Table 3. Time required to inject 0.5 ml of dye and total distance dye was forced (upward and downward) from injection point in branches of shade trees during 4 periods of the annual growth cycle.

	April		June		August		October	
Species	Time (sec)	Distance (cm)	Time (sec)	Distance (cm)	Time (sec)	Distance (cm)	Time (sec)	Distance (cm)
Norway maple	19.6 ± 3.3[z]	42.8 ± 1.0[z]	6.2 ± 1.1[z]	40.4 ± 1.6[z]	6.7 ± 0.8[z]	42.5 ± 0.6[z]	6.8 ± 1.1[z]	38.4 ± 2.3[z]
Red maple	9.0 ± 1.1	43.8 ± 1.2	4.0 ± 0.5	51.0 ± 2.6	3.9 ± 0.3	45.5 ± 2.1	8.0 ± 0.5	45.6 ± 3.6
Silver maple	y		10.6 ± 1.7	47.0 ± 3.2	3.2 ± 0.6	47.4 ± 1.9	9.0 ± 2.7	49.4 ± 2.3
Sweetgum	3.0 ± 0	46.2 ± 1.9	2.0 ± 0	51.4 ± 1.3	2.1 ± 0.7	52.6 ± 2.8	2.0 ± 0.2	43.6 ± 1.6
California privet	11.4 ±0.2	67.2 ± 3.5	5.4 ± 0.5	62.0 ± 1.0	4.3 ± 0.5	66.1 ± 3.4	8.6 ± 1.4	59.2 ± 3.5
Flowering dogwood	5.6 ± 0.7	49.2 ± 4.6	2.2 ± 0.2	42.8 ± 1.5	7.6 ± 0.7	52.8 ± 3.0	4.1 ± 0.4	42.0 ± 1.6
Tuliptree	7.0 ± 1.2	46.8 ± 3.2	1.4 ± 0.2	40.4 ± 1.5	2.9 ± 0.4	43.0 ± 2.7	3.2 ± 0.1	39.8 ± 1.2
Black locust	y		5.4 ± 1.6	86.2 ± 3.8	4.3 ± 0.5	74.6 ± 2.8	8.7 ± 2.1	78.0 ± 7.3
Pin Oak	y		20.6 ± 2.6	58.0 ± 2.7	y		8.9 ± 1.5	90.8 ± 6.8
Chinese elm	y		10.0 ± 3.9	77.2 ± 8.8	74.0 ± 8.0	90.6 ± 8.8	12.1 ± 0.5	72.4 ± 8.6
White ash	25.6 ± 4.3	76.6 ± 15.9	19.8 ± 2.9	85.8 ± 3.7	6.7 ± 1.2	60.2 ± 11.7	18.3 ± 3.9	65.2 ± 4.6

[z]Mean ± SE of 5 injected branches.

[y]Resisted injection.

not receptive to injection before bud break in April. Species with diffuse-porous wood (maple, sweetgum, California privet, flowering dogwood, and tuliptree) were generally more receptive to injection at all stages of growth, especially before bud break, than were species with ring-porous wood (black locust, pin oak, Chinese elm and white ash) (Table 3). Dye was forced greater distances from the injection point in ring-porous than in diffuse-porous species, with the exception of California privet, which supports the studies of Greenidge (2) and others that vessels of ring-porous species are longer than those of diffuse-porous species.

Only 0.5 ml of dye was injected for comparative purposes in these studies but the results of a cursory volume experiment indicated that several milliliters could be injected through the same hole by refilling the 1-ml syringe. Also, more than one mini-injector can be clamped to the same stem (one above the other) to assure more uniform distribution on larger diameter stems. No tissue injury was evident other than at the injection site and no permanent injury occurred from the injection holes which healed within 4 to 6 weeks, depending on species.

It was difficult to determine the extent of dye movement after injection because the red color was not detectable in the foliage or stem apices. However, immediately after injection the dye appeared to be uniformly distributed in the tissues of the cross-sectional face of the vascular system for several centimeters above and below the injection point, which indicates that translocation of solutions should be possible through either xylem or phloem depending on the mobility characteristic of the growth regulator. In preliminary experiments with growth regulators, injections of dipotassium salt of 7-oxabicyclo [2.2.1]heptane-2,3-dicarboxylic acid (endothall) defoliated red maple branches within 2 weeks and injections of succinic acid 2,2-dimethylhydrazide (daminozide) inhibited sprout growth of green ash seedlings for over a month. Research is in progress with the mini-injector to determine the response of fruit and shade trees to new growth regulators.

Although the mini-injector was designed to screen and study growth regulators, it should be a useful tool for the evaluation of any chemical solution that can be introduced into the vascular system of woody plants. Most machine shops should be able to fabricate the mini-injector at a relatively low cost from the specifications in Fig. 1.

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Multiple Herbicide Applications for Bittercress Control in Nursery Containers[1]

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Abstract. **Continuous control of bitterness (*Cardamine oligosperma* Nutt.) in nursery containers was maintained by repeated application of dichlobenil (2,6-dichlorobenzonitrile) at 2.2 kg/ha (4-week intervals) or 3.4 kg/ha (6-week intervals), and by oxadiazon [2-*tert*-butyl-4(2,4-dichloro-5-isopropoxyphenyl)-Δ2-1,3,4-oxadiazolin-5-one] at 2.2 or 3.4 kg/ha (6-week intervals), but not by simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine] at 1.3 or 1.8 kg/ha (4-week intervals). Bioassay of the upper 3 cm of the growing medium indicated that with an initial application of dichlobenil at 2.2 or 3.4 kg/ha, the amount decreased to 0.5 kg/ha or less within 4 to 6 weeks. Weed control was maintained by re-treatments maintaining the concentration at or above 0.5 kg/ha. Growth of azaleas was reduced by some treatments, but no effect on growth of rhododendrons was noted.**

Bittercress is a serious weed problem in nursery containers. In previous research (2) dichlobenil or simazine sometimes gave good control of bittercress and other weeds for about 6 weeks. Higher herbicide rates prolonged the control but seriously reduced growth of nursery stock. In one trial oxadiazon controlled bittercress for a much longer period than dichlobenil and simazine. Oxadiazon was the most effective against bittercress among 8 herbicides listed for container ornamentals by Elmore (1).

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Studies were conducted to (a) determine whether control of bittercress could be maintained with repeated applications of these herbicides, (b) assess the effects of repeated applications on growth of nursery plants, and (c) estimate herbicide persistence and movement in the containers with a bioassay procedure that could be used for determining timing of applications.

All experiments were outdoors, using 3.8 liter tapered metal cans with side drains. Watering was by sprinkler irrigation immediately following herbicide applications, and at 1 to 4 day intervals as needed. Simazine was applied with a power sprayer in water at 935 liters/ha. For granular herbicides, a shaker was used to apply the required weight of granules on a measured area. Four replications of 5 containers were used except as noted otherwise.

In the first experiment, bittercress seed was broadcast before herbicide application on containers filled with a sterilized medium of 6 parts Douglas fir and hemlock bark, 1 part sphagnum peat, and 1 part sand (by vol). The same herbicide treatments without seed were applied on containers planted a month earlier with rooted cuttings of azalea (*Rhododendron* X 'Caroline Gable') and rhododendron (*Rhododendron* X 'Bow Bells').

Control of bittercress was poor at the end of 12 weeks in all treatments except 2 applications of dichlobenil, and this treatment gave only 73% control after 2 seedings (Table 1). Growth of azaleas was decreased by multiple applications of simazine at 1.8 kg/ha and by a single application at 2.7 kg/ha (Table 1). Growth of rhododendrons was not significantly affected.

In another study, containers filled with a medium of 7 bark:1 peat were reseeded with bittercress after 8 weeks. Additional sets without seed were given the same herbicide treatments and a set was bioassayed every 2 weeks to estimate dichlobenil concentration in the upper 3 cm. The same treatments were applied to containers with rooted cuttings of two cultivars. Plant tops were cut and weighed in December.

Bioassay procedure. The layer of growing medium to be bioassayed was removed from the container. A plastic pot was filled to 4 cm from the top with untreated mix. A measured portion of the sample to give a depth of 1.5 cm was added, radish seeds were planted and covered to a depth of 1.5 cm with another portion. Emerged seedlings were counted at the end of 12 days. Pots, 10 cm square with 10 seeds, were used for bioassaying 3 cm layers of container media, and 5 cm square with 5 seeds for bioassaying 1.5 cm layers. Duplicate sets of 5 cans were bioassayed on each date, one pot per can.

Standard curves for estimating concentration were obtained on each bioassay date by following the same procedure using known concentrations of dichlobenil in the medium. Amounts from 0.1 to 1.2 kg/ha in a 3 cm deep sample or 0.1 to 0.6 kg/ha in a 1.5 cm deep sample could be estimated from these curves.

Bittercress was controlled for 8 to 10 weeks by dichlobenil at 3.4 kg/ha (Table 2). A second application after 4 weeks extended the control 2 to 4 weeks. Where applications were continued at 4-week intervals, but the rate was reduced to 2.2 kg/ha, good control was maintained for 18 weeks, 6 weeks after the last application. Control was nearly as good where 2.2 kg/ha was used from the start. Control was maintained throughout the 29 weeks where 4 applications were made at 6-week intervals at 3.4 kg/ha.

With an initial application of 2.2 kg/ha, the amount of dichlobenil in the upper 3 cm decreased within 4 weeks to less than 0.5 kg/ha (Fig. 1). By reapplying at 4-week intervals, the concentration was kept above that level and complete weed control was maintained. The residual level sustained at

Table 1. Effects of multiple applications of simazine or dichlobenil on control of bittercress and growth of nursery plants in containers, Expt. 1.

Treatment	Date of application and rate (kg/ha)				Control of bittercress Aug. 10 (%)		Fresh wt of plant tops as % of control[z]	
	May 16	June 16	July 15	Aug. 10	Seeded May 16 Appl. Aug. 10	Seeded May 16 and June 17 Appl. Aug. 10	Caroline Gable azalea	Bow Bells rhododendron
Control	–	–	–	–	(66)[y]	(82)	100ab	100a
Simazine	1.3	–	–	–	26bc[x]	17b	93abc	93a
Simazine	1.3	1.3	1.3	1.3	6c	6b	87bc	87a
Simazine	1.8	–	–	–	24bc	16b	94abc	91a
Simazine	1.8	1.8	1.8	1.8	30bc	32b	77c	95a
Simazine	2.7	–	–	–	17bc	3b	80c	97a
Simazine	2.7	–	2.7	–	50b	17b	90bc	86a
Dichlobenil	3.4	–	–	–	33bc	9b	109a	89a
Dichlobenil	3.4	–	3.4	–	95a	73a	106ab	83a

[z]The azalea tops were cut and weighed in Nov. and the rhododendrons in Dec. Three replications of 5 cans of each cultivar.
[y]No. in parenthesis are numbers of bittercress seedlings in 5 cans.
[x]Mean separation, within columns, by Duncan's multiple range test, 5% level.

Table 2. Control of bittercress in nursery containers with dichlobenil, and effects on growth of nursery plants, Expt. 2.

Rate of dichlobenil (kg/ha)	Interval between applications (wk)	Control of bittercress (%)[z] Weeks after first herbicide application 8	10	12	16	18	22	29	Fresh wt of plant tops as % of control: Hinodegiri azalea	Bow Bells rhododendron
0	–	(8)[y]	(111)	(113)	(111)	(168)	(232)	(247)	100a	100a
3.4 + 3.4 + 3.4 + 3.4	6	100	100a[x]	100a	100a	96a	99a	99a	88ab	105a
3.4 + 2.2 + 2.2 + 2.2	6	100	100a	99a	98a	89abc	96b	94a	100ab	82a
3.4 + 3.4 + 2.2 + 2.2	4	100	100a	100a	100a	94ab	67c	–	72b	90a
3.4 + 2.2 + 2.2 + 2.2	4	100	100a	100a	100a	87bc	66c	–	82ab	78a
3.4 + 2.2 + 1.1 + 1.1	4	100	100a	100a	98a	78c	–	–	104a	87a
3.4 + 3.4	4	100	99a	99a	84b	60d	–	–	–	–
3.4	–	100	74b	75b	43c	–	–	–	97a	118a
2.2 + 2.2 + 2.2 + 2.2	4	100	100a	100a	100a	91ab	65c	–	94a	96a

[z]The containers were seeded at the time of herbicide application (May 16), and after 8 weeks.
[y]Means in parenthesis are no. of bittercress seedlings in 5 cans.
[x]Mean separation, within columns, by Duncan's multiple range test, 5% level.

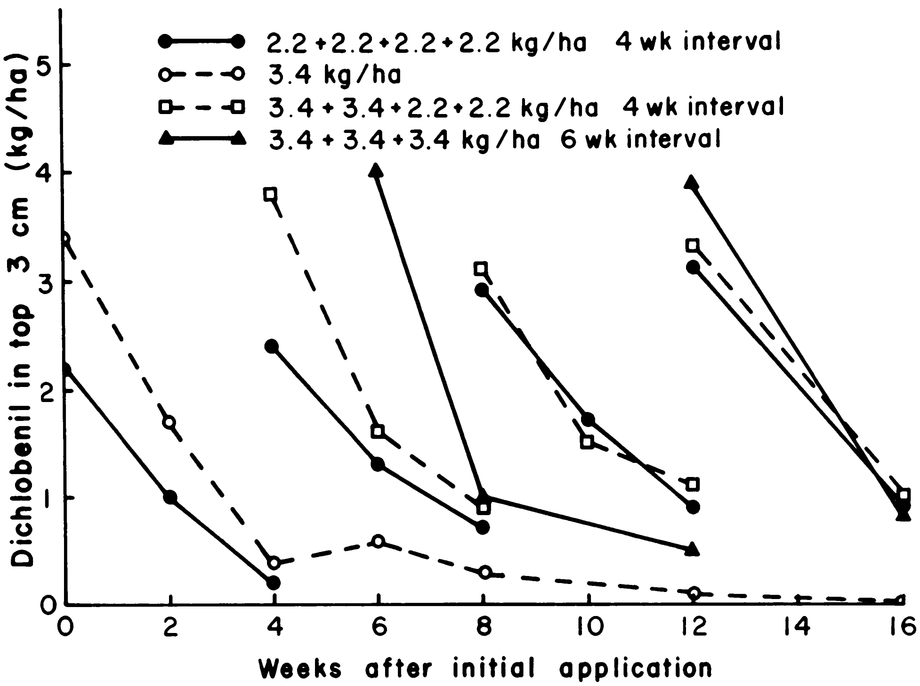

Fig. 1. Concentration of dichlobenil (measured by radish bioassay) in top 3 cm of bark-peat growing medium in nursery containers, with herbicide application repeated at 4 or 6 week intervals.

the end of a treatment period increased with successive applications. With an initial application of 3.4 kg/ha, the amount decreased to about 0.5 kg/ha within 4 to 6 weeks. With re-treatment at 6-week intervals, the amount of dichlobenil was kept at or above approximately 0.5 kg/ha, and weed control was maintained (Fig. 1, Table 2). The residual level reached was nearly the same regardless of the initial rate of application, indicating a faster loss from a higher initial concentration.

Azalea growth was reduced by 2 applications of dichlobenil at 3.4 kg/ha followed by 2.2 kg/ha, all at 4-week intervals (Table 2). Applications at lower rates or longer intervals did not significantly affect growth.

Results were similar using bark screened through 0.8 cm mesh instead of the bark-peat mix (Data not shown). Most of the dichlobenil was in the upper 1.5 cm. Small amounts were found in the second 1.5 cm layer where 3.4 kg/ha was applied, and after repeated applications at 2.2 kg/ha.

In a third experiment, dichlobenil and oxadiazon were applied May 29, alone or in combination, in single or multiple applications, to 7 bark:1 peat seeded with bittercress. The same treatments were applied on containers planted a month earlier with three cultivars.

One application of oxadiazon at 2.2 kg/ha was effective as long as one of dichlobenil at 3.4 kg/ha (Table 3). Multiple applications of oxadiazon at 2.2 or 3.4 kg/ha at 6-week intervals, or 4.5 kg/ha at 8-week intervals gave complete control throughout the season. A single application of dichlobenil plus oxadiazon increased the period of 98-100% control to 12 weeks compared with 6 weeks for each herbicide separately. Growth of 'Rosebud' azalea was reduced by one or multiple applications of dichlobenil at 3.4 kg/ha, and by application at 6-week intervals of oxadiazon at 2.2 or 3.4 kg/ha (Table 3). Single applications of oxadiazon, or multiple applications with an 8-week interval, did not significantly affect growth.

The radish bioassay developed in these studies measured the concentration of dichlobenil in the surface layers of the growing medium. It could be used as a guide in determining when to reapply herbicide to maintain continuous weed control.

Bittercress was controlled by dichlobenil without reducing growth of nursery plants where a suitable rate and interval between applications was used. Low rates of simazine reduced azalea growth and failed to control bittercress. Of the 3 herbicides used in this study, oxadiazon gave the best weed control, and single applications that controlled bittercress 12 weeks or longer were not phytotoxic to the 3 cultivars tested.

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Table 3. Control of bittercress in nursery containers with dichlobenil and oxadiazon, and effects on growth of nursery plants, Expt. 3.

Treatment	Rate (kg/ha)	Interval between herbicide applications (wk)	Control of bittercress (%)[z] Weeks after the first herbicide application 6	8	12	16	20	27	Fresh wt of tops as % of control Bow Bells rhododendron	Blue Diamond rhododendron	Rosebud azalea
Control	–	–	(10)[y]	(105)	(118)	(290)	(565)	(655)	100a	100a	100a
Dichlobenil	3.4	–	100	78b[x]	74b	–	–	–	97a	122a	76de
Dichlobenil	3.4 + 3.4 + 3.4 + 3.4	6	100	100a	97a	92c	97b	96b	105a	145a	68e
Oxadiazon	2.2	–	100	77b	84b	74e	–	–	96a	144a	79cde
Oxadiazon	2.2 + 2.2 + 2.2	6	100	100a	100a	100a	99a	100a	111a	126a	95ab
Oxadiazon	3.4	–	100	100a	99a	89cd	74d	–	123a	141a	81bcd
Oxadiazon	3.4 + 3.4 + 3.4	6	100	100a	100a	100a	100a	100a	100a	146a	91abc
Oxadiazon	4.5 + 4.5 + 4.5	8	100	100a	100a	100a	100a	100a	91a	108a	91abc
Oxadiazon	6.7	–	100	100a	100a	98b	89c	96b	105a	116a	91abc
Dichlobenil + Oxadiazon	3.4 2.2	–	100	100a	98a	83d	–	–	109a	127a	90abc

[z]Seeded with bittercress at time of first herbicide application and after 6 and 12 weeks.

[y]Means in parenthesis are no. of seedlings in 5 cans.

[x]Mean separation, within columns, by Duncan's multiple range test, 5% level.