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dodendron spp. (azaleas). Herbicides identified by nurserymen as causing injury on these plants were OH-2 (oxyfluorfen plus pendimethalin), Rout (oxyfluorfen plus oryzalin) and Ronstar (oxadiazon).

This survey, in addition to providing information on the status of weed control in the container industry, also points out opportunities and problems with weed control research in container-grown crops.

Growers are making an average of 3 herbicide applications annually, however, most researchers evaluate 1 or 2 applications made at potting and 90 days later. Fifty-three percent of all nurseries surveyed applied preemergence herbicides in the fall. Limited evaluation of the effectiveness of fall application of preemergence herbicides in container grown plants has been reported. Opportunities exist for evaluating weed control strategies under containers. With increasing environmental concerns, more attention should be given to this area of weed control. Our study raises questions with respect to the effectiveness of weed mats, disposal of plastics, alternatives to Princep use, use of mats or plastic impregnated with herbicides, and other possibilities.

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Overwintering Container-grown Herbaceous Perennials in Northern Regions[1]

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Abstract

A 3 year study was initiated to evaluate the survival of several species of container-grown herbaceous perennials with various overwintering techniques. Although species reacted individually to overwintering covers, those with white reflective surfaces generally provided adequate protection. Straw, non-reflective Plantfoam™, or no cover usually resulted in large losses. Container medium temperatures were 4° to 7°C (8° to 15°F) degrees warmer than surrounding air temperatures, with a "sandwich" of 30 cm (1 ft) fluffed oat straw between layers of white polyfilm providing the least medium temperature fluctuation (3°C or 6°F with ambient fluctuation of 16°C or 34°F), and the most temperature moderation (1°C or 34°F with ambient − 16°C or 3°F). Uncovering plants later than the first week in April occasionally resulted in plant losses.

Index words: cold hardiness, cold protection, microfoam

Species used in this study: Yarrow (*Achillea filipendulina* Lam. 'Parker's Variety'); Wallflower (*Cheiranthus Cheiri* L. 'Apricot Delight'); Shasta daisy (*Chrysanthemum* × *superbum* Bergmans ex J. Ingram 'Alaska'); Larkspur (*Delphinium elatum* L. 'Blue Fountains'); Pink (*Dianthus* L. 'Double Sonate Mix'); Baby's-breath (*Gypsophila paniculata* L. 'Double Snowflake'); Coralbells (*Heuchera sanguinea* Engelm. 'Bressingham Hybrids'); Coralbells (*Heuchera* L. 'Firesprite'); Lavender (*Lavandula angustifolia* Mill.).

Significance to the Nursery Industry

Since most nurseries overwinter all herbaceous perennials under the same cover, general recommendations are needed for type of covering and time of covering-uncovering. In northern climates some protection is needed to ensure survival when overwintering container-grown perennials. Although a few of the hardiest species may survive with no cover in mild winters, this risk is unacceptable.

For most species type of cover is not as important as having a white reflective surface, with straw or non-reflective Plantfoam™ alone often resulting in poor survival. For the less hardy perennials such as *Digitalis, Geum* and *Kniphofia*, under severe winters or where there may be little additional protection from snowfall, the sandwich cover should be used. It results in the least fluctuation and most moderation in temperature, equivalent to three layers of microfoam with white polyfilm on top, but is less expensive. This sandwich cover may also be best for hardier species, since roots on the edge and surface of the container will be close to the surrounding air temperature. Covering before

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mid-November is not as crucial as uncovering before the first of April. Uncovering by April 1 is needed to avoid excessive growth under covers which will be subject to disease and temperature extremes.

Introduction

With the increased number of herbaceous perennials grown in containers, more perennial growers are faced with overwintering. Unfortunately most of the research done on overwintering perennial plants has emphasized woody species (10, 16). Many overwintering methods have been used successfully for overwintering woody plants including poly houses (2, 3, 8), microfoam placed directly over plants (1, 3, 8, 11), and poly film directly over plants (5, 8). Because root hardiness is a main factor in overwintering woody plant species (7, 14), pot media temperatures have been monitored within the various protected environments (5, 11).

One study which was done using several herbaceous perennials evaluated the degree of hardiness when temperatures were dropped at a controlled rate (4, 15). Plants ranged in hardiness from *Kniphofia* at −2.7°C (27°F) to *Achillea* at −11°C (12°F). How approximately 80 species and varieties of herbaceous perennials in 3.8 cm (1.5 in) cells, overwintered in an unheated house with 2 layers of white polyfilm, and under 2 layers of Mirafly℠, survived 3 days at −6.7°C (20°F) air temperature (unpublished study of author) may relate to rate of temperature drop and fluctuation, as well as soil moisture. These factors influence the winter survival of alfalfa (9) yet remain to be studied for ornamental herbaceous perennials.

In a preliminary replicated trial of 19 herbaceous species at Hamlen's Nursery in Swanton, Vermont, four survived as well with no cover as with two layers of white polyfilm with straw between, although most required the cover to survive. *Rudbeckia* survived better with no cover due to rotting when covered (6). In another preliminary study, several dozen herbaceous perennials were evaluated for hardiness when overwintered in the ground in 3 hardiness zones with only natural snow covers (12). This study was initiated to determine the relative effectiveness of several overwintering coverings for herbaceous perennials as well as time of covering.

Materials and Methods

Studies on types of coverings were performed over four winters, with no data from 1986–87 due to severe mouse injury to plants. During 1982–83 four species were used—*Cheiranthus cheiri* 'Apricot Delight', *Dianthus* 'Double Sonate Mix', *Heuchera sanguinea* 'Bressingham Hybrids', and *Lavandula angustifolia*. There were 6 treatments applied November 20 and removed April 1—a control in which plants were left uncovered subject to ambient conditions, one layer of 4 mil white polyfilm, a layer of 0.63 cm (0.25 in) Microfoam™ (Ametek, Brandywine Four Building, Chadds Ford, PA 19317) with a layer of white polyfilm on top, 3 layers of Microfoam™ with a layer of white polyfilm on top, a 0.63 cm (0.25 in) material similar to Microfoam™ sold as Plantfoam™ (Almac Plastic, Inc., 6311 Erdman Ave., Baltimore, MD 21205) with no layer of polyfilm or reflective surface, and a "sandwich" of 30 cm (1 ft) fluffed oat straw between layers of white polyfilm. The white polyfilm was used on top to reflect much incoming radiation and help moderate temperatures.

During 1985–86 three species were used—*Achillea filipendulina* 'Parker's Variety, *Gypsophila paniculata* 'Double Snowflake', and *Heuchera* 'Firesprite'. There were 6 treatments applied November 15 and removed April 1—control and sandwich treatments as before, 30 cm (1 ft) straw only, Plantfoam™ this time having a white reflective surface, a 3 mm (0.12 in) thick felt material sold as Mirafy™ by a local plumbing supply firm for pipeline bases but also used effectively by two local growers for overwintering, and a plastic bubblefoam material having contiguous air bubbles 1.5 cm (0.60 in) thick and 3 cm (1.20 in) across and sold by a local packing firm. Mirafy™ has the advantage over foam materials of being permeable to water, and so plants can be watered through the cover during overwintering if they become too dry.

During 1987–88 three species were used—*Achillea* as previously identified, *Chrysanthemum* × *superbum* 'Alaska', and *Delphinium elatum* 'Blue Fountains'. Treatments were identical to those in 1985–86, applied November 19 and removed April 4.

Temperatures for covering treatments were monitored in the container medium in the center of each replicate with copper constantan thermocouples. Temperatures were recorded once daily at 6 am with a Honeywell multipoint recorder.

Studies on time of covering and uncovering were conducted over three winters, with no result from 1986–87 due to mouse injury. Four treatments were used each year. During 1985–86 covers were applied-removed October 15–April 1, November 15–April 1, November 15–April 15, and November 15–May 1. Species studied were *Achillea filipendulina* 'Parker's Variety', *Gypsophila paniculata* 'Double Snowflake', and *Heuchera* 'Firesprite'. During 1987–88 covers were applied-removed November 3–April 4, November 19–April 4, November 19–April 19, and November 19–May 2. Species studied this year were *Achillea* as previously identified and *Lupinus* 'Russell Hybrids'. For both years covers were the sandwich of 30 cm (1 ft) fluffed oat straw between layers of 4 mil white polyfilm.

Plants were established in 4 liter (#1) black containers in ProMix BX™, planted in May or June, and received 150 ppm N as 20N-8.6P-16.6K (20-20-20) at every watering through mid-August, each year prior to overwintering. After removing growth dead from frost, plants were placed upright tightly together with two guard rows around the block under the cover. Five pots of each species were used per replicate, with two replicates per treatment in a randomized complete block design. Each plant was rated 6 weeks after uncovering for winter survival and regrowth on a scale of 1 to 5 with 1 being dead with no regrowth of shoots and dead roots, 2 having very limited regrowth, 3 being marginally saleable, 4 having good regrowth, and 5 having the most vigorous regrowth. Replicate means were used for analysis of variance. Where differences occurred they were separated between treatments by least significant difference (13).

Results and Discussion

During 1982–83 the sandwich cover provided the best protection for *Cheiranthus* with all treatments having white reflective polyfilm on top providing similar protection for other species (Table 1). Most plants with no cover did not survive. *Cheiranthus* and *Lavandula* under just Plantfoam™

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Table 1. Winter survival ratings[z] for herbaceous perennials under several covering treatments[y].

Species	Covering treatments					
	Ambient	Poly/Straw/ Poly	Poly	Microfoam/ Poly	3 Microfoam/ Poly	Plantfoam
1982–83						
Cheiranthus cheiri 'Apricot Delight'	1.0 d[x]	5.0 a	1.0 d	2.3 c	4.4 b	1.8 c
Dianthus 'Double Sonate Mix'	1.5 a	3.4 a	2.5 a	3.3 a	3.0 a	3.8 a
Heuchera sanguinea 'Bressingham Hybrids'	1.3 b	3.8 a	4.8 a	3.6 a	4.1 a	4.8 a
Lavandula angustifolia	1.3 d	3.0 bc	4.3 ab	3.9 abc	4.9 a	2.3 cd
	Ambient	Poly/Straw/ Poly	Straw	Mirafy/ Poly	Bubblefoam/ Poly	Reflective Plantfoam
1985–86						
Achillea filipendulina 'Parker's Variety'	2.0 a	4.8 a	3.1 a	4.3 a	4.3 a	3.9 a
Gypsophila paniculate 'Double Snowflake'	1.5 b	4.3 a	3.5 a	4.4 a	4.2 a	3.9 a
Heuchera 'Firesprite'	2.6 a	3.9 a	3.8 a	3.9 a	4.4 a	4.2 a
1987–88						
Achillea filipendulina 'Parker's Variety'	1.3 c	4.0 a	1.7 c	3.2 ab	3.8 ab	3.4 ab
Chrysanthemum × *superbum* 'Alaska'	1.0 b	4.3 a	1.0 b	2.7 ab	3.6 a	2.3 ab
Delphinium elatum 'Blue Fountains'	1.1 a	2.7 a	2.4 a	3.2 a	2.3 a	3.0 a

[z]Scale of 1 = dead, no regrowth to 5 = most vigorous regrowth.

[y]Poly = 4 mil white polyfilm; used on top of other covers.

[x]Means within a row followed by the same letter are not significantly different by lsd = 0.05.

survived poorly. This is likely due to the lack of reflective surface resulting in extreme fluctuations. On a sunny day with no snow cover, air temperature under Plantfoam™ was 40°C (104°F) while temperatures were 18–20°C (64–68°F) under reflective covers with an ambient temperature of 10°C (50°F). During 1985–86 there were no differences among treatments due to a mild winter, except for little survival of *Gypsophila* with no cover. During 1987–88 best survival occurred with reflective treatments, with little survival for those not covered and under only straw.

The amount of temperature fluctuation is inversely related to the amount of temperature moderation with the sandwich cover providing the least fluctuation (Table 2) and most moderation (Table 3). While the sandwich provided the most moderation of 2 or 3°C (4 or 6°F), roots in media with no cover fluctuated 16 or 17°C (29 or 31°F). While the sandwich provided the greatest medium temperature difference of 17°C (31°F) over ambient, just the straw provided the least of 2°C (3°F). The only treatments which would provide protection to the least hardy perennials (4, 12) were the bubblefoam with poly or sandwich. Straw or no cover should not result in survival for even the most hardy under similar temperature conditions. Covers resulted in medium temperatures 6–7°C (10–13°F) warmer than air temperatures under covers, an important point to keep in mind when measuring temperatures in nursery situations.

In the time of covering-uncovering studies the only significant difference in 1985–86 was for *Gypsophila* with the best survival under early (October 15) and normal (November 15) coverings, and early (April 1) uncovering (Table 3). The early uncovering was the more important of the two since those covered at the normal time and uncovered at later times (Apr 15 and May 1) had poorer survival. In 1987–88 the only significant difference was for *Achillea* with best survival with normal covering-uncovering times. Although not statistically significant, highest ratings for all species occurred from the normal covering-uncovering times. Difference in reaction of *Achillea* to times of covering-

Table 2. Medium temperature fluctuation under overwintering covers during two winter periods.

Covering treatment	Dates	
	Jan. 14–18, 1983	Jan. 11–18, 1988
Poly/straw/poly[z]	2°C(4°F)[y]	3°C(6°F)
3 layers Microfoam™	4°C(8°F)	—
Bubblefoam/poly	—	5°C(10°F)
Plantfoam™/poly	—	8°C(16°F)
Poly	9°C(20°F	—
Mirafy/poly	—	9°C(20°F)
30 cm straw (1 ft)	—	11°C(24°F)
Ambient, no cover	17°C(31°F)	16°C(29°F)

[z]Poly = 4 mil white polyfilm; used on top of other covers.

[y]Temperatures measured 2.5 cm (1 in) in center of 4 liter (#1) black pot, 6 a.m.

Table 3. Air and medium temperatures under overwintering covers on January 14, 1988, 6 a.m.

Covering treatment[z]	Temperature[y]	
	Air	Medium
Ambient, no cover	−22°C(−8°F)	−16°C(3°F)
30 cm straw (1 ft)	−18°C(0°F)	−14°C(6°F)
Mirafy/poly	−13°C(9°F)	−6°C(21°F)
Plantfoam™/poly	−11°C(12°F)	−4°C(25°F)
Bubblefoam/poly	−8°C(18°F)	−2°C(28°F)
Poly/straw/poly	−6°C(21°F)	1°C(34°F)

[z]Poly = 4 mil white polyfilm; used on top of other covers.

[y]Temperature 2.5 cm (1 in) in center of 4 liter (#1) black pot; air temperature under cover just above soil level.

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Table 4. Winter survival ratings[z] for herbaceous perennials covered and uncovered at various times[y].

Species	Time of covering-uncovering			
	10/15–4/1	**11/15–4/1**	**11/15–4/15**	**11/15–5/1**
1985–86				
Achillea filipendulina 'Parker's Variety'	3.6[x]	4.5	4.3	2.9
Gypsophila paniculata 'Double Snowflake'	4.3 a	4.5 a	3.7 b	3.1 c
Heuchera 'Firesprite'	3.2	4.4	3.2	2.8
	11/3–4/4	**11/19–4/4**	**11/19–4/19**	**11/19–5/2**
1987–88				
Achillea filipendulina 'Parker's Variety'	3.0 b	4.6 a	2.8 b	2.0 b
Lupinus 'Russell Hybrids'	4.2	4.5	3.0	2.6

[z]Scale of 1 = dead, no regrowth to 5 = vigorous regrowth.

[y]Covered with 4 mil white polyfilm/30 cm straw/white polyfilm.

[x]Means within a row followed by the same letter are not significantly different by lsd = 0.01 or 0.05. No letters indicate no differences among means.

uncovering between the two years is likely due to differing temperatures although normal covering-uncovering was significantly best both years.

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