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Ornamental Plants -- 1979
A Summary of Research

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ON THE COVER: Joel P. Loufman, undergraduate student, E. Timothy Halsey, graduate student, and Dr. Charles H. Gilliam, assistant professor of horticulture, compare the root systems of container ornamentals grown in an amended fly ash medium. This work is part of a larger overall study concerned with the utilization of waste materials in nursery crop production.

Photo by Thomas A. Fretz

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An Analysis of Production Costs for Containerized Nursery Products

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INTRODUCTION

Containerized nursery production has increased significantly throughout the U. S. during the past two decades. Initially, many producers supplemented their field operations with containerized production. Currently, ornamental plants sold in containers account for 14% of total wholesale sales (4, 5). Previous studies indicate that labor is the largest single expense, accounting for approximately 40% of total costs (1, 2, 3). Little detailed information is available, however, on costs of producing containerized nursery products.

The objectives of this study were to determine current production costs of producing ornamental plant materials in containers and to provide benchmark costs which will serve as a guide for evaluating production costs of producing ornamental plant material in containers.

PROCEDURE

Data for this study were obtained from ten wholesale nurseries producing containerized stock throughout Ohio during the summer of 1977. For the purposes of this study, the entire production cycle was segmented into eight separate cost factor divisions. The production cycle began with the insertion of a rooted liner into a container and terminated with a marketable plant. The major cost factor divisions were: canning program, fertilizer program, weed control program, shifting program, pruning program, spacing program, overwintering program, and overhead.

A range of production costs associated with each cost factor division was developed. The values establishing the boundaries of the range represent actual costs for cooperating firms.

The results of this study were separated into two sections. First, production costs were analyzed on the basis of a 12-month production cycle for three separate container sizes: 1 gallon, 2 gallon, and 3 gallon. Second, an analysis of production costs based on the information obtained from the first section was used to estimate costs associated with the production of different genera of plant material having differing cultural requirements. In order to assign production costs, cultural groupings were made up of several genera which are handled similarly throughout their production cycles. The representative coefficient factors were applied to each cultural grouping and the corresponding cost factor division by the number of months needed to produce a salable product.

The analysis of the first section provides information about production costs on a 12-month basis regardless of cultural grouping. The second section provides detailed information concerning production costs of specific plant material based on their cultural requirements.

The specific genus and species for each cultural grouping are listed below.

Group I
Berberis thunbergi
Chaenomeles japonica
Cotoneaster apiculata
Cotoneaster horizontalis
Euonymus alatus
Ligustrum vulgare
Viburnum (species)
Weigela hybrida

Group II
Buxus microphylla koreana
Euonymus fortunei
Mahonia aquifolium
Pyrancantha coccinea
Cotoneaster dammeri

Group III
Chameacyparis (species)
Pinus (species)
Thuja (species)

Group IV
Rhododendron (species including *Azalea)*
Pieris japonica

To facilitate comparison of various production costs, the ten firms were divided into three size classifications. The classifications are presented in Table 1.

TABLE 1.—Producer Classification by Size.

Producer Size Classification	Production Area*
	(sq ft)
Small	Less than 100,000
Medium	100,000 - 400,000
Large	More than 400,000

*Production area is defined as that area enclosed within the hoop houses.

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RESULTS AND DISCUSSION

Production Costs for 12-Month Production Cycle

The format of Table 2 represents production costs by producer size classification on a per container basis for each of the eight cost factor divisions. Each value indicates the production cost for a 12-month cycle. The coefficient factors for each cost division were selected as the value most representative of the costs associated with the corresponding division. By reading across the table, costs associated with each division for a particular container size and producer class can be determined.

Table 2 provides the following information: 1) the boundaries for the range of production costs for each cost factor division, 2) the representative coefficient factor applicable to each cost division, and 3) the total production cost by container size. For example, the overwintering cost for the medium producers' containerized plant material requiring single poly had a range from $0.014 to $0.059, with the representative coefficient factor of $0.019. The overwintering cost range for double poly was $0.047 and $0.056, with the representative coefficient factor of $0.051. For those producers who used auxiliary heat in their poly houses, the boundaries were $0.050 and $0.131 with a coefficient factor of $0.090. The summation of the individual coefficient factors indicates the total production costs of a No. 1 container by type of overwintering method employed.

Production Costs Based on Cultural Requirements

Since the producer is ultimately interested in the profitability of his operation, the 12-month production cost analysis frequently does not provide adequate information. To evaluate the profitability of the many different types of plant material comprising the product mix, production costs should be apportioned based on cultural requirements of different genus classifications. For example, Group III plant materials (narrowleaf evergreens) require 24 months to reach salable size in a No. 1 container, whereas only 12 months are required for Groups I, II and IV.

In order to assign costs to the various groups based on cultural requirements, the following assump-

TABLE 2.—Production Costs for 12-Month Cycle by Cost Factor Division.

Producer Size	Container Size	Canning Low-High	Canning Factor*	Fertilizer Low-High	Fertilizer Factor	Weeding Low-High	Weeding Factor	Shifting Low-High	Shifting Factor‡	Pruning Low-High	Pruning Factor
		(Dollars)		(Dollars)		(Dollars)		(Dollars)		(Dollars)	
Small	No. 1	0.181-0.209	0.200†	0.016-0.018	0.018	0.011-0.020	0.017			0.006-0.074	0.018
	No. 2	0.318-0.413	0.390	0.027-0.041	0.035	0.013-0.024	0.020			0.008-0.088	0.030
	No. 3	0.421-0.534	0.511	0.035-0.052	0.041	0.019-0.033	0.024			0.012-0.116	0.040
Medium	No. 1	0.185-0.245	0.215	0.011-0.022	0.014	0.003-0.024	0.020			0.004-0.012	0.010
	No. 2	0.346-0.528	0.405	0.015-0.038	0.025	0.004-0.025	0.021			0.006-0.022	0.014
	No. 3	0.533-0.752	0.678	0.026-0.062	0.035	0.006-0.026	0.024	0.45 -0.479	0.463	0.008-0.032	0.020
Large	No. 1	0.203-0.217	0.209	0.009-0.012	0.010	0.005-0.007	0.006			0.002-0.012	0.006
	No. 2	0.387-0.413	0.390	0.017-0.022	0.020	0.006-0.010	0.009			0.002-0.018	0.012
	No. 3	0.596-0.623	0.610	0.022-0.029	0.025	0.009-0.014	0.010	0.464	0.464	0.002-0.026	0.018

Producer Size	Container Size	Spacing Low-High	Spacing Factor	Overwintering Single Cover Low-High	Overwintering Single Cover Factor	Overwintering Double Cover/Heat Low-High	Overwintering Double Cover/Heat Factor	Overhead	Summation of Representative Coefficient Factors** Single Cover	Summation of Representative Coefficient Factors** Double/Heat
		(Dollars)		(Dollars)		(Dollars)		(Dollars)	(Dollars)	(Dollars)
Small	No. 1	0.004-0.032	0.012	0.021-0.047	0.030			0.311	0.606	
	No. 2	0.006-0.038	0.018	0.027-0.056	0.050			0.519	1.062	
	No. 3	0.008-0.052	0.032	0.035-0.074	0.062			0.796	1.506	
Medium	No. 1	0.006-0.010	0.008	0.014-0.059	0.019	0.047-0.056 0.050-0.131	0.051 0.080	0.195	0.481	0.520 0.542
	No. 2	0.012-0.026	0.016	0.024-0.098	0.028	0.076-0.082 0.104-0.215	0.075 0.161	0.326	0.834	0.882 0.968
	No. 3	0.014-0.036	0.020	0.033-0.146	0.051	0.106-0.146 0.321	0.121 0.321	0.499	1.327	1.397 1.597
Large	No. 1	0.014-0.034	0.016	0.022	0.022	0.039-0.070	0.045	0.116	0.385	0.408
	No. 2	0.018-0.056	0.022	0.029	0.029	0.052-0.110	0.078	0.194	0.676	0.725
	No. 3	0.026-0.078	0.038	0.042	0.042	0.078-0.158	0.102	0.297	1.040	1.100

*Last number in each column is the representative coefficient factor, an attempt to combine the low and high figures into a realistic cost figure.

†Fractions of a cent between .0001 and .0009 are recorded as .001.

‡Costs for shifting are not included in 12 month totals.

**Represents costs for 12 months by container size.

TABLE 3.—Production Cycles by Cultural Requirements.

Cultural Group	Time Required No. 1 Containers	Time Required No. 2 Containers	Time Required No. 3 Containers
	months		
Group I	12	24	24
Group II	12	24	24
Group III	24	24	36
Group IV	12	24	24

tions were made: 1) all plant materials salable in No. 1 or No. 2 containers were canned and produced in their corresponding salable container size, and 2) all plants salable in No. 3 containers were shifted once from No. 1 containers. Production times required in the nursery by cultural groups to obtain salable size are listed in Table 3.

The combination of representative coefficient factors for each cost factor division by cultural class is represented in Table 4. The costs represented in this table could be categorized in a number of ways. One approach is to express each cost category as a percentage of total costs. The dollar values in Table 4 are expressed as percentages in Table 5.

As shown in Tables 4 and 5, canning, overhead, and liners were the three most important cost categories. The development and use of mechanized canning equipment has facilitated the canning operation, but the effect on canning costs is variable. Producers in the small size classification had the lowest unit canning costs reported. However, this group did not utilize any automation in their canning operation. Producers in the large size class followed with the second largest unit canning costs, but each large producer was fully automated for the canning operation. The highest unit canning cost was assignable to the medium size producers. Both mechanization and hand canning procedures were used by these producers.

Of the specific items which contributed to overhead costs, cash expenditures were most important, followed by annual depreciation and capital charges.

CONCLUSIONS

The following conclusions can be drawn from the results of this study:

- Production procedures for canning, fertilizer, weed control, shifting, pruning, and spacing programs did not differ by cultural groups as reported by the majority of producers. Many of the participating producers felt that production costs varied by cultural requirements of different species of plant materials, but they were unable to make the distinction in the majority of cases when reporting these costs.
- Plant material classified as Group III had slightly longer production cycles than the remaining group designations. Thus, the costs associated with their production, in particular the salable No. 1 and No. 3 containers, were the most costly to produce of the plant material studied.
- As container size increased, production cycles also increased. Thus, as the production cycles were lengthened, the costs for producing a salable plant also increased.
- Total production costs decreased as producer size increased. The cost factor divisions with the most impact on decreasing total costs for the large producers were overhead, canning, and liners.

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TABLE 4.—Analysis of Production Costs Based on Cultural Requirements.*

Cost Factor	Cultural Group	Group I			Group II			Group III			Group IV		
	Months in Production	12	24	24	12	24	24	24	24	36	12	24	24
	Container Size	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
	Producer Class		(Dollars)			(Dollars)			(Dollars)			(Dollars)	
Canning	Small	0.200	0.390	0.087	0.200	0.390	0.087	0.200	0.390	0.087	0.200	0.390	0.087
	Medium	0.215	0.405	0.102	0.215	0.405	0.102	0.215	0.405	0.102	0.215	0.405	0.102
	Large	0.209	0.390	0.096	0.209	0.390	0.096	0.209	0.390	0.096	0.209	0.390	0.096
Fertilizer	Small	0.018	0.070	0.082	0.018	0.070	0.082	0.036	0.070	0.123	0.018	0.070	0.082
	Medium	0.014	0.050	0.070	0.014	0.050	0.070	0.028	0.050	0.105	0.014	0.050	0.070
	Large	0.010	0.040	0.050	0.010	0.040	0.050	0.020	0.040	0.075	0.010	0.040	0.050
Weed Control	Small	0.017	0.040	0.048	0.017	0.040	0.048	0.034	0.040	0.072	0.017	0.040	0.048
	Medium	0.020	0.042	0.048	0.020	0.042	0.048	0.040	0.042	0.072	0.020	0.042	0.048
	Large	0.006	0.018	0.020	0.006	0.018	0.020	0.012	0.018	0.030	0.006	0.018	0.020
Shifting	Small			0.463			0.463			0.463			0.463
	Medium			0.463			0.463			0.463			0.463
	Large			0.464			0.464			0.464			0.464
Pruning	Small	0.018	0.060	0.080	0.018	0.060	0.080	0.036	0.060	0.012	0.018	0.060	0.080
	Medium	0.010	0.028	0.040	0.010	0.028	0.040	0.020	0.028	0.060	0.010	0.028	0.040
	Large	0.006	0.024	0.036	0.006	0.024	0.036	0.012	0.024	0.054	0.006	0.024	0.036
Spacing	Small	0.012	0.036	0.064	0.012	0.036	0.064	0.024	0.036	0.096	0.012	0.036	0.064
	Medium	0.008	0.032	0.040	0.008	0.032	0.040	0.016	0.032	0.060	0.008	0.032	0.040
	Large	0.016	0.044	0.076	0.016	0.044	0.076	0.032	0.044	0.114	0.016	0.044	0.076
Overwintering Single Cover	Small	0.030	0.100	0.124	0.030	0.100	0.124	0.060	0.100	0.186	0.030	0.100	0.124
	Medium	0.019	0.056	0.102	0.019	0.056	0.102	0.038	0.056	0.153			
	Large	0.022	0.058	0.084	0.022	0.058	0.084	0.044	0.058	0.126			
Overwintering Double/Heat	Small												
	Medium										0.051	0.150	0.242
	Large										0.045	0.156	0.204
Overhead	Small	0.311	1.038	1.592	0.311	1.038	1.592	0.622	1.038	2.388	0.311	1.038	1.592
	Medium	0.195	0.652	0.998	0.195	0.652	0.998	0.390	0.652	1.497	0.195	0.652	0.998
	Large	0.116	0.388	0.594	0.116	0.388	0.594	0.232	0.388	0.891	0.116	0.388	0.594
Average Cost of Liners		0.358	0.358	0.358	0.333	0.333	0.333	0.375	0.375	0.375	0.457	0.457	0.457
Total Cost	Small	0.964	2.092	2.898	0.939	2.067	2.873	1.387	2.109	3.802	1.063	2.191	2.997
	Medium	0.839	1.623	2.221	0.814	1.598	2.196	1.122	1.640	2.887	0.970	1.816	2.460
	Large	0.743	1.320	1.778	0.718	1.295	1.753	0.936	1.337	2.225	0.865	1.517	1.997

*In order to assign production costs, cultural groupings were made up of several genera which are handled alike during their production. The values for each cost factor division were calculated from the representative coefficient factors from Section I and applied to each cultural grouping and corresponding cost factor division by the months in production by group.

The specific genus and species for each cultural grouping are listed below.

Group I

Berberis thunbergi
Chaenomeles japonica
Cotoneaster apiculata
Cotoneaster horizontalis
Euonymus alatus
Ligustrum vulgare
Viburnum (species)
Weigela hybrida

Group II

Buxus microphylla koreana
Euonymus fortunei
Mahonia aquifolium
Pyracantha coccinea
Cotoneaster dammeri

Group III

Chameacyparis (species)
Pinus (species)
Thuja (species)

Group IV

Rhododendron (species including Azalea)
Pieris japonica

Months required to produce a salable plant by container size determined the values assigned to each individual cost factor division and cultural groups.

TABLE 5.—Production Costs as a Percent of Total Costs Based on Cultural Groups.

Cost Factor	Cultural Group	Group I			Group II			Group III			Group IV		
	Months in Production	12	24	24	12	24	24	24	24	36	12	24	24
	Container Size	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
	Producer Class	%	%	%	%	%	%	%	%	%	%	%	%
Canning	Small	20.7	18.6	3.0	21.3	18.8	3.0	14.4	18.4	2.3	18.8	17.8	2.9
	Medium	25.6	25.0	4.6	26.4	25.3	4.6	19.2	24.7	3.5	22.2	22.3	4.1
	Large	28.1	29.5	5.4	29.1	30.1	5.5	22.3	29.2	4.3	24.2	25.7	4.8
Fertilizer	Small	1.9	3.3	2.8	1.9	3.4	2.9	2.6	3.4	3.2	1.7	3.2	2.8
	Medium	1.6	3.1	3.2	1.7	3.2	3.2	2.5	3.0	3.6	1.4	2.8	2.8
	Large	1.3	3.0	2.8	1.4	3.1	2.9	2.1	3.0	3.4	1.2	2.6	2.5
Weed Control	Small	1.8	1.9	1.7	1.8	1.9	1.7	2.5	1.9	1.8	1.6	1.8	1.6
	Medium	2.4	2.6	2.2	2.5	2.6	2.3	3.5	2.5	2.5	2.1	2.3	2.0
	Large	0.8	1.5	1.1	0.8	1.3	1.1	1.3	1.3	1.3	0.8	1.2	1.0
Shifting	Small			16.0			16.1			11.8			15.5
	Medium			20.8			21.1			16.0			18.8
	Large			26.2			26.5			20.9			23.2
Pruning	Small	1.9	2.9	2.8	1.9	2.9	2.8	2.7	2.8	3.0	1.7	2.7	2.7
	Medium	1.1	1.6	1.8	1.2	1.8	1.8	1.8	1.7	2.1	1.0	1.5	1.6
	Large	0.8	1.8	2.0	0.8	1.9	2.0	1.3	1.8	2.4	0.8	1.6	1.8
Spacing	Small	1.2	1.8	2.2	1.3	1.8	2.2	1.7	1.7	2.5	1.1	1.6	2.1
	Medium	1.3	2.1	1.8	1.0	2.0	1.8	1.4	2.0	2.1	0.8	1.7	1.6
	Large	2.2	3.3	4.3	2.2	3.4	4.3	3.4	3.3	5.1	1.8	2.9	3.8
Overwintering Single Cover	Small	3.1	4.8	4.3	3.2	4.8	4.3	4.3	4.6	4.8	2.8	4.7	4.1
	Medium	2.3	3.5	4.6	2.3	3.5	4.6	3.4	3.4	5.3			
	Large	3.0	4.4	4.7	3.1	4.5	4.8	4.7	4.3	5.7			
Overwintering Double/Heat	Small												
	Medium										5.3	8.3	9.8
	Large										5.2	10.3	10 2
Overhead	Small	32.3	49.6	54.9	33.1	50.2	55.4	44.8	49.2	61.0	29.3	47.3	53.1
	Medium	23.1	40.1	44.9	24.0	40.8	45.4	34.8	39.8	51.9	20.1	35.9	40.6
	Large	15.6	29.4	33.4	16.2	30.0	33.9	24.8	29.0	40.0	13.4	25.6	29.8
Liners	Small	37.1	17.1	12.3	35.5	16.2	11.6	27.0	17.8	9.6	43.0	20.9	15.2
	Medium	42.6	22.0	16.1	40.9	20.8	15.2	33.4	22.9	13.0	47.1	25.2	18.5
	Large	48.2	27.1	20.1	46.4	25.7	19.0	40.1	28.1	16.9	52.6	30.1	22.9
Totals		100	100	100	100	100	100	100	100	100	100	100	100

Monoterpene Investigations with Creeping Juniper Cultivars (*Juniperus horizontalis* Moench.)[1]

THOMAS A. FRETZ[2]

ABSTRACT

Monoterpenes from the foliage of *Juniperus horizontalis* Moench. 'Plumosa' (Andorra juniper) grown under varying photoperiods and N fertility levels were compared. Increasing levels of supplemental night lighting significantly increased the quantity of α-pinene and γ-limonene, while all other monoterpenes decreased or remained unchanged. Only α-terpineol showed a significant increase in relation to increasing N fertility. From the 55 possible cultivar pairs, 54 were significantly different and could be distinguished from one another on the basis of the composition of their monoterpene profiles. In addition, seasonal monoterpene composition of Andorra juniper showed less fluctuation during the winter months (November-February).

INTRODUCTION

In chemotaxonomic investigations, one is faced with a multiplicity of problems of both a biochemical and a chemical nature. At present, it is well established that numerous secondary plant products, especially groups of biosynthetically related compounds, give the most useful results for plant identification. Harborne (6) outlined four basic requirements that must be met by any group of plant constituents if they are to be of significant value in taxonomic studies. They are: 1) the constituents should possess sufficient chemical complexity and structural variety, 2) they should be physiologically stable, 3) they should be widely distributed in plant families, and 4) each compound should lend itself to be easily and quickly identified.

The monoterpenes certainly meet Harborne's four basic requirements, but there are a number of inherent problems due to their volatility and reactive nature (15). In terms of their chemical complexity and structural variability, the monoterpenes surpass the flavenoids as taxonomic markers. When extracted from plants, these essential oils can contain upward of 100 individual monoterpenes. So their resolution and identification can put great demands on today's analytical techniques. At the present time the physiological function of the monoterpenes is not clearly understood and it is not certain whether they are stable end products of the mevalonic acid pathway (16).

[1]Supported in part by a grant from the Horticultural Research Institute, Washington, D. C.

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In many plant species, one finds that the monoterpene composition is unchanged during certain stages of plant ontogeny. In conifers, the monoterpenes are more or less stable during the dormant period in late fall and winter, making this the ideal time for sample collection. Although the monoterpenes are not as widely distributed in the plant kingdom as other groups of chemical constituents, *i.e.*, flavenoids, they are found in a wide variety of plant families, including the Coniferae, Cyperaceae, Gramineae, Labiatae, Lauraceae, Liliaceae, Myrtaceae, Rutaceae, Umbelliferae, and Compositae.

The traditional means of identifying plants using morphological descriptions present very unique problems when working with cultivars, as readily distinguishable features may be lacking. Many cultivars of ornamental plants are quite similar in appearance, particularly during the non-flowering periods, making identification difficult or nearly impossible. Compounded with the development of the U. S. Plant Patent Act of 1930 and the recently enacted U. S. Plant Variety Protection Act, the unequivocal identification of cultivars and clones and the establishment of their identity will assume increasing importance.

Creeping juniper (*Juniperus horizontalis*) is widely used as an ornamental plant, and numerous forms are presently available from nurserymen which offer either exceptional foliage and/or form. Due to the large number of clones in which identity may at times be uncertain or unknown because of propagation or handling errors, it would be highly desirable to be able to re-establish the identity of such individuals. In previous studies, the authors have been interested in creeping juniper cultivars which are not only widely available in the market place but in which considerable confusion exists in the nursery trade over their proper identification. An example of this is the cultivar 'Wiltonii' which also appears in the trade under the names 'Blue Wilton', 'Blue Rug', 'Wilton Carpet', 'Glauca', and 'Glauca Wiltonii'. This confusion is not an isolated case in plant identification (4).

There are many indications that the biosynthesis and metabolism of the monoterpenes are influenced by environmental factors. As an example, peppermint (*Mentha piperita*) oil of acceptable quality can be produced only in certain geographical areas (8). Langston and Leopold (9) demonstrated that peppermint was photoperiodically responsive and that plants grown on photoperiods of 14 hr or less produced only

traces of essential oils. In similar experiments, Biggs and Leopold (2) noted that temperature influenced the production of monoterpene hydrocarbons in peppermint, while Steward and coworkers (12) noted that nutrition was involved.

While the ultimate purpose of these studies has been to identify cultivars of creeping juniper by analysis of their monoterpenes, it was felt that due to the great quantity of literature concerning environmental and edaphic factors on their composition, an investigation to establish standardized growing conditions was warranted. The effects of daylength and nitrogen level on the quantity and quality of the monoterpenes of Andorra juniper were investigated in order to establish standard growing conditions prior to an analysis of the monoterpene composition from a selection of creeping juniper cultivars. In addition, monoterpenes in Andorra juniper were monitored monthly for a 13-month period in order to document the monoterpene seasonal fluctuation.

MATERIALS AND METHODS

Experiment I

Ninety 2-year-old plants of Andorra juniper grown in 2.8 liter containers in a meduim of peat and sand (2:1 by vol) were selected for their uniformity of growth and habit. All plants were tip-pruned and then placed in the greenhouse from July 1 through August 27. Using a 3 x 3 x 4 factorial design, with 10 plants per replicate, the plants were supplied nitrogen as NH_4NO_3 at rates of 100, 200, or 400 ppm, daily or as required, via a Chapin tube irrigation system. In addition, all plants received a natural photoperiod of 8 hr per day (8:00 a.m. - 4:00 p.m.), with 0, 4, or 8 hr of supplemental incandescent light interruption in the middle of the dark period. Temperatures were maintained as close to 28° C day and 21° C night as possible for the length of the experimental period.

At the completion of the experiment, 20 g of fresh plant tissue were collected from each replicate and immediately transferred to the laboratory for extraction. Each foliage sample was homogenized in 80 ml of distilled water and steam distilled using a circulating distillation apparatus as modified by Hefendahl (7) for a period of 15 min. The distilled oils were transferred to 1 ml sealed vials and stored at 0° C under N_2 until chromatographic analysis.

For analysis, a Packard 409 gas chromatograph equipped with a Vitar 1200 digital integrator was employed. Separation of the monoterpenes was accomplished using a 3.05 m x 3 mm O.D. stainless steel column packed with 20% LAC-446 on 80-100 mesh chromosorb W-HP. Injection and detection temperatures were maintained at 210° C. Carrier gas (N_2) flow rate was 20 ml/min. Linear temperature programming was employed from 80-190° C at a rate of 2.5 ° C/min with an upper temperature hold for 20 min. In all chromatographic analyses, a 1 μl aliquot of the monoterpenes was used.

The area under each chromatographic peak was calculated and expressed as a percentage of the total ion count for each respective oil sample. Major peaks, *i.e.*, those constituting more than 0.5% of the total oil fractions, were identified by retention time, peak enrichment, and mass spectrometry. A DuPont mass spectrometer interfaced with a Varian Aerograph Model 2440 gas chromatograph was used for the GC-MS analysis. Leaf oil samples analyzed by mass spectrometer were chromatographed using the 20% LAC-446 on 80-100 mesh chromosorb W-HP column at the conditions previously described.

Experiment II

Juniperus horizontalis and 10 of its cultivars were selected from a collection of individual plants maintained at The Ohio State University for the purpose of this investigation. All plants had been vegetatively propagated and grown under uniform conditions in 2.8 liter containers in a medium of composted hardwood bark, peat, and sand (2:1:1 by vol). Actively growing plants of each cultivar were tip-pruned prior to being placed in the greenhouse from Sept. 16 through Nov. 18 and received a natural photoperiod of 8 hr per day with 8 hr of supplemental incandescent light supplied during the dark period. Monoterpene analysis was conducted as described above.

Experiment III

A collection of Andorra juniper individuals were grown in 2.8 liter nursery containers at the university nursery. Foliage samples from the young growth were collected monthly and extracted as outlined above in order to evaluate the seasonal fluctuations in the monoterpene composition.

RESULTS AND DISCUSSION

Experiment I

In general, the quantity of the individual monoterpenes declined with increasing levels of nitrogen (Table 1). While the effect of this increasing nitrogen level appears to decrease the level of all of the monoterpene hydrocarbons, except γ-limonene and α-terpineol, care must be exercised in the interpretation of these data since only the levels of β-pinene and sabinene are significant. These results are in general disagreement with that of Steward and coworkers (12), who noted a sharp response not only in the quantity of total monoterpene production in peppermint but also that the quality of particular monoterpenes was influenced by the fertility level. These results, however, are in agreement with those of Thorin

TABLE 1.—Influence of Nitrogen Level on the Monoterpene Composition of Andorra Juniper.

Monoterpene	Nitrogen Level (ppm)			LSD
	100	200	400	0.05
		percent		
α-Pinene	12.03	11.93	11.64	n.s.
β-Pinene	2.21	2.28	1.78	0.23
Sabinene	1.64	1.68	1.42	0.17
β-Myrcene	16.83	16.48	16.00	n.s.
γ-Limonene	35.84	35.50	37.01	n.s.
Terpinolene	8.60	7.98	7.55	n.s.
Linalool	1.18	0.98	0.99	n.s.
α-Terpineol	2.13	2.43	3.12	0.61

TABLE 2.—Influence of Supplemental Night Lighting on the Monoterpene Composition of Andorra Juniper.

Monoterpene	Supplemental Night Light (hr)			LSD
	0	4	8	0.05
		percent		
α-Pinene	11.05	12.42	12.13	1.05
β-Pinene	2.15	2.14	1.97	n.s.
Sabinene	1.68	1.57	1.49	n.s.
β-Myrcene	17.03	16.60	15.67	0.76
γ-Limonene	33.45	37.78	37.12	2.08
Terpinolene	7.82	8.76	7.85	n.s.
Linalool	1.56	0.78	0.81	0.27
α-Terpineol	2.82	2.17	2.68	n.s.

and Nommik (14), who noted that the monoterpene composition of Scots Pine, (*Pinus sylvestris* L.), was not significantly affected by annual fertilizer applications, and the minimal variation they observed was attributed to genetic differences between clones.

Similar results as those noted for the effects of increasing nitrogen level on the monoterpene composition were also observed for the overall effects of increasing the hours of supplemental night light. All of the monoterpenes declined in quantity as photoperiod increased, with the exception of α-pinene and γ-limonene (Table 2). These results are in general disagreement with the data of Langston and Leopold (9), who noted that the quantity and quality of the monoterpenes in peppermint were photoperiodically responsive.

Based upon the literature, these data agree with those of Hanover (5) and Smith (11) whose results have shown that neither the quantity or the quality of the monoterpenes in several pine species are influenced as a result of changing environmental factors, suggesting that genetic composition plays a dominant role in the production of monoterpenes. Similarly Tatro *et al.* (13) noted that neither microclimate nor seasonal variation appeared to have a significant effect on the composition of leaf monoterpenes measured in three western juniper species. They reported, however, evidence of diurnal variation and suggested that these variations were related to air temperature.

Experiment II

When the monoterpene profiles of the 10 cultivars and the species *J. horizontalis* were compared, the results demonstrated that 54 of the 55 possible species pairs can be distinguished from one another on the basis of their monoterpenes' composition. Only the cultivars Plumosa 752-38 and Bar Harbor were unable to be chemically separated, although morphologically the plants are quite dissimilar (Table 4). There is clear evidence that an analysis of the foliage monoterpenes can be a valuable tool in the separation and identification of the cultivars of creeping juniper. These data are in general agreement with that of Rottink and Hanover (10), who demonstrated that of 45 possible cultivar pairs of blue spruce, 37 could be distinguished on the basis of their cortical monoterpenes. In addition, the data suggest that the levels of α-pinene, β-pinene, sabinene, γ-limonene, and α-terpineol are highly significant and individually each of these monoterpenes is capable of separating 39 or more of the 55 possible cultivar pairings (Table 3).

Overall, these results suggest that all of the cultivar pairs studied, with one exception, can be chemical-

TABLE 3.—Analysis of Variance for Monoterpenes for Creeping Juniper and Its Cultivars and the Number of Pairs Which Can Be Separated by Individual Monoterpenes.

Monoterpene	F Value at 0.0001	Cultivar Pairs Separated
α-Pinene	26.13	39
β-Pinene	14.42	34
Sabinene	45.97	41
γ-Limonene	89.06	47
α-Terpineol	42.16	38

ly separated from one another based upon their monoterpene composition. As a result, these procedures may be valuable tools in identifying juniper cultivars.

Experiment III

Analysis of the monoterpenes from the seasonal collections shows the existence of variation. However, no completely stable period at which time collection of monoterpene samples would be optimal was detected. Several ecological variables are considered to possibly influence terpene synthesis, including solar radiation, temperature profile for the year, and precipitation (13).

Of the monoterpenes reported here, sabinene, α-pinene, and α-terpineol appeared to be the most stable throughout the year, while β-pinene and γ-limonene exhibited seasonal variations. All of the monoterpenes with the exception of β-pinene and sabinene exhibited greater stability during the winter (November-February) period (Fig. 1).

However, it should be remembered that when using chromatographic or other chemical determinations in determining taxonomic relationships, a great deal of caution must be exercised because the absolute concentration for any given monoterpene for any given

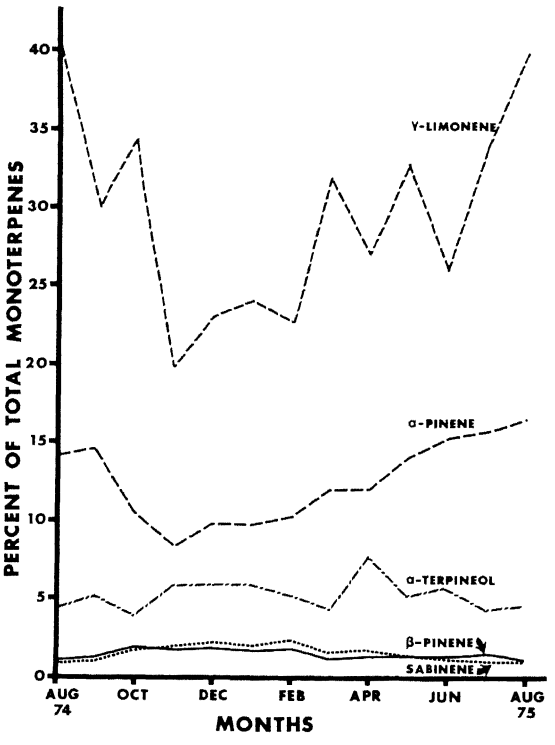

FIG. 1.—Seasonal variation for α-pinene, sabinene, β-pinene, γ-limonene and α-terpineol in Andorra juniper.

cultivar need not be closely maintained. Rather, a comparison of the relative compositions will be sufficient because of slight variations due to both environmental and other non-genetic causes (1, 3, 10).

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TABLE 4.—Mean Percentage Composition of the Monoterpenes of Creeping Juniper and 10 Cultivars.

Cultivars	Percent Composition of Monoterpene Hydrocarbons				
	α-Pinene	β-Pinene	Sabinene	Limonene	α-Terpineol
cv. Adpressa	9.60cd*	1.56ab	15.08bc	7.78g	5.48cd
cv. Alpine	15.37a	0.38de	14.99bc	17.29e	4.22ef
cv. Plumosa	14.98a	1.34bc	1.38d	32.71ab	3.94f
cv. Plumosa Compacta	10.02cd	1.15c	0.88d	30.91b	4.38def
cv. Plumosa-Tores Compacta	8.66d	1.77a	4.01d	22.22d	5.28cde
cv. Plumosa 752-38	10.49c	1.09cd	25.32a	25.99c	10.93a
cv. Plumosa Youngstown	12.60b	1.23bc	1.85d	26.54c	5.73bc
cv. Bar Harbor	10.72c	1.23c	23.67a	25.70a	11.17a
cv. Eximus	9.64cd	1.69a	17.77b	11.46c	6.78b
cv. Wiltoni	14.29a	1.32bc	12.60c	32.53ab	3.97f
J. horizontalis	6.34e	0.33f	24.30a	3.57h	5.59c

*For a given monoterpene, means not followed by a common letter or letters are statistically different from one another at the 0.05 level as determined by Duncan's Multiple Range Test.

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Woody Flora in Hokkaido Adaptable to the North Central United States

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INTRODUCTION

When the Ornamental Subcommittee of the North Central region convened in Wooster on Sept. 25, 1973, it was decided to request a plant exploration in northern China, northern Japan, Korea, the Amur River country, and Sakhalin Island. The author agreed to review the literature of the plants native to these areas so that a list of desired plants might be prepared. Since then, the author has studied the woody floras in these areas, and lists of the woody floras in the mid-northern Korean Peninsula, southeastern Manchuria, and southern Sakhalin were published in 1974 (2).

At the 1978 meeting in Madison, Wis., the Ornamental Subcommittee recommended that a high priority be placed on plant exploration in northeastern China, northern Korean Peninsula, and northern Japan as well as North America for superior hardy ornamental plants.

In this publication, the author presents a list of available woody species in Hokkaido, a northern island of Japan, potentially adaptable to the North Central region of the United States. Hokkaido is located between latitude 41.4° North and 45.6° North and between longitude 139.75° East and 145.8° East. The island is a rich source of hardy woody plant materials. Introduction of these species to the North Central states would enrich the collection of hardy ornamentals in this region.

Flora of Hokkaido has been extensively studied by many workers including Hara (1), Miyaba and Kudo (4, 5), Tatewaki (7-10), Toyokuni (11), and Yanagita (12). Woody species appearing in these reports and books have been alphabetically arranged in this publication according to their genus and species names. Nomenclature has been updated as much as possible to be consistent with present nomenclature. The name for each species, subspecies, variety, or form was first checked against Makino's New Illustrated Flora of Japan (3) and the nomenclature was updated. When there was no description for a particular name in Makino (3), the name was checked against the Manual of Cultivated Trees and Shrubs (6) and the nomenclature was updated. However, when there was no description for a particular species, subspecies, variety, or form in either Makino (3) or Rehder (6), its name has been listed in this publication as it was referred to in its original report.

This form of presentation resulted in some difficulty. For instance, *Salix Urbaniana* Seem. cited in (4) was changed to *Toisusu Urbaniana* Kimura according to Makino (3), but *Salix Urbaniana* Seem. var. *Schneideri* Miyabe et Kudo cited in (4) was not found in Makino (3) nor in Rehder (6) and the name was listed in this paper as it was cited in (4). Similarly, *Leucothoe Grayana* Maxim. (7) was changed to *Eubotryoides Grayana* Hara according to Makino (3), but *Leucothoe Grayana* Maxim. f. *angustifolia* Nakai (8), *Leucothoe Grayana* Maxim. var. glabra Koidz. (8), *Leucothoe Grayana* Maxim. var. *intermedia* H. d. Boiss (8), and *Leucothoe Grayana* Maxim. var. *typica* H. d. Boiss (8) were left without change. *Alnus japonica* Sieb. et Zucc. (1, 5) was changed to *Alnus japonica* Steud. according to Makino (3) and Rehder (6), but *Alnus japonica* Sieb. et Zucc. var. *arguta* Call. (1, 4), *Alnus japonica* Sieb. et Zucc. var. *genuina* Call. (1) were left as they were cited in their original reports. *Vitis Coignetiae* Pulliat (7) was verified by Makino (3), but its variety, *glabrescens* Nakai (7), was listed in Rehder (6) and in this publication as *Vitis Coignetiae* Planch var. *glabrescens* Nakai.

WOODY FLORA IN HOKKAIDO

Abies sachalinensis Fr. Schm.
Abies sachalinensis Fr. Schm. *Mayriana* Miyabe et Kudo
Abies sachalinensis nemorensis Mayr.
Acanthopanax divaricatum Seem.
Acanthopanax sciadophylloides Fran. et Sav.
Acer cissifolium C. Koch.
Acer Ginnala Maxim.
Acer japonicum Thunb.
Acer kobakoense Nakai
Acer Mayrii Schwer.
Acer Miyabei Maxim.
Acer mono Maxim.
Acer ornatum Carriere
Acer palmatum Thunb.
Acer Tschonoskii Maxim.
Acer ukurunduense Trautv. et Mey.
Actinidia arguta Planch.
Actinidia Kolomikta Maxim.
Actinidia polygama Miq.

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Aesculus turbinata Bl.
Alangium platinifolium Harms var. *macrophyllum* Wangerin
Alangium platanifolium Harms var. *Ogurae* Yanagita
Alnus borealis
Alnus fruticosa Rupr.
Alnus hirsuta Turcz.
Alnus japonica Sieb. et Zucc. var. *arguta* Call.
Alnus japonica Sieb. et Zucc. var. *genuina* Call.
Alnus japonica Sieb. et Zucc. var. *latifolia* Call.
Alnus japonica Steud.
Alnus Maximowiczii Call.
Alnus Mayri
Alnus Mayri Call. var. *glabrescens* Nakai
Alnus Mayri Call. var. *intermedia* Hara
Alnus pendula Matsum.
Alnus sinuata Rydb. var. *Kamtschatica* Call.
Ampelopsis brevipedunculata Trautv.
Aralia elata Seem.
Arcterica nana Makino
Arctous alpinus Niedenzu var. *japonica* Ohwi
Arctous japonica Nakai
Berberis amurensis Rupr.
Betula apoiensis Nakai
Betula Ermani Cham.
Betula Ermani var. *genuina*
Betula japonica Sieb.
Betula mandshurica (Reg.) Nakai
Betula Maximowicziana Regel
Betula Miyoshii
Callicarpa japonica Thunb.
Carpinus cordata Blume
Carpinus erosa
Carpinus laxiflora Blume
Cassiope lycopodioides D. Don
Castanea crenata Sieb. et Zucc.
Celastrus strigillosus Nakai
Celtis Bungeana Blume var. *jessoensis* Kudo
Celtis jessoensis Koidz.
Cephalotaxus drupacea Sieb. et Zucc.
Cercidiphyllum japonicum Sieb. et Zucc.
Chosenia bracteosa Nakai
Clematis alpina Mill. var. *ochotensis* Regel et Tiling
Clematis fusca Turcz. var. *mandshurica* Takeda
Clerodendron trichotomum Thunb.
Cornus controversa Hemsl.
Corylus brevirostris
Corylus heterophylla Fisch.
Corylus heterophylla Fisch. var. *yezoensis* Koidz.
Corylus Sieboldiana Bl.
Corylus Sieboldiana Bl. var. *brevirostris* C. K. Schn.
Crataegus jozana C. K. Schn.
Daphne jezoensis Maxim.
Daphne Miyabeana Makino
Daphniphyllum humile Maxim.
Dasyphora fruticosa Rydb.
Diapensia lapponica L. subsp. *obovata* Hulten
Diapensia lapponica L. var. *obovata* Fr. Schm.
Diapensia obovata Nakai
Dryas octopetala L. var. *asiatica* Nakai
Empetrum nigrum L.
Empetrum nigrum L. var. *japonicum* K. Koch
Eubotryoides Grayana Hara
Eubotryoides Grayana Hara var. *oblongifolia* Hara
Euonymus alata Sieb. var. *striatus* Makino
Euonymus hians Koehne
Euonymus japonicus Thunb. var. *radians* Miq.
Euonymus macroptera Rupr.
Euonymus oxyphylla Miq.
Euonymus radicans Sieb.
Euonymus sachalinensis (Fr. Schmidt) Maxim.
Euonymus Sieboldiana Blume
Euonymus tricarpa Koidz.
Euonymus yesoensis Koidz.
Fagus crenata Blume
Fagus Sieboldii Endl.
Fraxinus longicuspis Sieb. et Zucc. var. *Sieboldiana* (Bl.) Lingelsh.
Fraxinus mandshurica Rupr.
Fraxinus Sieboldiana Bl. var. *serrata* Nakai
Hydrangea paniculata Sieb.
Hydrangea paniculata Sieb. var. *floribunda* Regel.
Hydrangea petiolaris Sieb. et Zucc.
Hydrangea serrata (Thunb.) D. C.
Hydrangea serrata (Thunb.) D. C. var. *acuminata* (Sieb. et Zucc.) Wils.
Hypericum yamamotoi Miyabe et Y. Kimura var. *montanum* Y. Kimura
Ilex crenata Thunb.
Ilex Fauriei Makino
Ilex macropoda Miq.
Ilex radicans Nakai
Ilex rugosa F. Schm.
Ilex Sugeroki Maxim.
Ilex Sugeroki Maxim. subsp. *brevipedunculata* Makino
Ilex Vidali Fr. Schm.
Juglans Sieboldiana Maxim.
Juniperus chinensis L. var. *procumbens* Endl.
Juniperus chinensis L. var. *Sargenti* Henry
Juniperus communis L.
Juniperus communis L. var. *saxatilis* Pall.
Juniperus conferta Parl.
Kalopanax pictus (Thunb.) Nakai
Kalopanax sciadophylloides Franch. et Sav.
Larix dahurica Turcz. var. *japonica* Maxim.
Ledum palustre L. subsp. *groenlandicum* Hulten var *yesoense* Nakai
Ledum palustre L. var. *longifolium* Freyn.

Ledum palustre L. var. *maximum* Nakai
Ledum palustre L. var. *nipponicum* Nakai
Ledum palustre L. var. *yesoense* Nakai
Lespedeza bicolor Turcz.
Leucothoe Grayana Maxim. f. *angustifolia* Nakai
Leucothoe Grayana Maxim. var. *glabra* Koidz.
Leucothoe Grayana Maxim. var. *intermedia* H. d. Boiss
Leucothoe Grayana Maxim. var. *typica* H. d. Boiss
Ligustrum Tschonoskii Decaisne
Ligustrum Tschonoskii Dec. var. *glabrescens* Koidz.
Ligustrum yezoense Nakai
Linnaea borealis L.
Loiseleuria procumbens Desv.
Lonicera caerulea L. var. *longibracteata* (Schn.) Hara f. *ovata* Hara
Lonicera caerulea L. var. *venulosa* Rehder
Lonicera caerulea L. var. *venulosa* Rehder f. *oblonga* Hara
Lonicera Chamissoi Bunge
Lonicera Glehni Fr. Schm.
Maackia amurensis Rupr.
Maackia amurensis Rupr. et Maxim. var. *Buergeri* Schneid.
Magnolia Kobus DC.
Magnolia Kobus DC. var. *borealis* Sarg.
Magnolia obovata Thunb.
Malus baccata (L.) Borkh. var. *mandshurica* (Maxim.) Schneid.
Marlea macrophylla Sieb. et Zucc.
Menziesia pentandra Maxim.
Morus bombycis Koidz.
Myrica Gale L. var. *tomentosa* C. DC.
Ostrya japonica Sarg.
Oxycoccus vulgaris Hill
Pachysandra terminalis Sieb. et Zucc.
Phellodendron sachalinense (Fr. Schmidt) Sarg.
Photinia villosa (Thunb.) DC.
Phyllodoce aleutica A. Heller
Phyllodoce tsugaefolia Nakai
Picea Glehni Mast.
Picea jezoensis Carr.
Picrasma quassioides Benn.
Pinus parviflora Sieb. et Zucc.
Pinus pentaphylla Mayr
Pinus pumila Regel
Populus jesoensis
Populus Maximowiczii Henry
Populus Sieboldi Miq.
Populus tremula L. var. *Davidiana* (Dode) Schneid.
Potentilla apoiensis Nakai
Potentilla Dickinsii Franch. et Sav.
Potentilla Matsumurae Wolf
Potentilla Miyabei Makino
Potentilla nivea L.
Pourthiaea Zollingeri Decaisne
Prunus donarium Sieb. var *sachalinensis* Makino
Prunus Grayana Maxim.
Prunus Kurilensis Miyabe var. *Hagashi* Yanagita
Prunus Maximowiczii Rupr.
Prunus nipponica Matsum.
Prunus nipponica Matsum. var. *kurilensis* Wilson
Prunus Padus L.
Prunus Ssiori Fr. Schm.
Prunus verecunda Koehne
Pterocarya rhoifolia Sieb. et Zucc.
Quercus crispula Blume
Quercus dentata Thunb.
Quercus glandulifera Bl.
Quercus mongolica Turcz.
Quercus serrata Thunb.
Rhamnus Ishidae Miyabe et Kudo
Rhamnus japonica Maxim.
Rhododendron Albrechti Maxim.
Rhododendron aureum Georgi
Rhododendron camtschaticum Pall.
Rhododendron chrysanthum Pall.
Rhododendron dauricum L.
Rhododendron Fauriae Fran.
Rhododendron Fauriae Fran. var. *roseum* Nakai
Rhododendron Kaempferi Planch.
Rhododendron Kaempferi Planch. var. *latisepalum* Nakai
Rhus javanica L.
Rhus orientalis Schneid.
Rhus trichocarpa Miq.
Ribes japonicum Maxim.
Rosa acicularis Lindl.
Rosa acicularis Lindl. var. *Gmelini* C. K. Schn.
Rosa rugosa Thunb.
Rubus crataegifolius Bunge
Rubus idaeus L.
Rubus idaeus L. var. *aculeatissimus* C.A. Mey.
Rubus idaeus L. var. *strigosus* (Michx.) Maxim.
Rubus Kinashii Lev. et Vnt.
Rubus parvifolius L.
Rubus pedatus Smith
Rubus phoenicolasius Maxim.
Rubus pseudojaponicus Koidz.
Rubus vernus Nakai
Salix ampherista
Salix amygdalina L.
Salix Bakko Kimura
Salix caprea L.
Salix Gilgiana Seemen
Salix gracilistyla Miq.
Salix hidaka-montana Hara
Salix hideoi Koidz.
Salix Hultenii
Salix integra Thunb.

Salix jessoensis Seemen
Salix Koriyanagi Kimura
Salix Miyabeana Seemen
Salix neoreticulata Nakai
Salix paludicola Koidz.
Salix pauciflora Koidz. (var. *cyclophylla* Kimura)
Salix pseudo-paludicola Kimura
Salix Reinii Franch. et Sav.
Salix rorida Lacks
Salix sachalinensis Fr. Schm.
Salix sendaica
Salix subfragilis Anders.
Salix taraikensis
Salix triandra L. var. *discolor* Anders.
Salix Urbaniana Seem. var. *Schneideri* Miyabe et Kudo
Salix viminalis L.
Salix viminalis L. var. *yezoensis* C.K. Schn.
Salix vulpina Anders.
Salix yezoalpina
Salix yezoensis
Sambucus Buergeriana Blume
Sambucus Buergeriana Bl. var. *Miquelii* Nakai
Sambucus Buergeriana Blume var. *Nakayamai* Yanagita
Schizandra chinensis Baill.
Schizophragma hydrangeoides Sieb. et Zucc.
Sieversia pentapetala Greene
Skimmia japonica Thunb.
Smilax China L.
Sorbaria sorbifolia A. Br. var. *glabra* Maxim.
Sorbaria sorbifolia A. Br. var. *stellipila* Maxim.
Sorbus alnifolia K. Koch
Sorbus commixta Hedlund
Sorbus macrophylla Koidz.
Sorbus Matsumurana Koehne
Sorbus pseudo-gracilis Koehne
Sorbus sambucifolia M. Roemer
Sorbus sitchensis Roem.
Spiraea Aemiliana Schn.
Spiraea betulaefolia Pall. var. *grandifolia* (Nakai)
Spiraea betulaefolia var. *oblanceolata* Tatewaki
Spiraea betulifolia Pall.
Spiraea grandifolia Nakai
Spiraea media Schmidt.
Spiraea media Schm. var. *sericea* Regel.
Spiraea Miyabei Koidz.
Spiraea salicifolia L.
Staphylea Bumalda DC.
Stephanandra incisa Zabel
Styrax japonica Sieb. et Zucc.
Styrax Obassia Sieb. et Zucc.
Symplocos paniculata Miq.
Syringa amurensis Rupr. var. *japonica* (Maxim.) Fr. et Sav.
Syringa amurensis Rupr. var. *macrophylla* Nakai
Syringa amurensis Rupr. var. *Tatewakiana* Yanagita
Taxus cuspidata Sieb. et Zucc.
Tilia japonica Simk.
Tilia japonica Simk. var. *Ishiharai* Yanagita
Tilia Maximowicziana Shirasawa
Thujopsis dolabrata Sieb. et Zucc.
Thujopsis dolabrata Sieb. et Zucc. var. *Hondai* Makino
Thymus quinquecostatus Celak.
Toisusu Urbaniana Kimura
Tripetaleia paniculata Sieb. et Zucc.
Ulmus japonica (Rehd.) Sarg.
Ulmus laciniata Mayr
Ulmus propinqua
Vaccinium Chamissonis Bong.
Vaccinium Oldhami Miq.
Vaccinium praestans Lamb.
Vaccinium Smallii Gray
Vaccinium Smallii A. Gray var. *glabrescens* Hara
Vaccinium Smallii A. Gray var. *latifolium* Nakai
Vaccinium uliginosum L.
Vaccinium Usunoki Nakai
Vaccinium Vitis-idaea L.
Vaccinium Vitis-idaea L. var. *minus* Lodd.
Viburnum dilatatum Thunb.
Viburnum furcatum Blume
Viburnum pubinerve Bl. f. *calvescens* Nakai
Viburnum Sargenti Koehne var. *calrescens* Rehder
Viburnum Wrightii Miq.
Viburnum Wrightii var. *pilosum* Hara
Viscum album L.
Viscum coloratum Nakai
Viscum coloratum var. *lutescens*
Viscum coloratum var. *rubro-auratiacum*
Vitis Coignetiae Planch var. *glabrescens* Nakai
Vitis Coignetiae Pulliat
Weigela japonica Thunb.
Weigela Middendorffiana Lem.
Xanthoxylum piperitum DC.

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An Evaluation of Microfoam on Plant Quality Following Overwintering of Container-Grown Woody Ornamentals

CHRISTOPHER F. RIZZO, ELTON M. SMITH, and THOMAS A. FRETZ[1]

ABSTRACT

The quality of container grown *Juniperus horizontalis* 'Plumosa Compacta' and *Cotoneaster dammeri* 'Royal Beauty' was evaluated following 4 months of winter storage under single and double layer Microfoam covered with white or clear plastic. *Juniperus* overwintered in excellent condition under both double and single layer Microfoam treatments. *Cotoneaster* overwintered in good condition under double layer Microfoam and in fair condition under single layer Microfoam. However, no significant differences were found in ambient air or soil temperatures for any treatment. Both ambient air and container temperatures remained within acceptable ranges throughout the storage period.

INTRODUCTION

The structureless Microfoam method for overwintering container-grown nursery stock was first introduced by Gouin in 1973 (3, 5). This method consists of covering tightly packed plant materials with 0.64 cm thick Microfoam sheets after the plants have been watered thoroughly, treated with a fungicide, and baited for rodents. Upright growing plants are tipped on their sides and spreading plants are left standing. The Microfoam is then covered with a plastic film and sealed to the ground with gravel or soil at the edges (3).

Microfoam is an insulating and packaging product made of light weight polypropylene material with a thermal conductivity of 68 cal/hr/0.1 m^2/0.5° C/2.5 cm. It is available in rolls 1.5 m (5 ft) or 1.8 m (6 ft) wide and 147 m (475 ft) or 69 m (225 ft) long with thicknesses of 0.16 cm (1/16 in), 0.32 cm (1/8 in), or 0.64 cm (1/4 in). It is a brittle material, but if handled carefully will last for 2 or 3 years (5).

Recent studies have demonstrated that plant losses and poor growth are frequently due to root injury from low temperatures during overwintering of container grown plants (2, 3, 5, 6, 9, 10). This often occurs because roots are less cold hardy than shoots (9, 10).

Gouin (4) found that soil temperatures in the outer rows of container grown plants covered with 0.64 cm thick Microfoam and 4 mil clear plastic rarely dropped below —1° C even though outside ambient air temperatures were recorded as low as —8° C and plants overwintered in excellent condition. Soi temperatures were slightly lower under Microfoan beds covered with 4 mil white plastic than those cov ered with 4 mil clear plastic. In contrast, soil tem peratures in the outer rows under small 1 meter higl plastic covered shelters were nearly identical to out side ambient air temperatures and severe root dam age to test plants resulted.

The purpose of this study was to evaluate plan quality and monitor ambient air and soil tempera tures of *Juniperus* and *Cotoneaster* in 2.8 liter (3/4 gal) containers stored under single and double laye Microfoam covered with clear or white plastic.

MATERIALS AND METHODS

On Nov. 26, 1976, 252 *Juniperus horizontali* 'Plumosa Compacta' and 252 *Cotoneaster dammer* 'Royal Beauty' grown in 2.8 liter containers were wa tered and sprayed until runoff with a mixture of cap tan (Captan 50 WP) and PCNB (Terraclor 75 WP) at a rate of 1.3 gm/liter each plus 4.5 ml of Wilt-Pru NCF. The following day 21 plants of each specie were grouped together, placed on their sides, anc baited for rodents with zinc phosphide treated grain The plants were covered with Microfoam (0.64 cn thickness) and the Microfoam was covered by 4 mi plastic. The Microfoam and plastic were secured a the edges with gravel, forming a bed 1.3 m by 2 m fo each replication. The study was conducted in th container nursery at The Ohio State University, Co lumbus.

Four treatments with three replications of 21 plants per species per replication were used in a ran domized complete block design. The treatments in cluded:

1. One layer of Microfoam with a clear plastic film.
2. One layer of Microfoam with a white plastic film.
3. Two layers of Microfoam with a clear plastic film.
4. Two layers of Microfoam with a white plastic film.

Ambient air and soil temperatures were recorded at 4 a.m. and 2 p.m. daily on alternate weeks with a Honeywell multipoint recording thermograph. Copper constantine thermocouples were placed approximately 10 cm from the ground toward the center of the beds and those in containers were placed

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TABLE 1.—Plant Quality Following Overwintering Under Microfoam Treatments.*†

Treatment	Plant Quality	
	Juniperus horizontalis 'Plumosa Compacta'	Cotoneaster dammeri 'Royal Beauty'
Single layer Microfoam and clear plastic cover	8.6 a‡	5.7 a
Double layer Microfoam and white plastic cover	8.6 a	7.3 b
Single layer Microfoam and white plastic cover	8.4 a	6.3 a
Double layer Microfoam and clear plastic cover	8.4 a	7.8 b

*Quality was evaluated on a visual scale from 0-9, with 0 being dead and 9 in perfect condition. 6 was considered a saleable plant.
†Plants were stored from Nov. 21, 1976, through March 21, 1977.
‡Mean separation within columns by Tukey's HSD test, 5 % level.

approximately 5 cm from the outside of the containers and approximately 10 cm from the container's soil surface.

Two thermocouples per replication were included, one for ambient air inside the bed and one for container soil temperatures. Outside ambient air temperatures were also recorded.

Light transmission through each treatment was measured on a LiCor Model L1 185 photometer.

On March 31, 1977, the Microfoam beds were uncovered and a visual examination of plant quality was made using a scale from 0 to 9, with 0 completely dead and 9 in perfect condition. A value of 6 was considered a saleable plant.

RESULTS AND DISCUSSION

Cotoneaster overwintered in superior condition under double layer Microfoam treatments when compared to single layer treatments, while the Junipers overwintered in excellent condition under all treatments (Table 1).

Light transmission was greatest for those treatments of single layer Microfoam with clear plastic coverings, followed by single layer Microfoam with white plastic coverings (Table 2). The greater light transmission of these two treatments may have resulted in increased foliage temperatures. If foliage temperatures were higher than air temperatures, a vapor pressure deficit between the foliage and surrounding air could have been sufficiently high to promote desiccation.

TABLE 2.—Percent Light Transmission Through Microfoam Treatments.

Treatments	Percent Light Transmission
Single layer Microfoam and clear plastic cover	34
Double layer Microfoam and white plastic cover	8
Single layer Microfoam and white plastic cover	19
Double layer Microfoam and clear plastic cover	14

No significant differences were found between any treatments for average high or average low temperatures during the experimental period. Average minimum soil temperatures for all treatments were between 0.1 and 1.6° C while average maximum soil temperatures were between 3.3 and 4.4° C (Table 3). Similar results were found for ambient air temperatures under the Microfoam beds, with average maximum temperatures of 9.5 and 11.1° C and average minimum temperatures of —0.6 to —1.1° C.

In contrast to Gouin's work (5), temperatures under all treatments dropped to a low of —6° C dur-

TABLE 3.—Average Ambient Air and Soil Temperatures Within Microfoam Beds.*†

Treatments	Temperature °C			
	Soil		Ambient Air	
	Av. 2 p.m.	Av. 4 a.m.	Av. 2 p.m.	Av. 4 a.m.
Single layer Microfoam and clear plastic cover	4.4	0.2	11.1	— 1.2
Double layer Microfoam and white plastic cover	3.3	1.6	9.5	— 0.6
Single layer Microfoam and white plastic cover	4.4	0.1	10.6	— 0.8
Double layer Microfoam and clear plastic cover	3.9	0.1	10.0	— 1.1
Outside			5.5	— 9.8

*Temperatures were taken daily during alternate weeks from Jan. 10, 1977, through March 13, 1977.
†No significant differences were found between any treatments.

ing the month of January. This was only for short periods of time (1 hour or less) when outside ambient air temperatures were —18° C or less. The outside temperatures in this study were lower than those reported by Gouin and explain the lower recordings under Microfoam.

The winter of 1976-77 was the coldest on record in Columbus. The average daily temperature was 9° C below normal for the month of January alone. The minimum daily average temperature for January was —16° C, with temperatures dropping as low as —28° C (1). This prolonged cold period in conjunction with extensive cloud cover (two-thirds of possible sunshine was cloud covered in January) (1) was greatly responsible for the reduced temperature under the Microfoam and may have reduced the usual variations noted between white and clear plastic covered Microfoam treatments.

The similarities in temperature between double and single layer treatments suggest that the insulative capacity of the Microfoam alone may be secondary to the heat supply from the ground or the wind and cold protection provided by the plastic film. This is supported by the work of Havis (8) on various plastic thermal blankets within quonset-shaped walk-in type storage houses. His studies indicate that there is no protective advantage with Microfoam over 2 mil plastic film when used as an innerliner over plants. Less expensive materials may prove adequate in providing plant protection in a structureless bed and deserve further research.

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Evaluation of Winter Barrels as a Heat Source in Woody Ornamental Winter Storage Structures

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ABSTRACT

The heat provided by 55 gallon (208 liter) metal oil drums filled with water and placed in plastic covered woody ornamental overwintering structures was evaluated for its effect on plant quality and temperature moderation. During the winter season of 1976-77, minimum night temperatures were increased up to 4° C until mid-December when the water in the barrels froze. After the water froze, no temperature modification was found. In the following winter season the water froze early in December and remained frozen until spring. During this season, plant quality and minimum night temperatures (from December to March) were unaffected by the water barrels. If this water barrel technique is to be effective in modifying plant storage under winter conditions in Ohio, a greater volume of water will be required.

INTRODUCTION

Improved methods for overwintering container and balled and burlapped nursery stock must be developed if the Ohio nursery industry is to remain competitive with Southern U. S. and California growers. The cost of overwintering a 3.8 liter plant in Ohio under single layer plastic film covered structures is approximately 10 cents (4). This compares favorably with the shipping cost of Southern U. S. growers. However, single layer films do not provide adequate winter protection for many woody ornamental species commonly grown in Ohio.

The use of water as a heat source within winter storage structures is a possible method for protecting nursery stock from subfreezing temperatures. No other energy source is as readily available and inexpensive as water, yet it has been largely ignored by growers and researchers alike.

One gram of water at 0° C releases 80 calories of heat (1/3 of a BTU) upon freezing (1). This heat is released at 0° C, an optimum temperature for the winter storage of woody ornamentals. Thus, growers have a 'minimum heat' facility contained within their water system. If an adequate quantity of water could be introduced within a winter storage structure, the severity of low temperatures could be lessened as well as freezing injury to plants. In addition, relative humidity would be increased, thereby reducing plant desiccation.

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Outside sprinkler systems have been used to protect forest tree seedlings and woody ornamentals from low temperatures with great success (2, 6). Water channels within plastic covered storage structures have also proven effective in moderating low temperatures (9). A third possibility is the use of barrels filled with water and spaced periodically within storage structures. Tinga (8) evaluated this system in Georgia and reported excellent moderation of low temperatures. Steavenson (6) reported success with a combination of water barrels and mist lines in Missouri in preventing plant injury.

To estimate the heat potential of water barrels in Ohio, a hypothetical model was constructed using the measurements of available experimental storage facilities.

The total quantity of heat provided by any number of water barrels at 0° C (32° F) upon freezing can be calculated by the equation (1):

$$\text{no. g} \times 80 \text{ cal.} = \text{total no. of cal.}$$

If 19 208-liter barrels and 17 114-liter barrels were filled and placed at 3 m intervals in the structure, the equation becomes:

$$5890.0 \text{ liters} \times 1000 \text{ g} \times 80 \text{ cal./g} \simeq 4.7 \times 10^8 \text{ cal.} = 4.7 \times 10^5 \text{ Kcal.}$$

This value is equal to the total number of Kcal provided by the water in the barrels at 0° C while freezing.

The total quantity of heat required to maintain a double layer air inflated storage unit at 0° C with an outside ambient air temperature of — 18° C (0° F) per hour is estimated by the equation (5):

$$Q = AU\triangle T$$

where Q = heat loss, Kcal
A = exposed surface in m^2
U = Kcal hr^{-1} m^{-2} ° C^{-1}
T = temperature differential between the inside and outside air, ° C.

The calculated U value (a measure of the rate of heat transfer) for double layer air inflated plastic films is 3.4 Kcal hr^{-1} ° C^{-1} m^{-2} (3, 5) and $\triangle T$ for the hypothetical situation above is 18° C. The surface area of a 55 m long, 6 m wide and 2.7 m high storage structure is 546.3 m^2. Substituting these values in the above equation, the total heat loss per hour becomes:

$$Q = 546.3 \text{ m}^2 \times 3.4 \text{ Kcal hr}^{-1} \text{ ° C}^{-1} \text{ m}^{-2} \times 18° \text{ C} = 33433 \text{ Kcal hr}^{-1}$$

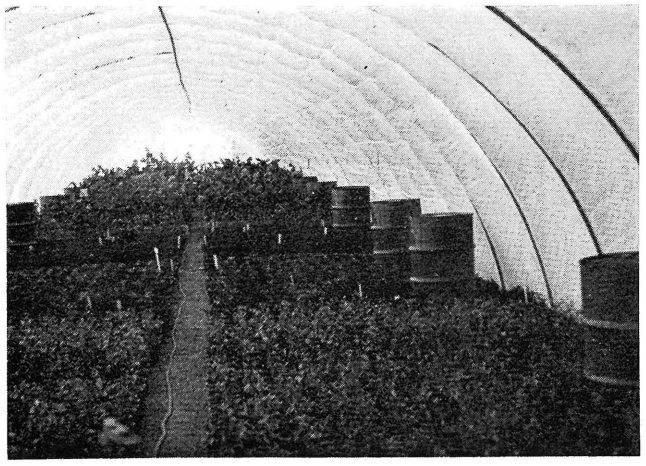

FIG. 1.—An end view of a plastic-covered quonset-shaped winter storage structure with water barrels.

By comparing the total heat requirements of the experimental storage unit with the total quantity of heat provided by the barrels, it is calculated that the barrels are capable of supplying enough heat to maintain the temperatures within the structure at 0° C for approximately 14 hours:

$$4.7 \times 10^5 \text{ Kcal}/33433 \text{ Kcal hr}^{-1} \simeq 14 \text{ hr}$$

In view of these calculations, a study was initiated to evaluate the practical value of using water barrels to heat double layer plastic storage structures in Ohio and to evaluate their effect on plant quality.

MATERIALS AND METHODS

On Nov. 6, 1976, two quonset-shaped pipe frame structures 5.5 m long, 6 m wide, and 2.7 m high were covered with two layers of 4 mil plastic film, clear inside and white outside, at a commercial nursery in New Carlisle, Ohio (Figure 1). Seventeen 114 liter barrels and nineteen 208 liter barrels were spaced at 3 m intervals on both sides of the structure and filled with water. This design was chosen in conjunction with the owner's needs and availability of water barrels. Approximately 11,000 plants grown in 3.8 liter containers were included in each structure.

Minimum and maximum temperatures were recorded at plant height three times weekly on Taylor No. 2354 Weather Hawk recording thermometers from Nov. 19, 1976, to March 31, 1977.

The study was continued the following winter using similar structures at the same location in central Ohio. Thirty-six 208 liter barrels filled approximately two-thirds full were included in each of three structures, while three other structures had no barrels, and three structures were supplied with propane gas heaters providing minimum heat at — 1° C.

Structures were covered on Nov. 15, 1977, and uncovered on April 6, 1978. Three randomized blocks of five species with three plants per species were included in each structure. The species included: *Cotoneaster apiculata, Pyracantha coccinea* 'Mojave', *Berberis purpurea* 'Crimson Pygmy', *Ligustrum* x *vicaryi,* and *Juniperus conferta* 'Blue Pacific'. All plants were grown in 3.8 liter containers.

Air temperatures were recorded three times per week on Taylor high-low thermometers placed at plant height toward the center of the house from Dec. 1, 1977, to March 30, 1978.

On April 2, 1978, both shoots and roots were evaluated using a visual scale from 0 to 9 (9 = excellent, 6 = acceptable, and 0 = dead).

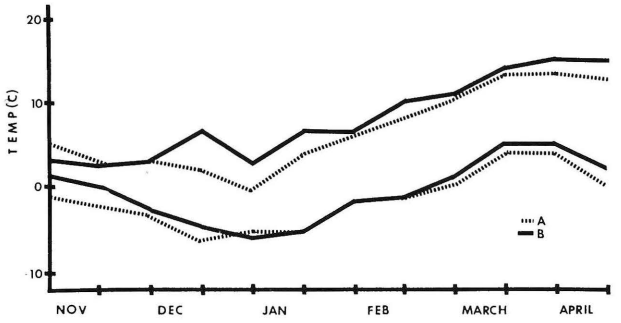

FIG. 2.—A comparison of average minimum and maximum temperatures for storage structures without water barrels (A) and with water barrels (B) during the winter of 1976-77.

RESULTS AND DISCUSSION

In November and early December 1976, minimum night temperatures were recorded up to 4° C higher in the structure with water barrels than the structure without water barrels (Figure 2). Unfortunately, outside temperatures dropped very low during mid-December and the water barrels froze solid without completely thawing until spring. Once the barrels were frozen, they had little if any effect on storage temperatures. In addition, maximum day temperatures were not reduced by the frozen barrels in the spring.

During the second season, severely cold temperatures occurring early in December again froze the barrels solid and again no temperature modification was observed (Figs. 3 and 4). Structures with and without water barrels resulted in similar plant quality and temperatures during the winter of 1977-78 (Table 1). The structures with minimum heat maintained higher minimum night temperatures in general; however, temperature data suggest that the heating system at — 1° C was not always working or not working efficiently. Temperatures in the structures with minimum heat decreased to a low of — 7° C in January and, as

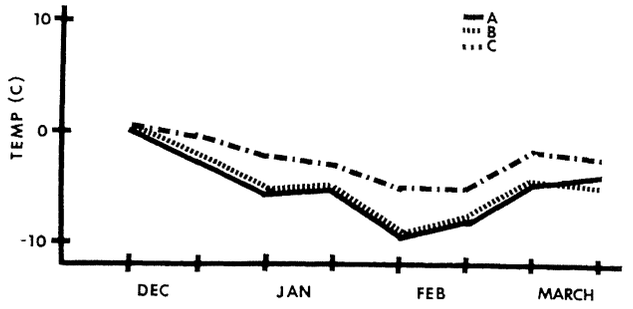

FIG. 3.—A comparison of average minimum temperatures for storage structures with no additional heat (A), water barrels (B), and minimum heat (C) during the winter of 1977-78.

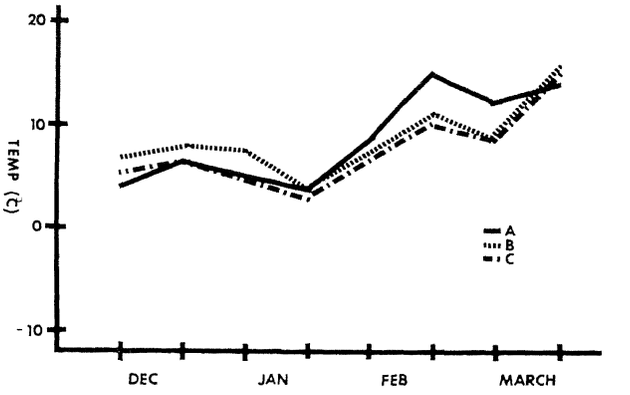

FIG. 4.—A comparison of average maximum temperatures for storage structures with no additional heat (A), water barrels (B), and minimum heat (C) during the winter of 1977-78.

a result, *Pyracantha,* the least hardy of all the species tested, was injured.

Despite the unacceptable quality of the *Pyracantha* for all treatments, they overwintered in better condition in the heated treatment than in the other treatments. All other species overwintered in good to excellent condition in all storage treatments.

In the Southern states, the quantity of heat provided by water barrels may be sufficient to protect plants from infrequent cold nights, especially if warm days follow, allowing the barrels to thaw. Once the barrels are frozen they are ineffective in raising minimum night temperatures. During the winter seasons of 1976-77 and 1977-78 in Ohio, temperatures were too low for 36 208-liter water barrels to maintain any prolonged temperature modification and did not satisfactorily provide cold temperature protection for the root tender species.

The failure of the water barrel system to modify temperatures for prolonged periods in Ohio does not mean the concept from which it was developed should be disregarded. Greater quantities of water or flowing *channels* through the storage structures will probably be necessary if this system is to succeed in northern climates.

SUMMARY

During two seasons of the coldest winter on record in Ohio, water barrels as a heat source within woody ornamental winter storage structures proved ineffective. The water barrels provided a considerable quantity of heat and increased minimum night temperatures (4° C) for a short period until the barrels were frozen. The freezing occurred early in the season, at which point no beneficial effect on storage temperatures was noted. A water barrel system with a limited quantity of water, as in this study, is not recommended for winter protection of woody ornamentals in Ohio.

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TABLE 1.—Plant Quality Following 3½ Months of Winter Storage in Structures with Minimum Heat, Water Barrels, and No Water Barrels.

	Treatment					
	Water Barrels		No Water Barrels		Minimum Heat	
Species	Shoot	Root	Shoot	Root	Shoot	Root
Cotoneaster apiculata	8.9 a*	6.3 a†	9 0 a	7.1 a	9.0 a	7.4 a
Pyracantha coccinea 'Mojave'	4.1 a	2.9 a	3.3 a	3.1 a	5.7 b	5.0 b
Berberis purpurea 'Crimson Pygmy'	8 9 a	8 0 a	9.0 a	8.0 a	9 0 a	8.5 a
Ligustrum x vicaryi	7.5 a	7.3 a	7.3 a	7.3 a	8 3 a	7.4 a
Juniperus conferta 'Blue Pacific'	9.0 a	8.1 a	9.0 a	8.3 a	8 8 a	8.3 a

*Shoot mean separation within rows by Tukey's HSD, 5% level.
†Root mean separation within rows by Tukey's HSD, 5% level.

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Effective Utilization of Applied Fertilizer in Relation to Multiple Flushes of Growth on 'Helleri' Holly

C. H. GILLIAM and R. D. WRIGHT[1]

ABSTRACT

The response of *Ilex crenata* Thunb. 'Helleri' to 15 fertilizer treatments consisting of different times and lengths was studied. Fertilizer applied during a period following the cessation of stem elongation and before the next flush resulted in greater total tissue N and shoot growth than applications made during other stages of growth. Root growth was suppressed by three or more fertilizer applications, regardless of the time of application.

INTRODUCTION

The correct timing of fertilizer applications has been shown to result in greater growth with woody plants having annual flushes of growth. De Werth and Chadwick (2) stated that for elm and maple, spring applications of fertilizer were more beneficial than fall applications. Autumn applications were shown to be as effective as spring applications when growth response of *Ligustrum* was examined by Good and Tukey (6).

The previously mentioned papers were concerned with plants having one primary flush of growth annually. However, limited information is available on the timing of fertilizer applications coinciding with multiple flushes of growth during the summer months. The relative intensity of a growth flush has been shown to be dependent upon the level of fertilizer added preceding the flush (3). A previous report (5) has shown that tissue N accumulated rapidly during the latter stage of a growth flush, between the cessation of stem elongation and the beginning of a new growth flush. These data suggested that correctly timed fertilizer applications to woody plants during a flush of growth may result in more efficient use of applied fertilizer.

The purpose of this study was to determine if a specific time existed during a growth flush on *Ilex crenata* 'Helleri' when added fertilizer would be more effectively utilized.

MATERIALS AND METHODS

Multiple-stemmed liners of *Ilex crenata* 'Helleri' were potted on March 1, 1977, in plastic quart containers in a 100% milled pine bark medium. To each cubic yard of the medium, 2.7 kg (6 lb) of dolomitic limestone, 0.9 kg (2 lb) of gypsum, and 1.8 kg (4 lb) of 20% superphosphate were added. Plants were grown in a greenhouse at 28° C (day) and 21° C (night) under natural photoperiod from March 1 to May 10. A randomized block design with four replications (eight plants/replicate) was used.

Fifteen treatments consisted of various times and numbers of weekly fertilizer applications (Table 1). A nutrient solution containing 300 ppm N, 130 ppm P, and 247 ppm K was used at each application. Week 1 corresponded to the beginning of the first growth flush (March 15) and week 3 corresponded to the cessation of shoot elongation. The beginning of the second flush of growth started 1 week after the last fertilizer application (week 5).

At the beginning of the second flush of growth, 6 weeks after initial N applications, two plants were removed from each replication to determine fresh and dry weight of shoots and roots. Tissue N was determined on the most recently matured leaves using a modified micro-Kjeldahl method (8).

Twelve weeks after fertilization treatments were initiated, at the end of the second flush of growth, two plants per replication were used to determine fresh and dry weight of shoots and roots. Plants were not fertilized during the latter 6 weeks.

TABLE 1.—Fertilizer Treatments Applied to 'Helleri' Holly to Investigate the Relationship Between Time and Length of Fertilizer Application on Plant Growth.

Week or Weeks When Fertilizer Applications Were Made During the First Flush of Growth*	Number of Fertilizer Applications
1	1
2	1
3	1
4	1
5	1
1-2	2
2-3	2
3-4	2
4-5	2
1-3	3
2-4	3
3-5	3
1-4	4
2-5	4
1-5	5

*Treatments began at week 1 when shoots were just beginning to elongate.

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RESULTS

At the end of the first growth flush, there were no differences in shoot or root growth among treatments (data not shown). Nitrogen levels in the tissue were greatest when fertilizer applications were made during a period of growth between cessation of stem elongation at week 3 and the second flush of growth at week 6 (Table 2). For example, when applied for a 1-week period, plants receiving fertilizer during the fourth week had greater tissue N, or when applied for a 2-week period, plants receiving fertilizer weeks 4-5 had greater tissue N. Tissue N was also increased by increasing the number of fertilizer applications. However, little difference occurred between treatments applied for a 3, 4, or 5-week period if they included the fourth week.

During the second flush, shoot growth (dry weight) was generally greatest on treatments which accumulated the higher tissue N levels during the first growth flush (Table 2). Again those treatments which included week 4 appeared to be the most effective in promoting growth during the next flush.

Regardless of the time of fertilizer application during a flush of growth, root dry weight was suppressed with increasing numbers of fertilizer applications (Table 2). For example, root weight averages between the number of applications showed plants receiving four, three, two, and one fertilizer application(s) had 0, 11, 25, and 31% greater root weight, respectively, than plants receiving five fertilizer applications.

DISCUSSION

This study showed no advantage to continuous weekly fertilization at 300 ppm N for optimum shoot growth of *Ilex crenata* 'Helleri'. The second flush of growth on plants receiving two or three weekly fertilizer applications after the cessation of stem elongation in the first flush was equal to growth on plants receiv-

TABLE 2.—Effect of the Time and Number of Weekly Fertilizer Applications During a Flush of Growth on Tissue N Accumulation and Subsequent Shoot and Root Dry Weight of 'Helleri' Holly.*

Total N
Total No. of Weeks Fertilizer Applied

1		2		3		4		5	
wk	% N	wks	% N	wks	% N	wks	% N	wks	% N
4	2.27	4-5	2.27	2-4	2.58	1-4	2.69	1-5	2.59
5	2.04	4-5	2.26	3-5	2.38	2-5	2.55		
3	2.01	2-3	2.23	1-3	2.13				
2	1.99	1-2	2.10						
1	1.88								
LSD 5% = .26									

Shoot Dry Wt
Total No. of Weeks Receiving Fertilizer

1		2		3		4		5	
wk	wt	wks	wt	wks	wt	wks	wt	wks	wt
4	6.2	3-4	6.9	2-4	7.1	1-4	6.5	1-5	7.0
2	5.3	4-5	6.1	3-5	6.7	2-5	6.5		
5	5.2	2-3	5.9	1-3	6.1				
1	5.1	1-2	5.5						
3	4.9								
LSD 5% = 1.24									

Root Dry Wt
Total No. of Weeks Receiving Fertilizer

1		2		3		4		5	
wk	wt	wks	wt	wks	wt	wks	wt	wks	wt
3	2.9	2-3	2.4	1-3	1.9	1-4	1.8	1-5	1.7
1	2.4	3-4	2.4	2-4	1.9	2-5	1.6		
2	2.4	1-2	2.3	3-5	2.0				
4	2.4	4-5	2.0						
5	2.2								
LSD 5% = .50									

*Plants were harvested 12 weeks after initial fertilizer treatments were applied—at the end of the second flush of growth.

ing five weekly fertilizer applications over the entire flush. One explanation for elevated growth with fertilizer treatments applied after the cessation of stem elongation is that the uptake of N, or other nutrients not monitored in this experiment, was more efficient during the period following the cessation of stem elongation. Higher tissue N levels of plants fertilized during the latter part of the flush supported this view. This coincided with an earlier study (5) which showed tissue N to accumulate rapidly during a period following cessation of shoot elongation. Also fall fertilization, which has been reported to stimulate spring growth (7), is applied during the latter part of a growth flush.

Since two or three flushes occur during a growing season with 'Helleri' holly and some other woody species, concentrating fertilization during critical periods following the cessation of stem elongation would reduce the frequency and cost of fertilization without reducing shoot growth.

This study also showed that root growth of 'Helleri' holly was suppressed with three or more fertilizer applications. This agrees with work by Brouwer (1), which showed greater root growth when N was limiting. When one or two fertilizer applications were timed correctly, after the cessation of stem elongation on 'Helleri' holly, both root and shoot growth were at or near maximum for this experiment. These results show that limited fertilization may yield more total growth (shoot + root) if fertilizer applications are timed correctly.

These data concur with earlier work (4) which showed that plants exhibiting episodic growth responded to prior N fertilization. The second flush of growth was a result of N accumulation during or after the first flush, since fertilization was withheld in the second flush of growth.

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Tissue Nitrogen Changes During a Growth Flush on 'Helleri' Holly

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ABSTRACT

The effects of three nitrogen (N) treatments on tissue N fluctuations of *Ilex crenata Thunb.* 'Helleri' were studied. All N concentrations increased following the cessation of shoot elongation until a concentration of tissue N was reached where a new flush of growth began. Nitrogen concentrations at which new growth began were approximately the same for all N treatments. The time necessary to reach this concentration was dependent on the level of N added: 5 weeks for 300 ppm, 13 weeks for 150 ppm, and 18 weeks for 50 ppm N. Once new growth began, tissue N concentration began to decrease.

INTRODUCTION

Tissue analysis in the area of woody ornamentals has been increasing in use as a diagnostic tool for maintaining an efficient fertilizer program, especially for container-grown woody ornamentals. Although limited information is available on tissue analysis and growth of woody ornamentals, tree fruit crops have been extensively investigated. Work with deciduous fruit crops has shown that the concentrations of mobile plant elements generally decrease throughout the summer months. Koo and Young (11) working with avocado showed N, P, and K content of new, fully expanded leaves to decrease from June to December. Similar results were reported by other workers with avocado (2, 6). Pistachio leaflets were initially high in N, P, and Zn, but dropped rapidly during leaf expansion, reaching a steady state during the early summer when stem elongation ceased (16). Other elements reached constant levels later in the season. Similar results with seasonal changes in nutrient concentration were reported for peach (1) and apple (13).

Smith discussed the effect of the second flush of growth on mineral composition of the spring flush of Valencia orange leaves (15). He reported significantly less N, K, and Mg in leaves subtending the additional growth, indicating that these elements were transported to the new growth. This demonstrated that the mobile elements from leaves near the origin of new growth tend to move into new growth. It was also suggested that the presence, absence, or extent of subsequent growth be given consideration in tissue sampling and interpretation of results, especially with N and K.

Davidson (5) has shown that the seasonal nutrient trends of both deciduous and evergreen species of woody ornamentals resembled those reported for deciduous fruit trees. Nitrogen and K decreased throughout the summer; Ca, Mg, Fe, and Mn increased, while P, B, and Cu did not change. This concurred with results reported by Cannon *et al.* (4), Boonstra *et al.* (3), and Smith (14).

Limited data are available on the fluctuations of nutrients in woody ornamentals, which may exhibit two or more flushes of growth during the summer months as has been reported with citrus crops (15). Until this information becomes available, the use of tissue analysis as a means of predicting fertility requirements for plants with multiple growth flushes is limited.

This study was designed to investigate the fluctuation of tissue N during a flush of growth on *Ilex crenata* 'Helleri' grown at three N levels and to determine tissue N concentration at which new growth occurs.

MATERIALS AND METHODS

Unbranched 'Helleri' holly cuttings were taken March 3, 1976, and propagated in 7.6 cm (3 inch) rose pots containing a Weblite (brick by-product) medium. Plants were subsequently grown in a greenhouse at 28° C (day)/21° (night) under natural photoperiod.

On May 23, 1976, three N treatments were initiated. Nutrients were applied with a modified Hoagland and Arnon (9) nutrient solution lacking N and a Hoagland and Arnon micronutrient solution in which 5 ppm of iron was supplied in the form of Na-FeEDTA. The basic nutrient solution was supplemented with N (ammonium nitrate) at 50, 150, and 300 ppm. Twenty ml of the nutrient solution was added weekly to each plant. Plants were watered as needed. A randomized block design with four replications (20 plants/replicate) was used.

Eight weeks later, after shoot elongation for the first flush of growth had ceased on plants grown at 300 ppm N, two plants per replication were used to determine fresh and dry weight of shoots and roots. Tissue samples of shoots were used to determine tissue N by a modified micro-Kjeldahl method (12). For plants receiving 150 and 50 ppm N, initial samples were taken on August 31 and Oct. 7, 1976, respec-

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tively, since it took this long for shoot elongation to cease on these treatments. Weekly sampling continued for all treatments after shoot elongation for the first flush of growth had ceased until stem elongation had ceased on the second flush (9-10 weeks later).

RESULTS

Once shoot elongation and leaf expansion were completed, tissue N concentration began to increase for all three N treatments, until similar levels of 2.1%, 2.0%, and 1.9% were reached for 50, 150, and 300 ppm, respectively (Fig. 1). A new flush of growth began when tissue N concentration reached the above mentioned levels, after which a drop in the tissue N concentration occurred with shoot elongation with the exception of plants grown at 50 ppm N, where tissue N concentration dropped approximately 50% from the beginning of a growth flush to the cessation of shoot elongation. An important difference between the fertilizer treatments was that plants grown at 300 ppm reached the level of N at which a new flush of growth was initiated 9 and 13 weeks before plants grown at 150 and 50 ppm N, respectively. The length of time between growth flushes, and the occurrence of sporadic growth on plants grown at 50 ppm N, resulted in tissue N levels remaining relatively high during the sampling period of the second flush. Plants grown at 300 ppm N had a rapid uniform flush of growth, resulting in a more dramatic fluctuation of tissue N.

DISCUSSION

This study shows that 'Helleri' holly, which has more than one growth flush per season, exhibited rapid fluctuations in tissue N during these flushes. For 'Helleri' holly, rapid changes in tissue N would limit the use of tissue analysis for N during the summer months to critical periods when little change in N concentration is occurring—normally just prior to a new flush. Even then, sampling for tissue N just prior to a new flush is not very meaningful with 'Helleri' holly since, regardless of the rate of fertilizer added, shoots attained similar levels of N just before new growth occurs (Fig. 1). However, these data do not preclude the use of tissue analysis for diagnosis of nutrient deficiencies. For example, sampling plants grown at low N levels (50 ppm) during mid to late summer should indicate a low N status because of the long interval between flushes and slow N accumulation. Consequently, the use of tissue analysis on plants exhibiting low vigor in the summer months may be valuable in detecting plant nutrient deficiency.

Tissue analysis for N also should be beneficial in the fall after the onset of dormancy since studies conducted by Kelly and Shier (10) reported the autumn months to be the most desirable sampling period for *Taxus* because of minimal changes in nutrient concentration at this time. Plants having low tissue N could be supplemented with N during the fall or early spring when media temperatures are above freezing to increase tissue N to the desired concentration (11). Nitrogen added before the spring flush would be available for growth during the spring flush. Tissue N concentration is important since studies have shown the intensity of the spring flush to be dependent upon tissue N levels at the time the flush begins (7, 8).

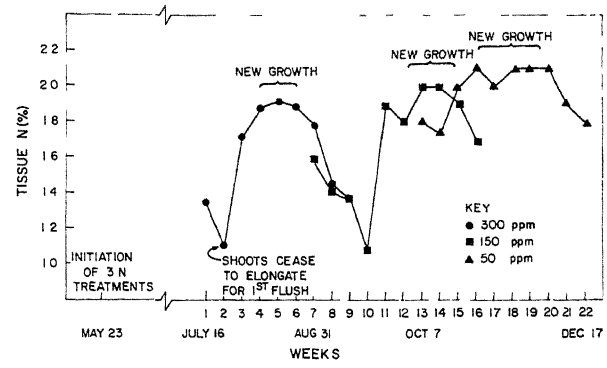

FIG. 1.—Effects of three N levels on tissue N fluctuations during a flush of growth on 'Helleri' holly.

Although the level of tissue N concentration attained before the new growth begins is independent of added fertility, the time necessary to reach this concentration is dependent on the rate of applied fertility. Thus, the advantage of the higher fertilizer rates is that the flushes of growth are more frequent, and thereby result in more total growth at the end of a growing season. Plants grown at higher N levels have a faster rate of growth and more total growth in a given flush than plants grown at lower N rates (7).

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Controlling Winter Annual and Perennial Weeds in Field-Grown *Cotoneaster divaricata*

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ABSTRACT

Dichlobenil (marketed as Casoron) and pronamide (marketed as Kerb) at X, 2X, and in combination controlled winter annuals. Dichlobenil at the X rate controlled perennial weeds and in combination with pronamide at the X rate controlled perennials and winter annuals.

INTRODUCTION

The application of simazine to control annual weeds in field grown nursery stock has been a standard practice in Ohio for more than 20 years. During this period of nearly constant use, certain weeds have not been controlled, particularly winter annual and perennial weeds, which have increased and become a serious problem. Until recently the only preemergent herbicide available that could be used in existing nursery plantings to control perennial weeds has been dichlobenil. The granular form of dichlobenil has been shown to be very effective in the control of both annual and perennial weeds (1, 2, 3, 4). However, its higher cost has limited its use.

A relatively new herbicide, pronamide, effectively controls perennial grasses (1, 5) and selected broadleaved perennials (4). However, it has not been utilized extensively within the nursery industry due to its limited registration.

A study was undertaken to evaluate dichlobenil and pronamide used singly and in combination for the control of winter annual and perennial weeds in a field nursery of Spreading Cotoneaster.

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MATERIALS AND METHODS

This study was conducted in the field research nursery on the campus of The Ohio State University, Columbus. *Cotoneaster divaricata* (Spreading Cotoneaster) 30-36 inches in size were selected as the test plants since most nurseries grow Cotoneaster species and data are needed to add this plant to the pronamide label.

Dichlobenil at 6.0 lb ai/A and pronamide at 2.0 lb ai/A were applied at recommended and 2X rates alone and in combination.

The herbicides were applied on Dec. 16, 1977, and the results evaluated May 24, 1978. Each plot 21 feet long by 4 feet wide and containing a minimum of seven plants was replicated three times in a randomized design.

The winter annuals evaluated on a visual scale of 0-100% were: Downy Brome (*Bromus tectorum*), Prickly Lettuce (*Lactuca scariola*), and Shepherdspurse (*Capsella bursa-pastoris*). The perennial weeds included: Canada Thistle (*Circium arvense*), Curly Dock (*Rumex crispus*), Dandelion (*Taraxacum officinale*), and Yellow Rocket (*Barbarea vulgaris*).

RESULTS AND DISCUSSION

Both dichlobenil and pronamide, at all rates, controlled Downy Brome, Prickly Lettuce, and Shepherdspurse. Outstanding control was achieved when the two herbicides were combined into a single application, even though each was applied separately. Among the three winter annuals, Downy Brome is the more serious weed and pronamide resulted in 100% control at all rates. These results with Downy Brome were not surprising as pronamide is most effective against grass weeds.

TABLE 1.—Control of Winter Annual Weeds with Dichlobenil and Pronamide in Cotoneaster divaricata.

Treatment and Rate		Percent Control*		
		Downy Brome	Prickly Lettuce	Shepherdspurse
Dichlobenil 4G	6.0 AIA	93	100	97
Dichlobenil 4G	12.0 AIA	100	100	97
Pronamide 50W	2.0 AIA	100	93	100
Pronamide 50W	4.0 AIA	100	90	93
Dichlobenil 4G + Pronamide 50W	6.0 AIA + 2.0 AIA	100	100	100
Dichlobenil 4G + Pronamide 50W	12.0 AIA + 4.0 AIA	100	100	100
Control		20	10	30

*Values of 70 or above are considered commercially acceptable.

TABLE 2.—Control of Perennial Weeds in Dichlobenil and Pronamide in Cotoneaster divaricata.

Treatment and Rate		Percent Control*			
		Dandelion	Canadian Thistle	Yellow Rocket	Curly Dock
Dichlobenil 4G	6.0 AIA	93	90	93	100
Dichlobenil 4G	12.0 AIA	100	90	100	100
Pronamide 50W	2.0 AIA	0	0	87	100
Pronamide 50W	4.0 AIA	0	0	70	100
Dichlobenil 4G + Pronamide 50W	6.0 AIA + 2.0 AIA	100	87	97	100
Dichlobenil 4G + Pronamide 50W	12.0 AIA + 4.0 AIA	100	97	97	100
Control		0	0	0	0

*Values of 70 or above are considered commercially acceptable.

Dichlobenil controlled Canada Thistle, Curly Dock, Dandelion, and Yellow Rocket very satisfactorily at the 6.0 and 12.0 rates (Table 2). These results are encouraging because Canada Thistle is always a problem in nurseries and Dandelion is becoming a very serious weed pest since it's tolerant to simazine. Pronamide controlled Curly Dock as shown previously (4) and Yellow Rocket, while Canada Thistle and Dandelion were not controlled.

Good control of all four perennial weeds was achieved with the combination of the two products at recommended rates, but control was not appreciably better than with dichlobenil alone.

The cotoneaster was not injured with either product at the recommended or 2X rates.

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Evaluation of Oxadiazon for Weed Control in Container-Grown Nursery Stock

THOMAS A. FRETZ and WENDY J. SHEPPARD[2]

ABSTRACT

Pre-emergent applications of oxadiazon (Ronstar) at 2.0, 4.0, 8.0, and 16.0 lb ai/A in three granular formulations (2, 5, and 10G) were made to five species of container-grown nursery stock. The 4.0 lb ai/A rate of oxadiazon in the 2G formulation resulted in effective grass and broadleaf weed control with no phytotoxicity.

INTRODUCTION

Research by the senior author has previously demonstrated that weed growth can significantly reduce growth of ornamental plants grown in containers (2). Since cultivation in the container nursery is impossible and manual weeding on a large scale becomes exceedingly expensive (5), losses resulting from this competition can be devastating (2). Thus, it is necessary to rely on the use of herbicides to reduce these losses.

Numerous reports have been published comparing the effects of pre-emergent herbicides for controlling weeds in container-grown nursery stock (1, 3, 4, 6). However, in most cases only limited information is available on the means of application. For this reason, a study was initiated to compare the weed control and phytotoxicity resulting when oxadiazon (Ronstar) was applied at the same rates in three different granular formulations.

MATERIALS AND METHODS

This study was conducted in the Department of Horticulture container nursery at The Ohio State University to evaluate the effects of oxadiazon (2-tert-butyl-4-(2,4 dichloro-5-isopropoxyphenyl)-Δ^2-1, 3, 4-oxadiazolin-5-one) when applied to five species of container-grown plants. All granular formulations (2, 5, and 10G) of the oxadiazon were applied with a hand shaker to distribute the granules uniformly over a predetermined area. Each formulation was applied at a rate of 1/2, 1, 2, and 4x the recommended rate. All plants received a standard fertilization and maintenance program following the herbicide applications.

Uniform cuttings of Blue Rug Juniper (*Juniperus horizontalis* 'Blue Rug'), Cranberry Cotoneaster (*Cotoneaster apiculata*), Red Osier Dogwood (*Cornus sericea*), Border Forsythia (*Forsythia intermedia* ('Spectabilis'), and Manhattan Euonymus (*Euonymous kiautschovicus* 'Manhattan') were planted in 1-gallon nursery containers on May 24, 1977. The medium used for all plants was composed of 2 parts sphagnum peat, 1 part sand, and 1 part composted hardwood bark.

Twenty-four hours prior to the application of the herbicides, large crabgrass (*Digitaria sanguinalis*), rough pigweed (*Amaranthus retraflexus*), and lambsquarter (*Chenopodium album*) were sown in the containers to insure a uniform weed population.

Weed control and phytotoxicity evaluations were made 35, 70, and 105 days after herbicide application, using a 0-100% scale in comparison to the control treatments. The study was designed and analyzed as a completely randomized block with four replications (three plants/replicate) of each treatment.

RESULTS AND DISCUSSION

In terms of both grass and broadleaf weed control, it was a general observation that the minimum acceptable rate was 4.0 lb ai/A. Regardless of the formulation, applications of oxadiazon at the 2.0 lb ai/A rate (one-half the recommended rate) generally resulted in unacceptable grass and broadleaf weed control (Table 1).

Season-long control of crabgrass was achieved with the 2G formulation of oxadiazon at the 4.0 lb

TABLE 1.—Percent Control of Large Crabgrass 35, 70, and 105 Days After Application of Oxadiazon on Container-grown Nursery Crops.

Formulation	Rate	Percent Crabgrass Control Days After Application		
(%)	(lb ai/A)	35	70	105
2G	2.0	91*	71	68
2G	4.0	100	96	97
2G	8.0	100	98	98
2G	16.0	100	100	100
5G	2.0	75	59	59
5G	4.0	92	79	79
5G	8.0	98	98	98
5G	16.0	100	97	98
10G	2.0	51	31	27
10G	4.0	60	49	47
10G	8.0	93	80	81
10G	16.0	98	97	95
Weedy Control		31	16	13

*Weed control values less than 75% are considered commercially unacceptable.

[1]Supported in part by a grant from the Rhodia, Inc., Chipman Division, Somerset, N. J.

[2]Associate Professor and Agricultural Technician, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

TABLE 2.—Percent Control of Rough Pigweed and Lambsquarter 35, 70, and 105 Days After Application of Oxadiazon on Container-grown Nursery Crops.

Formulation	Rate	Percent Control					
		Rough Pigweed			Lambsquarter		
		Days After Application					
(%)	(lb ai/A)	35	70	105	35	70	105
2G	2.0	90*	84	92	100	95	100
2G	4.0	100	98	98	99	98	100
2G	8.0	100	100	100	100	100	100
2G	16.0	100	100	100	100	100	100
5G	2.0	92	84	92	100	100	100
5G	4.0	97	94	100	99	100	100
5G	8.0	100	100	100	100	100	100
5G	16.0	100	100	100	100	100	100
10G	2.0	57	61	85	91	91	94
10G	4.0	74	81	87	100	98	100
10G	8.0	97	100	100	100	100	100
10G	16.0	99	100	100	100	100	100
Weedy Control		31	19	51	34	32	53

*Weed control values less than 75% are considered commercially unacceptable.

ai/A rate, but not with the 5G and 10G formulations at the same rate (Table 1). It was observed at the time of application that a more even distribution over the soil surface was achieved with the 2G formulation when compared to the other two formulations. Both the 5G and 10G formulations were difficult to distribute over the measured area at the 2 and 4 lb ai/A rates and as a result the weed control was less than desirable.

The greatest phytotoxicity occurred on the Cranberry Cotoneaster plants treated with the 2G formulation at rates of 8 and 16 lb ai/A and with the 5G formulation at the 16 lb ai/A rate. Phytotoxicity was noted within 30 days of application of the oxadiazon in the form of marginal leaf scorch and an overall loss of green color. This injury was less than 20% and could not be detected at the completion of the growing season (Table 3).

In general, the most significant phytotoxicity occurred with the high rates of the 2G formulation of oxadiazon on Forsythia, Red Osier Dogwood, and Cranberry Cotoneaster within the first month after application (Table 3). Presumably, with the 2G formulation there was better distribution of the oxadiazon over the soil surface, thereby resulting in greater root absorption. By the end of the growing season, this injury was undetectable (Table 3).

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TABLE 3.—Percent Phytotoxicity 35, 70, and 105 Days After Application of Oxadiazon on Five Species of Container-grown Nursery Stock.

Formulation (%)	Rate (lb ai/A)	Percent Phytotoxicity														
		Blue Rug Juniper			Manhattan Euonymus			Forsythia			Cranberry Cotoneaster			Red Osier Dogwood		
		Days After Application														
		35	70	105	35	70	105	35	70	105	35	70	105	35	70	105
2G	2.0	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2G	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2G	8.0	0	0	0	0	0	0	15	0	0	15	10	0	15	0	0
2G	16.0	0	0	0	0	0	0	0	0	0	20	13	5	18	8	0
5G	2.0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
5G	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5G	8.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5G	16.0	0	0	0	0	0	0	0	0	0	15	5	0	0	8	0
10G	2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10G	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10G	8.0	0	10	8	0	0	0	0	0	0	0	5	0	0	0	0
10G	16.0	0	0	0	0	0	0	0	0	0	0	5	10	0	0	0
Weedy Control		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Values greater than 20% are considered commercially unacceptable.

A 10-Year Evaluation of Flowering Crabapple Susceptibility to Apple Scab in Ohio

ELTON M. SMITH[1]

ABSTRACT

From 1969-1978, approximately 150 species, hybrids, and cultivars of flowering crabapples have been evaluated for susceptibility to apple scab. Seventy-four selections have been found to be resistant or highly resistant and represent those which form the basis for future production.

INTRODUCTION

The flowering crabapple is the most popular small tree for landscape planting in Ohio, due to its spectacular display of flowers in spring and attractive fruit in autumn. The main disadvantage to flowering crabapple is its susceptibility to a number of diseases, the most serious being apple scab caused by the fungus *Venturia inaequalis*. This fungus causes the foliage of certain species and cultivars to develop olive-gray spots which often become yellow and defoliate by mid-summer. Spraying existing trees with one of several fungicides such as Benlate, Cyprex, or Captan will prevent this disease.

There are more than 600 species, hybrids, and cultivars of flowering crabapples including new selections and older forms found mainly in arboretums. Certain selections are resistant or nearly resistant to apple scab and these are the types which should be propagated and commercially produced, assuming horticultural qualities warrant their production and subsequent consumer acceptance.

MATERIALS AND METHODS

A survey has been conducted of arboretums and nurseries in Ohio during July or August in each of the years between 1969 and 1978 to rate flowering crabapples according to their susceptibility to apple scab (1-9). In addition, the presence of other diseases has been noted, although not rated because they are usually not as serious as apple scab. Among the diseases observed were fireblight, cedar-apple rust, powdery mildew, and frog eye leaf spot.

The scale for apple scab evaluation was as follows: HR = Highly Resistant = no indication of disease; R = Resistant = mild infection with no defoliation; S = Susceptible = medium infection with only slight defoliation; and HS = Highly Susceptible =heavy infection often accompanied by considerable defoliation. Since more than one observation was made for most flowering crabapples each year in different locations and severity of diseases varied due to weather conditions from year to year, more than one notation appears in the table for a number of types.

[1]Professor, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

RESULTS AND DISCUSSION

Approximately 150 types have been included in these evaluations and of this total one-half are rated highly resistant or resistant. These resistant species, hybrids, and cultivars should be considered for future planting. Not all of the resistant types are excellent horticultural specimens. For example, 'Centennial' and 'Marshall Oyama' have very large fruit, *M. hartwigii* and 'Sissipuk' are older types with poor overall foliage and fruit qualities, *M. tschonoski* does not flower well, *M. hupehensis* is alternate bearing, and several types such as 'David', 'Robinson', and *M. zumi* 'Wooster' are relatively new in the trade and complete performance data are unavailable.

If plants are selected from the susceptible and highly susceptible list, consumers should be made aware of the problem(s) and a spray program provided. It would be preferable that plants in this category no longer be grown including the very popular 'Almey', 'Hopa', *M. purpurea* 'Eleyi', and 'Radiant'.

To learn more about the flower, fruit, and habit of growth of the flowering crabapples on this list, visit one of the arboretums in Ohio in early May or mid-autumn. The Secrest Arboretum in Wooster, Dawes Arboretum in Newark, and Holden Arboretum in Kirtland Hills feature excellent collections of flowering crabapples.

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TABLE 1.—Susceptibility of Flowering Crabapples in Ohio to Apple Scab, 1969-1978.

Species, Hybrid, or Cultivar	Apple Scab Rating* HR	R	S	HS	Diseases Noted
'Adams'	X				
M. x adstringens				X	
'Almey'				X	
'American Beauty'			X		
'Amisk'			X	X	
M. x arnoldiana			X	X	
'Arrow'			X	X	
M. x atrosanguinea		X			
M. baccata			X		Fireblight
M. baccata 'Columnaris		X			
M. baccata 'Jackii'	X				
M. baccata var. mandshurica	X				
'Beverly'	X				
'Bob White'	X				
M. brevipes				X	
'Cashmere'	X	X			
'Centennial'	X				
'Cheal's Crimson'			X	X	
'Chestnut'		X			
'Chilko'		X	X		
'Coralburst'	X	X			Frog eye leaf spot
M. coronaria			X	X	Cedar apple rust
M. coronaria 'Charlottae'			X	X	Cedar apple rust
M. coronaria 'Dasycalyx'			X		Cedar apple rust
M. coronaria 'Nieuwlandiana'		X	X		Cedar apple rust, Frog eye leaf spot
'Cowichan'			X		
'Crimson Brilliant'				X	
'Dainty'		X			
'David'	X				
'Dolgo'	X				
'Donald Wyman'	X				
'Dorothea'			X		
'Ellen Gerhart'		X			
'Evelyn'	X	X			Fireblight, Frog eye leaf spot
'Flame'			X		
M. florentina	X				
M. floribunda	X				
'Geneva'			X		Frog eye leaf spot
'Gorgeous'		X			
M. glaucescens		X			
M. gloriosa			X		Frog eye leaf spot
'Golden Hornet'	X				
'Gwendolyn'	X				
M. halliana	X				
M. halliana 'Parkmanii'	X				
M. x hartwigii	X				
'Henrietta Crosby'				X	
'Henry Dupont'		X	X		
'Hopa'				X	
'Hopa Rosea'				X	

*HR = Highly Resistant, R = Resistant, S = Susceptible, and HS = Highly Susceptible

TABLE 1. (Continued)—Susceptibility of Flowering Crabapples in Ohio to Apple Scab, 1969-1978.

Species, Hybrid, or Cultivar	Apple Scab Rating HR	R	S	HS	Diseases Noted
M. hupehensis	X				
M. hupehensis 'Rosea'	X				
'Indian Magic'	X	X			
M. ioensis 'Klehms'		X	X		Fireblight, Cedar apple rust, Frog eye leaf spot
M. ioensis 'Klehms Improved'			X		
'Irene'				X	
'Jay Darling'				X	
'Dwarf Kaido'	X				
'Katherine'		X	X		
'Dwarf Katherine'		X	X		
'Kibele'	X				
'Kingsmere'			X		
M. lancifolia			X		
M. lancifolia 'Allegeny'		X			
'Leslie'				X	
'Liset'	X				
M. x madgeburgensis	X	X			Powdery mildew
'Makamik'	X				
'Mary Potter'	X				
'Marshall Oyama'	X	X			
'Masek'		X			
M. x micromalus	X				
'Oakes'			X	X	Powdery mildew
'Oekonomierat Echtermeyer'			X	X	
'Ormiston Roy'	X				
'Patricia'			X		
'Pink Beauty'			X		
'Pink Cascade'			X		
'Pink Flame'			X		
'Pink Perfection'				X	
'Pink Spires'		X	X		
'Pink Weeper'			X		
'Prairie Rose'	X				Cedar apple rust, Frog eye leaf spot
'Prince Georges'	X				Cedar apple rust
M. prunifolia var. rinkii				X	
M. pumila 'Elise Rathke'			X		
M. pumila 'Niedzwetzkyana'			X	X	
'Purple Wave'			X	X	
M. x purpurea			X	X	
M. x purpurea 'Aldenhamensis'			X		
M. x purpurea 'Eleyi'				X	
M. x purpurea 'Lemoinei'			X		
'Pygmy'		X			
'Radiant'				X	
'Redfield'			X	X	
'Red Jade'	X	X			
'Red Jewel'	X				
'Red Silver'		X	X		
'Red Splendor'		X			
'Ringo'		X			
'Robinson'	X				
M. x robusta	X				
M. x robusta 'Erecta'				X	
M. x robusta 'Leucocarpa'	X				Fireblight
M. x robusta 'Persicifolia'	X				
'Rose Tea'	X				
'Rosseau'	X				
'Royal Ruby'			X		
'Royalty'			X		
'Rudolf'		X	X		

*HR = Highly Resistant, R = Resistant, S = Susceptible, and HS = Highly Susceptible

TABLE 1. (Continued)—Susceptibility of Flowering Crabapples in Ohio to Apple Scab, 1969-1978.

Species, Hybrid, or Cultivar	Apple Scab Rating HR	R	S	HS	Diseases Noted
M. sargentii	X				
M. sargentii 'Rosea'	X	X			
M. x scheideckeri		X	X		
M. x scheideckeri 'Hillieri'		X	X		
M. x scheideckeri 'Dwarf Hillieri'		X			
'Scugog'		X	X		
'Selkirk'	X	X			
M. sieboldi var. arborescens	X				
M. sikkimensis	X				
'Silver Moon'	X				
'Simcoe'		X	X		
'Sissipuk'	X				Powdery mildew
'Snowcap'	X	X			
'Snowcloud'	X	X			
'Snowdrift'	X				Fireblight
M. x soulardii			X		
'Sparkler'			X		
M. spectabilis 'Albi-Plena'		X	X		
M. spectabilis 'Riversii'		X			Powdery mildew
M. spectabilis 'Van Eseltinei'		X			
'Spring Snow'		X	X		
'Strathmore'				X	Frog eye leaf spot
M. x sublobata		X	X		
'Sundog'		X			
'Tanner'		X	X		
M. transitoria	X	X			
M. tschonoski	X				Fireblight
'Turesi'			X		
'Valley City 4'			X	X	
'Vanguard'			X	X	
'Wabiskaw'			X	X	
'White Angel'	X				
'White Candle'		X	X		
'Wilson'			X	X	
'Winter Gold'		X			
M. yunnanensis 'Veitchi'	X				Fireblight
M. zumi		X	X		Fireblight
M. zumi 'Calocarpa'	X				Fireblight
M. zumi 'Wooster'	X	X			

*HR = Highly Resistant, R = Resistant, S = Susceptible, and HS = Highly Susceptible

Fungicides for the Control of Diseases of Ornamental Plants: Results of 1977 Trials

C. C. POWELL and JAMES A. CHATFIELD[1]

INTRODUCTION

Research in 1977 to determine fungicides useful in controlling some common diseases of ornamental plants was largely centered on gathering data that could be used to expand labels of products already labeled for use on other crops and diseases. This label expansion work was part of a national effort funded by the USDA and coordinated specifically to aid in achieving additional labeled uses for *minor* or *specialty* crops.

Federal laws pertaining to the use of pesticides state that any use not specifically listed on a label is illegal. Users are subject to federal prosecution. Therefore, there is a great need to get more ornamental uses labeled so growers are not forced to break the law to manage diseases on their crops. In order to get a use labeled, disease control plus lack of plant damage (phytotoxicity) must be demonstrated.

In addition to the label expansion program, several tests were conducted which included combinations of fungicides. The objective was to determine if total pesticide use could be lessened with such combinations. Finally, several tests included materials not yet on the market (experimental compounds).

METHODS AND RESULTS

Trial 1: Shot-hole leafspot (caused by *Cercospora cladosporiodes*) on cherry laurel (*Prunus caroliniana*): Sprays were initiated on May 19 and repeated on May 31, June 14, 28, July 28, August 10, 24, and Sept. 11. Note that one spray date (scheduled for July 15) was missed between the dates of June 28 and July 28. Four replicates of approximately 40 plants per replicate were sprayed for each of six treatments. Sprays were applied to runoff with a 2-gallon CO_2-charged sprayer (25 psi). Plants were potted in 1-gallon containers, placed in a field bed, and overhead irrigated.

Disease appeared late in the season and severity was rated on Sept. 19. The two rates of Daconil 6F and the higher rate of MF-598 provided significantly better disease control than the other treatments. No phytotoxicity or unacceptable residue were noted.

TABLE 1.—Chemical Control of Shot-hole Leafspot on Cherry Laurel.

Treatment	Rate/100 Gallons	Disease Severity*
Daconil 6F	3.0 pt	1.4 a†
MF 598 + Exhalt-800	42.0 oz + 8 oz	1.5 a
Daconil 6F	1.5 pt	1.5 a
MF 598 + Exhalt-800	21.0 oz + 8 oz	2.0 b
Benlate 50 WP + Exhalt-800	16 oz + 8 oz	2.4 c
Check		2.7 c

*Disease severity rated on a 0 to 5 scale, with 0 = no disease, 5 = maximum disease severity (75% of leaves with at least one lesion).

†The letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

Trial 2: Bacterial leafspot (caused by *Xanthomonas hederae*) on Thorndale Ivy (*Hedera helix* 'Thornedale'): Biweekly sprays were applied on May 3, 18, 31, June 14, 28, July 14, 27, August 10 and 25, 1977. Six replicates of approximately 8 feet of row (approximately eight plants per replicate) of ground bed plantings in the field were sprayed for each of nine treatments. A 2-gallon, CO_2-charged sprayer was used at 25 psi. Plants were sprayed to runoff.

Heavy residues were present on the Kocide 101 and Manzate 200 combination treatments, with slightly lesser residue on the Kocide 101 alone treatments. Treatments were evaluated on August 30 for disease incidence. Disease was moderately heavy. Kocide 101 treatments with and without Manzate 200 gave the best control of disease, with Agri-Strep giving less satisfactory control and Terramycin little improvement over the untreated plants. The addition of Manzate 200 to the Kocide 101 treatment only slightly improved control. No phytotoxicity was noted.

[1]Associate Professor and Graduate Student, Dept. of Plant Pathology, The Ohio State University and Ohio Agricultural Research and Development Center.

TABLE 2.—Bacterial Leafspot of Ivy Controlled Best with Copper.

Treatment	Rate/100 Gallons	Disease Severity*
Kocide 101, 77 WP + Manzate, 80 WP + Exhalt-800	16 oz + 16 oz + 8 oz	0.4 a†
Kocide 101, 77 WP + Exhalt-800	32 oz + 8 oz	0.7 ab
Kocide 101, 77 WP + Manzate 200, 80 WP + Exhalt-800	32 oz + 32 oz + 8 oz	0.8 ab
Kocide 101, 77 WP + Exhalt-800	16 oz + 8 oz	1.0 bc
Agri-strep, 21.2 WP + Exhalt-800	16 oz + 8 oz	1.3 cd
Agri-strep, 21.2 WP + Exhalt-800	32 oz + 8 oz	1.5 d
Terramycin, 17 WP + Exhalt-800	16 oz + 8 oz	2.2 e
Terramycin, 17 WP + Exhalt-800	8 oz + 8 oz	2.4 ef
Check		2.6 f

*Disease severity rated on a 0 to 4 scale, with 0 = no disease, 4 = maximum disease severity (approximately 20% of leaves with lesions).
†The letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

Trial 3: Canker (caused by *Diaporthe vincae*) on vinca (*Vinca minor*): *Vinca minor* grown in plastic flats with slat shading were sprayed bi-weekly on June 20, July 5, 20, August 3, 17, and 30. Four replications of five flats per replication (25 plants per flat) for each of seven treatments were sprayed to runoff with a 2-gallon CO_2-pressurized sprayer (25 psi). Flats were placed on the ground and overhead irrigated.

Disease ratings were made on Sept. 19. With light disease incidence, all sprays provided good control over the untreated plants with the Benlate 50 WP, Manzate 200, and the higher rate of Daconil 6F providing the best control. No phytotoxicity was noted.

TABLE 3.—Control of Vinca Canker and Blight with Chemicals.

Treatment	Rate/100 Gallons	Disease Severity*
Benlate 50 WP + Manzate 200 + Exhalt-800	8 oz +16 oz + 8 oz	0.3 a†
Daconil 6F	3 pt	0.5 ab
Benlate 50 WP + Exhalt-800	16 oz + 8 oz	0.7 ab
Manzate 200 + Exhalt-800	48 oz + 8 oz	0.7 ab
Manzate 200 + Exhalt-800	24 oz + 8 oz	0.7 ab
Daconil 6F	1.5 pt	1.1 c
Check		3.7 d

*Disease incidence given as the average number of infected plants out of 25 per flat.
†The letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

Trial 4: Blight (caused by *Volutella pachysandrae*) on *Pachysandra:* .Pachysandra cuttings were stuck in flats between July 1 and July 15. The flats were placed in a slat house with overhead irrigation supplemented with mist (automatic, once each 15 min until August 15). On spray dates, mist was shut off prior to spraying and kept off until the next morning. Biweekly sprays were initiated on July 27 and continued on August 10, 24, and Sept. 10. Five replicates of eight flats each (approximately 25 plants per flat) for each of 11 treatments were sprayed to runoff with a 2-gallon, CO_2-pressurized sprayer (approx. 25 psi).

Disease ratings were made on Sept. 19. Disease incidence was light, but even at this level several treatments provided significantly better control of disease than the untreated plants. The addition of Manzate 200 to Benlate only slightly improved control. No phytotoxicity was seen.

TABLE 4.—Pachysandra Blight Control.

Treatment	Rate/100 Gallons	Disease Severity*
Benlate 50 WP + Manzate 200 + Exhalt-800	8 oz + 16 oz + 8 oz	0.7 a†
MF 598 + Exhalt-800	42 oz + 8 oz	0.8 ab
Benlate 50 WP + Exhalt-800	16 oz + 8 oz	0.8 ab
Benlate 50 WP + Exhalt-800	8 oz + 8 oz	0.9 ab
Daconil 6F	3 pt	0.9 abc
MF 598 + Exhalt-800	21 oz + 8 oz	1.0 abc
Daconil 6F	1½ pt	1.2 bcd
Manzate 200 + Exhalt-800	24 oz + 8 oz	1.2 bcd
Daconil 75 W	24 oz	1.2 bcd
Manzate 200 + Exhalt-800	48 oz + 8 oz	1.4 cd
Check		1.5 d

*Disease severity rated on a 0 to 5 scale, with 0 = no disease, 5 = maximum disease expression (50% of plants in flat infected).

†The letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

Trial 5: Powdery mildew (caused by *Microsphaera alni*) on Mollis azalea (*Rhododendron* sp.): Three sprays were applied on July 20, August 4 and 18 to field-grown Mollis azaleas (approximately 2 feet tall). Four replications of approximately 13 plants per replication were sprayed for each of nine treatments. Plants were sprayed to runoff with a 10-gallon power sprayer (centrifugal pump—45 psi). Disease was present in the test plants prior to initiation of the experiment. Heavily infected plants at that time were marked and excluded from the trials.

Disease severity ratings were made on August 30. Disease ratings were based on infection of upper foliage, which occurred after the trial was begun. All treatments provided excellent control of disease with the exception of Nimrod. No phytotoxicity was noted.

TABLE 5.—Benlate Plus Spreader for Azalea Mildew Control.

Treatments	Rate/100 Gallons	Disease Severity*
Benlate 50 WP + Exhalt-800	8 oz + 8 oz	0.1 a†
MF 598 + Exhalt-800	42 oz + 8 oz	0.1 a
Benlate 50 WP + Nimrod (PP 588) 25 EC	8 oz + 3.5 oz	0.2 a
Bayleton 50 WP + Exhalt-800	2 oz + 8 oz	0.3 a
Bayleton 50 WP + Exhalt-800	4 oz + 8 oz	0.5 ab
MF 598 + Exhalt-800	21 oz + 8 oz	0.8 b
Nimrod (PP 588)	14 oz	2.1 c
Nimrod (PP 588)	7 oz	2.5 c
Check		4.2 d

*Disease severity was rated on a 0 to 5 scale, with 0 = no disease, 5 = 100% of upper leaves with powdery mildew lesions.

†The letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

Trial 6: Black spot (caused by *Diplocarpon rosae*) on Peace and Command Performance roses (*Rosa dilecta*): Black spot appeared on the 'Peace' roses about June 15. Biweekly sprays on both cultivars were initiated on June 27 and repeated on July 12, 26, August 12, 23, and Sept. 11. Two-year-old plants were in field plantings, on 4-foot centers in the row. They were not irrigated. Three replications of three plants each for six treatments were sprayed to runoff with a 2-gallon, CO_2-pressurized sprayer (25 psi).

Disease severity ratings were made on Sept. 12. Benlate 50 WP and MF 598 provided the best control of disease on both cultivars. Disease had already appeared on the 'Peace' cultivar prior to spraying; thus, severity in all treatments was higher. Benlate 50 WP provided significantly better control than MF 598 on the 'Peace' cultivar. Bayleton failed to satisfactorily control the disease at these rates on either cultivar. No phototoxicity was noted.

TABLE 6.—Black Spot of Rose Spray Trial Results.

Treatment	Rate/100 Gallons	Disease Rating*	
		Command Performance	Peace
Benlate 50 WP + Exhalt-800	8 oz + 8 oz	0.0 a†	1.6 a
MF 598 + Exhalt-800	21 oz + 8 oz	0.1 a	3.1 b
MF 598 + Exhalt-800	42 oz + 8 oz	0.2 a	2.8 b
Bayleton 50 WP + Exhalt-800	2 oz + 8 oz	2.3 b	
Bayleton 50 WP + Exhalt-800	4 oz + 8 oz	3.6 c	4.4 c
Bayleton 50 WP + Exhalt-800	8 oz + 8 oz	3.6 c	4.6 c
Check		4.3 d	4.8 c

*Disease severity rated on a 0 to 5 scale, with 0 = no disease, 5 = 100% of foliage with at least one lesion or defoliated.
†The letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level. Each cultivar analyzed separately.

DISCUSSION

Because of light rainfall during the summer of 1977, disease incidence was light in most of the reported trials. The ability of the chemicals to control disease was demonstrable in spite of light incidence. The higher rate of Daconil (3.0 pints/100 gallons) seemed to be more efficacious than the 1.5 pint rate. Such an effect may be even more pronounced under heavier disease pressure. The Manzate-Benlate combinations or the Manzate-Kocide combinations did not significantly improve the control as compared to either chemical alone in these trials. Less active ingredient of chemical was used, however. Again, the value of this combination of fungicides should be further tested under heavier disease pressure. Bayleton 50 WP continues to be a promising fungicide for powdery mildew control on many ornamentals. However, it was not effective for control of rose black spot.

TABLE 7.—Experimental Chemicals Used in 1977 Trials.

Name (or Code Number)	Formulation	Common Name	Technical Name	Supplier
1) MF 598	15-60	15% Thiophanate Methyl + 60% Mancozeb		Mallinkrodt
2) Bayleton	50 WP		1-(4-chlorophenoxy)-3, 3-dimethyl 1-(1 H-1, 2, 4-triazol-1-yl)-2 butanone	Chemagro Division of Mobay Chemical Corp.

An Evaluation of Fungicides on Container-Grown Woody Ornamentals During Winter Storage Under Microfoam

CHRISTOPHER F. RIZZO, ELTON M. SMITH, and THOMAS A. FRETZ[1]

ABSTRACT

Three fungicide treatments chlorothalonil (tetrachloroisophtholonitrile), captan (cis-N-(trichloromethyl) thio-4-cyclohexene-1, 2-dicarboximide) plus PCNB (pentachloronitrobenzene), and benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate) were evaluated for their control of storage molds on woody ornamentals during winter storage under Microfoam. All treatments provided adequate control of storage molds when compared to untreated plants.

INTRODUCTION

The Microfoam bed as described by Gouin (3) is a newly developed method for overwintering container-grown and balled and burlapped woody ornamentals. Field studies have indicated that this system will provide adequate freeze protection against temperatures as low as —8° C for many root tender species such as Ilex, Pyracantha, and Cotoneaster (3, 4, 5).

One disadvantage of the Microfoam bed system is the development of storage molds on overwintering plants (3, 11). These molds are prevalent under this system due to the high relative humidity. Aeration to alleviate this problem is not possible during most of the winter for the Microfoam and plastic film edges are often frozen to the ground. Thus, optimal conditions for the spread and growth of many storage molds are nearly always present under Microfoam beds (12). In addition, when tightly packed plants are tipped on their sides the foliage, buds, and stems are likely to be in contact with defoliated leaves, weeds, and soil, providing sources of storage mold inoculum (11).

Gray mold, *Botrytis,* is the most significant fungal disease found under Microfoam beds (8, 9). *Botrytis* spores will germinate and penetrate plant tissues only when the relative humidity is 95% or more for several hours with optimum temperatures from 22-25° C (9). After infection takes place, growth of *Botrytis* will occur at temperatures of 0-35° C if high relative humidities are present (12).

Benomyl is currently the only fungicide registered to control *Botrytis* on woody ornamentals (8). Two major problems, however, are associated with the use of this product. The label specifies that the product should be applied every 10-14 days and a spray program with this frequency is not only economically unfeasible but often impossible during cold winter months when the edges of the beds are frozen to the ground (9). Secondly, many strains of *Botrytis* attacking other crops such as cyclamen, strawberry, and tomato have developed resistance to benomyl (2, 6, 7). It has been suggested that this resistance may occur with *Botrytis* strains found on stored ornamentals (9). As a result, a second study was initiated to evaluate possible alternative fungicides for control of this organism.

In work by Partyka (8) in both cold and common storage of *Rosa, Ligustrum, Lonicera,* and *Euonymus,* the combination of captan-PCNB and chlorthalonil alone provided the best control of *Botrytis.* Powell (9) found on evergreen ornamentals stored under plastic covered structures without Microfoam that both chlorothalonil and the combination of captan-PCNB fungicide treatments were effective. Due to their success, the above fungicides were included in the evaluations.

MATERIALS AND METHODS

Three fungicide treatments and one water control were sprayed on four container-grown plant species prior to 4 months' winter storage under Microfoam beds in the research nursery at The Ohio State University campus in Columbus. Plants were sprayed and baited for rodents with zinc phosphide treated grain on Dec. 10, 1976, 1 day after they were irrigated. The plants were then placed on their sides and packed tightly side by side directly on the ground. A single layer of 0.64 cm Microfoam followed by a single layer of white 4 mil plastic film was placed directly over the plants. The edges of the plastic and Microfoam were then sealed to the ground with a gravel covering, forming beds 25 cm high, 1 m wide, and 6 m long.

All treatments were replicated three times using a randomized complex block design with 10 plants per species per replication. The species included: *Euonymus kiautschovicus* x 'Manhattan'; *Cornus sericea; Forsythia intermedia* 'Spring Glory'; and *Viburnum* x *rhytidophylloides.* The fungicides were applied until runoff and included:

1. Chlorothalonil - (tetrachloroisophtholonitrile) (Daconil 2787 75 WP) 0.45 gms/liter.
2. Captan (cis-N-(trichloromethyl) thio-4-cyclohexene 1, 2-dicarboximide) (Captan 50 WP)

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+ PCNB (pentachloronitrobenzene) (Terraclor 75 WP) 1.32 gms/liter each + 1.1 ml/liter of Wilt-Pruf NCF.

3. Benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate) (Benlate 50 WP) at 1.32 gms/liter + 1.1 ml/liter of Wilt-Pruf NCF.
4. Tap water control.

On March 31, 1977, plants were uncovered and evaluated visually for gray mold on a scale of 0 to 5. Plants with no observable mold were assigned a rating of 0. Plants with 50% of their aerial portions infected with some mold were assigned a rating of 5.

RESULTS AND DISCUSSION

A light invasion of gray mold was observed consistently throughout all three experimental replications. Disease incidence was light in the control block, probably due to the prolonged low temperatures of the storage period (1). Storage molds are usually greater under warmer conditions with the onset of new plant growth and more optimum temperatures for the growth of storage molds (11). Disease ratings were, however, lower for all plant species except the Forsythia under all fungicide treatments in comparison to the control according to Tukey's HSD test at the 5% level (Table 1).

A lower inccidence of gray mold was found on the Forsythia treated with chlorothalonil than with any other treatment. Other than this, no significant differences were found between any of the three fungicide treatments. These results are in agreement with Powell's work (9) on ornamentals stored under poly covered houses without Microfoam. No phytotoxicity was observed from any treatment, which is also in accordance with Powell's findings.

The data from this study indicate that all three fungicide treatments, with a single application at the above rates, will provide adequate but not complete control of gray mold on woody ornamentals stored under Microfoam. If benomyl resistant strains of *Botrytis* develop on woody ornamentals, chlorothalonil or the captan-PCNB combination may provide alternative control measures.

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TABLE 1.—Control of Storage Molds with Fungicides During Overwintering of Woody Ornamentals Under Microfoam.

Treatment and Rate (g/liter)	Disease Index*			
	Euonymus kiautschovicus x 'Manhattan'	Cornus sericea	Forsythia x intermedia 'Spring Glory'	Viburnum x rhytidophylloides
Chlorothalonil 0.45 g/liter	0.31 a†	0.32 a	0.02 a	0.33 a
Captan + PCNB 1.32 g/liter	0.26 a	0.36 a	0.25 b	0.38 a
Benomyl 1.32 g/liter	0.28 a	0.40 a	0.25 b	0.35 a
Control - Tap Water	0.75 b	0.68 b	0.33 b	1.03 b

*Plants were visually rated, with 0 = no mold through 5 = 50% aerial portion of plant with noticeable mold incidence.
†Mean separation within columns by Tukey's HSD test, 5% level.

Resistance of Maple Cultivars and Species to Verticillium Wilt—A Preliminary Report

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ABSTRACT

Norway and sugar maple cultivars tested by artificial inoculation were highly susceptible to Verticillium wilt. Red maple cultivars appeared resistant after 5 months of testing. These results were supported by field observations.

INTRODUCTION

Verticillium wilt of maple has been a serious disease of ornamental trees and shrubs for decades. The disease can be caused by two soil-borne species of *Verticillium, V. albo-atrum* (V.a.a.) and *V. dahliae*. These pathogens may survive in soils 20 years or more in the absence of host plants (5). The use of resistant varieties has been the main approach to control of Verticillium wilt in vegetables.

Little information is available on resistance of maple cultivars. Recently, serious outbreaks of the disease have occurred on maple in Ohio nurseries. This paper reports preliminary findings on occurrence of the disease in nurseries and the screening for resistance of cultivars under controlled conditions.

MATERIALS AND METHODS

Cultures of V. a. a. used in this study were isolated during 1974-1976 from maple trees with wilt symptoms. All were screened for virulence to: 1) 'Bonny Best' tomato (*Lycopersicum esculentum*), and 2) 2-year-old sugar maple (*Acer saccharum*) seedlings in 1976 and 1977. Tomato plants were inoculated by dipping roots of 2-week-old seedlings into conidial suspensions (10^8/ml) before transplanting. Plants were incubated at 65-75° F in a greenhouse and rated for symptoms after 12 weeks.

Dormant sugar maple seedlings were planted in late April in a peat-sand container medium in 2-gal containers. The container medium (60% Canadian peat and 40% silica sand, pH 6.4) was amended with 1 lb Treble Super phosphate and 3 oz fritted trace elements per cu yd. Four weeks after planting, the container medium was removed from one side of each plant. The resulting hole was then filled with container medium mixed with V.a.a. inoculum (50 ml of a 2-week-old millet seed culture/2-gal container). Inoculum, therefore, came into direct contact with wounded roots. Maples were examined after 4 months and assigned a disease severity rating of 1 = healthy, 2 = streaking (in the xylem tissue), 3 = streaking and wilting or leaf scorch, and 4 = dead.

During February 1978, several dormant maple species and cultivars were received from various nurseries in Ohio and screened for resistance. Two-year-old seedlings were planted in 2-gal containers and inoculated with 50 ml inoculum/pot. One and 2-inch diameter trees were planted in 7-gal containers and inoculated with 120 ml inoculum/pot.

RESULTS

Only V.a.a. was isolated from maples in Ohio nurseries. Isolates of *V. dahliae* were not obtained. None of the 11 V.a.a. isolates from maple caused streaking or wilt symptoms on 'Bonny Best' tomato and the pathogen could not be isolated from the basal to-

TABLE 1.—Susceptibility of Maple Cultivars and Species to Verticillium Wilt.

Species or Cultivar	Artificial Inoculation		Field Observations
	No. Plants	Disease Index*	Percent Killed†
Norway Maple			
Cleveland	8	3.3	
Columnaris	8	3.3	
Crimson King	8	3.3	7
Crimson Sentry	8	3.9	
Emerald Queen			3
Royal Red	8	3.6	11
Schwedleri	8	3.3	100
Summer Shade	8	3.3	
Superform	8	3.1	
Sugar Maple	17	3.2	8
Green Mountain	8	2.3	5
Red Maple			
Armstrong	8	1.0	0
Autumn Flame	8	1.0	0
Bowhall	8	1.0	0
October Glory	8	1.0	0
Red Sunset	8	1.0	0
Scarlet	5	1.0	0
Schlessinger	8	1.0	
Silver Maple	60	1.0	
Hedge Maple	8	2.0	
Amur Maple	8	3.0	
Paperbark Maple	6	2.6	

*Disease index: 1 = healthy, 2 = streaking in xylem tissue, 3 = streaking and leaf scorch or wilting, and 4 = dead plant.
†Based on 13,360 trees and a minimum of 380 per cultivar.

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[2]The authors wish to thank American Garden, Cole Nursery, Lake County Nursery Exchange, Manbeck Nursery, and Studebaker Nursery for supplying trees and Carol A. Musselman for technical assistance.

mato stem. However, a tomato isolate of V.a.a. included in this study killed all tomatoes (20 plants/isolate) within 3 weeks after inoculation. Two isolates of V.a.a., which were originally isolated from maple and subsequently killed all inoculated sugar maple seedlings (10/isolate), were selected for further screening of maple species and cultivars for resistance. Other maple isolates were either mildly virulent or avirulent.

Results of a preliminary screening with an inoculum mixture of two highly virulent V.a.a. isolates are presented in Table 1. These results are also compared with field observations on susceptibility of cultivars to the disease. Sugar maple and Norway maple (*A. platanoides*) cultivars started wilting 3 months after inoculation. All Norway and sugar maple cultivars tested were highly susceptible. Amur maple (*A. ginnala*), paperbark maple (*A. griseum*), and hedge maple (*A. campestre)* also were susceptible. However, none of the red maple (*A. rubrum*) or silver maple (*A. saccharinum*) cultivars showed symptoms of the disease.

DISCUSSION

Pathogens which cause Verticillium wilt of maple are widely distributed in Northern U. S. soils, including landscape sites. Besides causing wilts of trees, they also attack other plants including vegetables (4, 6, 7). Some isolates, however, can attack only a limited number of hosts. For example, maple isolates used in this study did not cause wilt on tomato.

Chemical control of V.a.a. on maple in the landscape and nursery has not been successful (1). The development and selection of resistant cultivars, therefore, seems a feasible approach to control. An extensive list of tree and shrub species susceptible to V.a.a. has been published (3). In this list, hedge maple, Amur maple, black maple (*A. nigrum*), Norway maple cultivars 'Crimson King' and 'Schwedleri', sugar maple, silver maple, and red maple were included as hosts. In addition, silver maple has been identified as susceptible (2). More recently, some selections of red maple were identified as tolerant to *V. dahliae* (7).

Preliminary results in this study indicate that resistance of some red maple cultivars may be adequate to avoid serious problems in the landscape. However, more isolates of *Verticillium* of both species need to be tested to verify this. Furthermore, results in this study are based on cultivars grafted on seedling rootstocks with possibly a wide range of resistance.

Recently, red maples and some other species have been produced successfully from rooted cuttings to avoid the graft incompatibility problem which can result from budding onto seedling rootstocks. Future plans are to screen trees produced from rooted cuttings. Nurserymen are invited to participate in this program by making available rooted cuttings or budded plants of maple species and cultivars for testing. Only those not previously tested are requested.

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