark and sand used in this study.

Sieve size (mm)	Bark (%)	Sand (%)
4.7	8.7[z]	0.0[z]
2.0 –4.7	28.3	1.4
1.0 –2.0	22.0	5.9
0.5 –1.0	20.7	21.7
0.25–0.5	12.7	51.2
0.1 –0.25	5.7	19.2
0.05–0.01	0.4	0.1
Pan	0.4	0.1

[z]Mean of three replications.

Received for publication 2 Oct. 1986. Technical Contribution no. 2628 of the South Carolina Agricultural Experiment Station, Clemson Univ. We thank the Dow Chemical Co., Midland, Mich. for donating the nitrapyrin (N-Serve 24E) and Estech, Inc., Chicago, for the IBDU fertilizer and the micronutrient (Perk) used in these tests. A mention of a tademark does not constitute a guarantee or warranty of the product by the authors and does not imply its approval to the exclusion of other products that may also be suitable. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.
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Table 2. Level of N in leachate from U-, U + NI- and IBDU-treated potting medium.

Day	NO_2^- + NO_3^--N				NH_4^+-N			
	U	U + NI	IBDU	LSD	U	U + NI	IBDU	LSD
	mg·liter^{-1} of leachate							
0	10.7	6.0	6.6	6.0[z]	173.5[z]	161.3	7.4	26.6
7	5.0	5.0	5.9	3.5	168.1	172.4	115.1	38.4
14	18.1	1.4	22.4	4.8	99.9	102.6	82.2	20.5
21	68.4	3.0	98.6	9.0	46.4	70.7	42.4	8.8
28	85.5	4.6	98.4	14.4	15.4	48.6	11.6	7.2
35	85.7	3.0	107.4	17.2	3.2	39.3	2.1	6.2
42	66.6	1.4	73.9	9.5	0.6	28.8	0.6	5.7
49	46.0	1.5	55.1	10.0	0.4	17.6	0.4	4.4
56	29.8	1.2	40.1	7.3	0.0	11.8	0.0	2.1
63	23.0	1.8	25.7	7.9	0.0	9.6	0.0	2.6
67	11.1	2.5	10.2	7.4	0.0	5.1	0.0	1.3
70	8.7	3.1	7.7	5.9	0.0	4.7	0.2	1.1
74	2.8	0.5	1.6	1.6	0.4	2.3	0.4	1.1
78	0.6	1.2	1.2	NS	0.0	0.6	0.0	0.5
80	0.2	0.4	0.1	NS	0.0	0.5	0.0	0.4
84	0.0	0.1	0.0	NS	0.1	0.2	0.6	0.3
87	0.0	0.0	0.0		0.0	0.0	0.0	---
	mg.kg^{-1} of oven-dried medium							
Total	45.4%	3.9	59.6	4.6	52.2	70.4	26.0	5.4
	Percentage of total							
	46.5%	5.2	69.6		53.5	94.8	30.4	

[z]Mean separation within row by LSD, $\alpha = 0.05$.

Table 3. Cumulative loss of N in leachate from potting medium treated with U, U + NI, and IBDU.

Day	Cumulative loss of N (mg·kg^{-1} oven-dried medium)			
	U	U + NI	IBDU	LSD
0	21.6[z]	20.9	1.5	6.3
7	35.3	35.4	11.2	6.2
14	49.5	48.1	24.3	5.6
21	61.1	55.1	38.9	7.1
28	70.5	60.2	49.3	7.3
35	79.0	64.2	62.0	8.4
42	87.6	68.0	73.5	9.9
49	90.9	69.5	77.6	10.3
56	93.3	70.6	80.9	10.2
63	94.9	71.6	82.9	10.2
67	95.9	72.3	84.2	9.7
70	97.1	73.3	85.1	10.2
74	97.5	73.8	85.6	10.2
78	97.5	74.1	85.6	10.0
80	97.5	74.2	85.6	10.1
84	97.6	74.3	85.6	10.0
87	97.6	74.3	85.6	10.0

[z]Mean separation within row by LSD, $\alpha = 0.05$

Table 4. Visual ratings of 'Hinodegiri' Azalea as influenced by U, U + NI, and IBDU N under greenhouse growing conditions. Plants rated 5.0 or greater were acceptable.

Day	Treatment			
	U	U + NI	IBDU	LSD
35	6.5[z]	6.8	6.2	NS
42	6.8	6.8	7.0	NS
49	5.4	6.0	6.6	1.9
56	5.5	6.2	6.8	1.3
63	6.2	5.5	6.8	1.6
70	5.2	5.0	6.6	1.5
77	4.8	5.5	6.9	0.8
84	4.8	5.2	6.6	1.6
87	5.0	5.8	6.8	1.3

[z]Mean separation within row by LSD, $\alpha = 0.05$.

Osmocote, and isobutylidene diurea (IBDU) by the ornamental nursery and turf industries (5). A continuing search for ways to reduce production costs, together with a need to control leaching losses of N, prompted this investigation into the use of less-expensive N-source materials and nitrification inhibitors as an alternative means of increasing N fertilizer efficiency (2, 3, 6, 9–11). The objectives of this study were to a) determine leaching losses of N from urea and IBDU, b) evaluate the influence of nitrapyrin on leaching losses from U, and c) evaluate effects of these materials on growth, quality, and N uptake by azalea.

Investigations were initiated 1 Apr. 1985 and terminated 27 June 1985. The experimental design was a randomized complete block with four replications. Statistical analysis consisted of analysis of variance and mean separation by LSD at the 0.05 level. 'Hinodegiri' azalea liners were transplanted to 2.8-liter white, plastic pots containing 1.6 kg oven-dry (OD) medium composed of 60 hammer-milled pine bark : 30 sand (Table 1) : 10 Cecil sandy loam topsoil (clayey, kaolinitic, thermic Typic Hapludults) by volume. The medium was adjusted to pH 6.3 with granular hydrated lime [$Ca(OH)_2$]. Bark CEC was 57.4 cmol·kg^{-1} and N content was 0.09% (8). Nitrogen fertilizer materials used were a) urea (U) (46% N), b) IBDU (31% N, particle size 0.5 to 0.7 mm), and c) U (46% N) + 2-chloro-6-(trichloromethyl) pyridine (nitrapyrin, NI). Each N-source granular material was incorporated in medium at 200 mg N/kg of OD medium using a portable rotary mixer. The appropriate medium sample was sprayed with an aqueous solution of NI at 20 mg a.i./kg of OD medium during the mixing process. All medium samples were amended with 0N–14P–14K (6.1 mg P/kg and 11.6 mg K/kg). Micronutrients (in mg·kg^{-1}) were: Mg (12.25), Mn (4.90), Cu (1.23), Zn (2.45), Fe (22.05), S (12.25), B (0.05), and Mo (0.0074), applied as Perk (Estech, Inc., Chicago).

Transplanted azaleas were placed on leachate collection racks and grown in a fiberglass greenhouse with day/night temperatures of 35°/18°C. Styrofoam sheets shielded the rack to minimize temperature fluctuations in the medium. Plants were irrigated as required with 800 ml of tap water per container on day 0 and 500 ml per container thereafter. Leachate was collected in plastic containers and 20-ml aliquots were collected and analyzed immediately for NH_4^+ and NO_2^- + NO_3^- by steam distillation (1).

Weekly visual plant quality ratings based on foliage color, compactness of growth, and overall marketability were initiated 35 days following treatment. Plants were rated on a scale from 0 (dead) to 9 (excellent); those with ratings < 5 were considered unmarketable. Above-ground portions of plants were harvested at termination of the study, dried for 2 weeks at 80°C for shoot dry weights, and analyzed for total N (percentage) content using Kjeldahl digestion. Media pH were 5.5 (U), 5.4 (IBDU), and 5.6 (U + I) at the termination of the study.

Leachate from medium treated with U and U + NI contained 173.5 and 161.3 mg NH_4^+-N/liter, respectively, on day 0. Only a trace (7.4 mg·liter^{-1} NH_4^+) was detected in leachate of IBDU-treated medium (Table 2), indicating that urease hydrolized a portion of the urea within 2 hr after treatment. The leachate from IBDU-treated medium increased to 115.1 mg·liter^{-1} during the first 7 days of the study. After an initial peak, the amount of NH_4^+ in leachate from all treatments decreased with time. The decrease in the NH_4^+ from medium treated with U and IBDU after 35 days appears to be primarily due to oxidation to NO_2^- and NO_3^-. Ammonium in leachate from U + NI was greater than that from U and IBDU treatments from day 21 to day 78. The prolonged decrease in NH_4^+ may be attributed to adsorption, immobilization, and/or plant absorption.

The leachate from U and IBDU treatments had the greatest amounts of NO_2^- + NO_3^- for the period from 14 to day 67 (Table 2). The level of NO_2^- + NO_3^--N in the leachates from medium treated with either U or IBDU peaked on day 35 at 107.4 and 85.7 mg·liter^{-1}, respectively. This increase in NO_2^- + NO_3^--N explains the decrease in the NH_4^+-N in these treatments. The amounts of NO_2^- + NO_3^--N in the leachates decreased beginning after day 42 and was attributed to 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 $mg \cdot liter^{-1}$, 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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HORTSCIENCE 23(2):356–358. 1988.

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

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Additional index words. cold storage, dormancy, vernalization

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).

Recieved for publication 12 June 1987. Advice from J. Hall, Agriculture Canada, on statistical methods is gratefully acknowledged. Trade names are used for information purposes. Mention of trade names does not constitute a guarantee or warranty of the products by Agriculture Canada, nor does it imply an endorsement over similar commercial products. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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