in total shoot fresh weight was observed with Roundup at 2.2 kg/ha (2.0 lb/A) plus surfactant, Banvel or Garlon (Table 2). Roundup at 4.5 kg/ha (4.0 lb/A), with or without surfactant, reduced total shoot weight by approximately 60%. English ivy can tolerate Roundup to a certain degree, although the rain that occurred three hours after treatment should have reduced activity of this herbicide. Complete control of English ivy was observed with two applications of Weedar 64, 2,4-D.

Ed. note: This paper reports the results of research only and does not imply registration of a pesticide under amended FIFRA. Before using any of the products mentioned in this paper, be certain of their registration by appropriate state and/or federal authorities).

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Evaluation of Structureless Overwintering Systems for Container-Grown Herbaceous Perennials[1]

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Abstract

Five structureless overwintering systems were evaluated for temperature moderation and protection of 18 container-grown herbaceous perennials from low-temperature injury. Two light-excluding treatments; 30 cm (1 ft) of straw between two layers of 4-mil white polyethylene and 18 cm (7 in) deep, in-ground beds protected with one layer of 4-mil white polyethylene and 30 cm (1 ft) of woodchips, provided the greatest moderation of winter low and early spring high temperatures, but also resulted in severe etiolation. A bonded white polyethylene/microfoam overwintering blanket (thermoblanket) with translucent properties provided comparable plant survival percentages despite dramatic temperature extremes recorded beneath this cover and, in late winter, created an environment conducive to moderate plant growth without formation of etiolated tissue.

Index words: etiolation, temperture monitoring, thermocouple, winter protection

Species used in this study: Yarrow (*Achillea taygetea* x *millefolium* L. 'The Beacon'); Lance coreopsis (*Coreopsis lanceolata* L. 'Goldfink'); Threadleaf coreopsis (*Coreopsis verticillata* L. 'Moonbeam'); Threadleaf coreopsis (*Coreopsis verticillata* L. 'Zagreb'); Delphinium (*Delphinium elatum* L. 'Giant Pacific Hybrid'); Blanket flower (*Gaillardia* x *gradiflora* Van Houtte. 'Goblin'); Geum (*Geum quellyon* Sweet. 'Mrs. Bradshaw'); Coralbells (*Heuchera sanguinea* Engelm. 'Bressingham Hybrids' and 'Splendens'); False dragonhead (*Physostegia virginiana* (L.) Benth. 'Pink Bouquet' and 'Summer Snow'); Balloon flower (*Platycodon grandiflorus* (Jacq.) A. DC. 'Fuji Blue'); Salvia (*Salvia* x *superba* Stapf. 'Stratford Blue'); Sedum (*Sedum spectabile* x *telephium* L. 'Autumn Joy'), Sedum (*Sedum spectabile* Boreau. 'Brilliant'); Painted daisy (*Tanacetum coccineum* Willd. 'Robinsons Mix'); Spike speedwell (*Veronica spicata* L. 'Icicle'); and Creeping veronica (*Veronica repens* Loisel.).

Significance to the Nursery Industry

Most container-grown herbaceous perennials require winter protection if they are to survive low temperatures and wide winter temperature fluctuations typical of a continental climate. Structureless overwintering systems are easy to assemble and maintain and can provide growers and retailers with an inexpensive method of protecting these valuable plants.

Several structureless overwintering systems in this study resulted in high plant survival percentages and high quality ratings after winter storage. Polyethylene/woodchip and sandwich covers were the most effective in moderating temperature extremes and should be favored when over-

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wintering cold-sensitive species, but must be removed early in the season to prevent tissue etiolation. Translucent thermoblanket covers prevented etiolation and would be appropriate for protecting hardier perennial species.

Introduction

Environmental stress may be responsible for 90% of the shortfall between crop yield potential and average yield (3). A major cause of ornamental plant loss is freeze injury, mostly to roots of overwintering container-grown nursery stock (14). Any nursery crop can be protected from freeze injury, but economic and logistic factors limit the methods that can be used. In cold climates, costs of overwintering containerized nursery plants can approach 20 to 33% of the total nursery operation capital outlay (13). Profitability becomes the dominant factor determining which freeze protection method to use, if any (9).

Above-ground growing systems, favored by many perennial producers, permits a greater degree of control over fertility and moisture levels than does field production and makes possible the delivery of a finished product to retailers. Container-grown herbaceous perennials require winter protection to survive low temperatures and temperature fluctuations typical of many regions in the United States and Canada. Ideally, overwintering systems should insulate plant roots and crowns from undesirable high and low temperatures and should buffer rapid temperature fluctuation.

White polyethylene-covered quonset huts have been shown to provide adequate protection for many containerized nursery plants, but such structures may be too costly for small-scale growers (1), and be impractical in regions of the country where heavy snow loads are routine (7). Alternatively, laying polyethylene film, thermoblankets, and/or nonwoven fabrics directly over tightly grouped containers, forming a structureless protective blanket, is an effective and inexpensive overwintering method (5, 6, 10, 15). In fact, thermoblanket structureless systems can provide greater freeze protection than more costly polyethylene shelters (4).

Perry (8) studied several freeze-protection methods for container-grown herbaceous perennials and found that a sandwich structureless system consisting of two layers of 4-mil white polyethylene with 30 cm (1 ft) of straw between the layers provided the least temperature fluctuation and the greatest temperature moderation in the container medium. Still et al. (12), conducting similar studies in Ohio, found a microfoam thermoblanket effective in protecting containerized perennials from freeze injury. Unfortunately, additional overwintering information specific for perennials is scarce, particularly as it might relate to climates like that of the upper Midwest that experience minimal or transient winter snow cover, high light intensities, and dramatic temperature fluctuations. Therefore, our objective was to investigate the effectiveness of five structureless overwintering systems to protect 18 species of container-grown herbaceous perennials from low-temperature injury during winter and from potentially harmful high late-winter and early spring temperatures.

Materials and Methods

Winter protection systems were evaluated during 1989-90 and 1990-91 at the Iowa State University Horticulture Research Station at Gilbert, Iowa (USDA Hardiness Zone 5a). Eighteen commercially important herbaceous perennial species with different degrees of winter hardiness were chosen as test plants for the study. *Geum* and *Tanacetum* were included because of their reported lack of cold tolerance, and *Achillea* and *Sedum* represented the hardiest species. Because of supply difficulties, *Coreopsis lanceolata* 'Goldfink' was not used in the second year, but *Physostegia virginiana* 'Summer Snow' and *Veronica spicata* 'Icicle' were included. In spring 1989 and 1990, perennials were established in 3.5 1 (#1) black plastic containers using a medium of Canadian *Sphagnum* peat, perlite, field soil (2:2:1 by vol) amended to pH 6.5. Plants were grown outdoors under 20% shade until time of winter covering. Each plant was top-dressed with 5 g 17N-2.6P-10K (17-6-12) Sierra fertilizer plus minor elements (Sierra Chemical Company, Milpitas, CA) and fertilized bi-weekly until the end of August with an additional 150 ppm N from a 20N-4.4P-16.6K (20-10-20) Peters water-soluble fertilizer. Container-grown plants were hand-weeded, watered by overhead irrigation, and treated for insect pests as needed.

A split-plot design was employed with structureless winter protection treatments as main plots, and individual perennial species as subplots. Covering treatments were completely randomized and replicated three times. On November 14, 1989, and November 18, 1990, main treatment plots measuring 1.7 by 2.0 m (5.5 by 6.5 ft) were assembled and covered. These plots consisted of three plants of each species randomly arranged pot-to-pot on bare soil and a border row of extra container-grown perennials at the perimeter. The main treatment plots were; **control**—containers arranged pot-tight with no additional protection; **sandwich**—two layers of 4-mil white polyethylene with 30 cm (1 ft) fluffed brome grass/oat straw between the layers and secured with lumber; **thermoblanket**—a bonded 4-mil white polyethylene/microfoam 0.6 cm (0.25 in) cover pulled tight over the plants and secured with lumber; **polyethylene/woodchip**—containers arranged in 18 cm (7 in) deep in-ground beds and covered with a layer of 4-mil white polyethylene and 30 cm (1 ft) of woodchips. In 1990-91 a fifth structureless winter protection treatment was added; **PLS-80**—one layer of PLS-80 Environmental Screen made of clear UV-stabilized polyester strips knitted to each other with high density polyethylene yarn and coated with strips of aluminum to give an 85% shade level (Ludvig Svensson Inc., Charlotte, NC) pulled tight over the plants and secured with lumber.

Before structureless winter protection systems were installed, each plant had existing foliage removed and was drenched with Daconil 2787 fungicide (*chlorothalonil*) to prevent storage disease (2), and was irrigated to container capacity. Ground Force rodent bait (*chlorophacinone*) was placed in several locations within each plot to deter rodent damage. Protective covers were not removed at any time during the experiment.

Container medium temperatures were monitored at three locations in each covering treatment replicate with copper-constantan thermocouples (Omega Engineering, Stamford, CT) placed 7.6 cm (3 in) below medium surface, 2.5 cm (1 in) from the west wall of the pot, and ambient air temperatures were monitored by a shielded sensor. Thermocouples connected to a CR10 Datalogger recorded temperatures every five minutes and calculated mean hourly temperature. For both studies, temperature data were recorded from time of cover installation to April 1.

On April 5, 1990 and 1991, overwintering covers were removed. Plants were maintained according to conventional nursery practices until survival and regrowth were evaluated 8 weeks later. Each plant was rated visually on a scale of 1 to 5, where 1 = dead plant; 2 = alive with little top growth; and 3 to 5 = acceptable quality, 5 = highest rating. Shoot dry weights were recorded after visual evaluation. Analysis of variance was used to determine effects with mean separation by least significance difference. Selected temperature data were subject to analysis of variance according to the general linear model procedure within SAS and means separated by Duncan's Multiple Range Test. Iowa State University Statistical Consulting Services aided with data analysis.

Results and Discussion

Minimal snow cover and very low temperatures characterized the 1989-90 test winter, but an untimely snow cover blanketed plots during the coldest part of the 1990-91 winter. Temperature data from months representing the greatest extremes are presented. In-ground beds with a polyethylene/woodchip protective cover were the most effective treatment for moderating medium temperatures of container-grown herbaceous perennials, as the medium remained above −3°C (26.6°F) throughout the coldest period of the 1989-90 study (December 21 to 31) (Fig. 1). Minimum temperatures in the medium beneath sandwich protective covers were 2 to

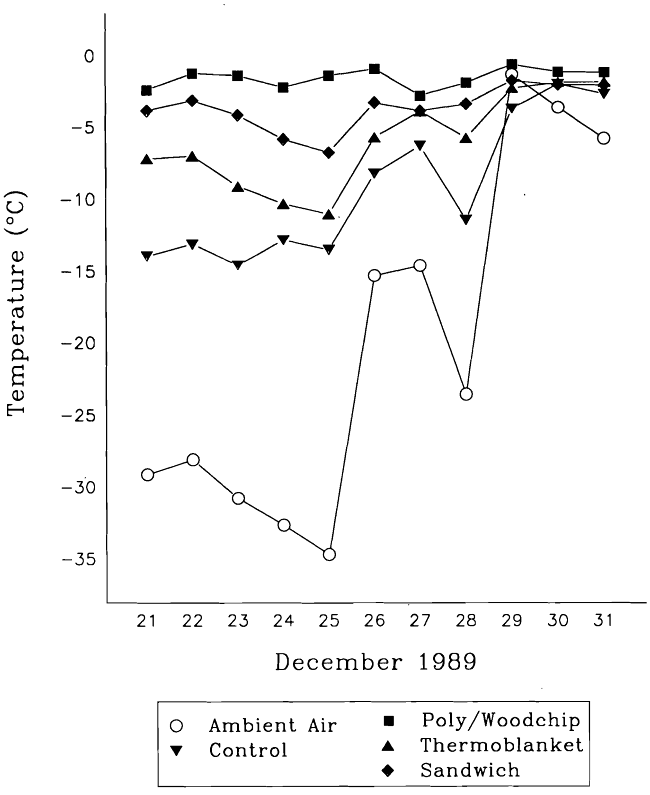

Fig. 1. Comparison of daily minimum ambient air temperatures and medium temperatures of container-grown herbaceous perennials protected by structureless overwintering systems. Each value is the mean of 3 observations × 3 replications. Data presented includes the warmest day of the 1989–90 experiment, March 14, 1990.

3°C (3.6 to 5.4°F) lower than polyethylene/woodchip for the same period except during the coldest two days of the study when medium temperatures dropped below −5°C (23°F). Root-zone temperatures of −2.7°C to −6°C (27 to 21°F) injure certain cold-sensitive perennial species (11). A thermoblanket provided a comparable degree of protection to the sandwich when ambient temperatures remained above −15°C (5°F) but was less effective at lower temperatures. From December 21 to 25, unprotected control medium temperatures approached a lethal −15°C (5°F) (Fig. 1). Polyethylene/woodchip, sandwich, and thermoblanket covers were different from the control in reducing medium temperature fluctuation during December, the coldest month of the 1989-90 study (Table 1). In 1990-91, extended periods of snow cover provided extra insulation and resulted in relatively uniform medium temperatures with only slight treatment differences and no difference in temperature fluctuation between treatments (Table 1). Still, medium temperatures in control treatments approached a potentially lethal −6.5°C (20°F) while temperatures in containers protected by polyethylene/woodchip and sandwich covers remained near −2.5°C (27°F) on the coldest day of the 1990-91 study, January 31. On this same day, the PLS-80 treatment moderated medium temperatures only slightly better than the control, and medium temperatures under the thermoblanket were only slightly warmer than those recorded beneath the PLS-80 cover.

It also is important for structureless overwintering systems to limit heat build-up on sunny days. In 1989-90, warm ambient air temperatures in March resulted in elevated medium temperatures in all treatments (Fig. 2). On the warmest day of the experiment, March 14, as ambient air temperatures reached 26°C (78°F), maximum medium temperatures in the control treatment and under thermoblanket covers approached 20°C (68°F), while maximum medium temperatures beneath sandwich and polyethylene/woodchip covers remained near 10°C (50°F). Medium temperatures were considerably more uniform when ambient air temperatures stayed below 15°C (59°F). Daily medium temperature fluctuation was higher in the control and thermoblanket plots than the sandwich and polyethylene/woodchip plots (Table 1). In 1990-91, maximum medium temperature differences were more pronounced (Fig. 3). The polyethylene/woodchip cover was consistently superior in mitigating warm day-time temperatures, keeping maximum medium temperatures approximately 4°C (7.2°F) lower than those recorded under the sandwich cover. On most warm days, the PLS-80 material with reflective aluminum strips and the thermoblanket cover were better than the control in modulating daily maximum medium temperatures. But, PLS-80 was not different from either the sandwich or polyethylene/woodchip treatment in reducing differences between daily maximum and minimum medium temperatures (Table 1).

When covers were removed, considerable etiolation was noted on perennials protected by light-excluding sandwich and polyethylene/woodchip covers. Perennials protected with a translucent thermoblanket, and to a lesser degree with the PLS-80 cover, were green and growing vigorously upon uncovering.

All structureless overwintering treatments resulted in greater survival percentages than control treatments in both years (Table 2). Exceptionally hardy perennials like *Achillea* 'The Beacon', *Platycodon* 'Fuji Blue', *Sedum* 'Autumn Joy', and

Table 1. Effect of structureless overwintering systems on mean medium temperature fluctuations (°C).

Date	Treatment				
	Control	PLS- 80[z]	Sandwich	Thermoblanket	Poly/Woodchip
December 1–31, 1989[w]	6.29[x]a[y]	—	3.94 b	4.46 b	4.14 b
January 1–31, 1991[v]	4.93 a	4.78 a	4.91 a	4.71 a	5.00 a
March 1–31, 1990[u]	7.24 a	—	4.99 b	6.83 a	5.34 b
March 1–31, 1991[t]	8.56 a	6.75 bc	5.59 c	7.37 ab	6.16 bc

[z]Treatment not included in 1989–90 experiment.

[y]Means across columns followed by the same letter are not signficantly different from each other using Duncan's Multiple Range Test, P=0.05.

[x]Σ (Daily maximum medium temperature – Daily minimum medium temperature) = MEAN 31 days

[w]Time period includes coldest day of the 1989–90 experiment, December 25, 1989.

[v]Time period includes coldest day of the 1990-91 experiment, January 31, 1991.

[u]Time period includes warmest day of the 1989–90 experiment, March 14, 1990.

[t]Time period includes warmest day of the 1990–91 experiment, March 27, 1991.

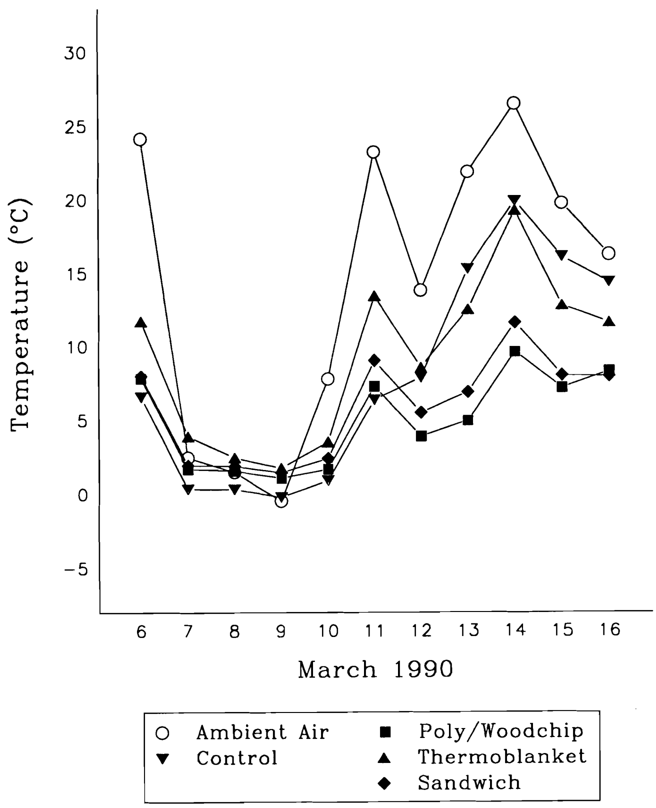

Fig. 2. Comparison of daily maximum ambient air temperatures and medium temperatures of container-grown herbaceous perennials protected by structureless overwintering systems. Each value is the mean of 3 observations × 3 replications. Data presented includes the warmest day of the 1989–90 experiment, March 14, 1990.

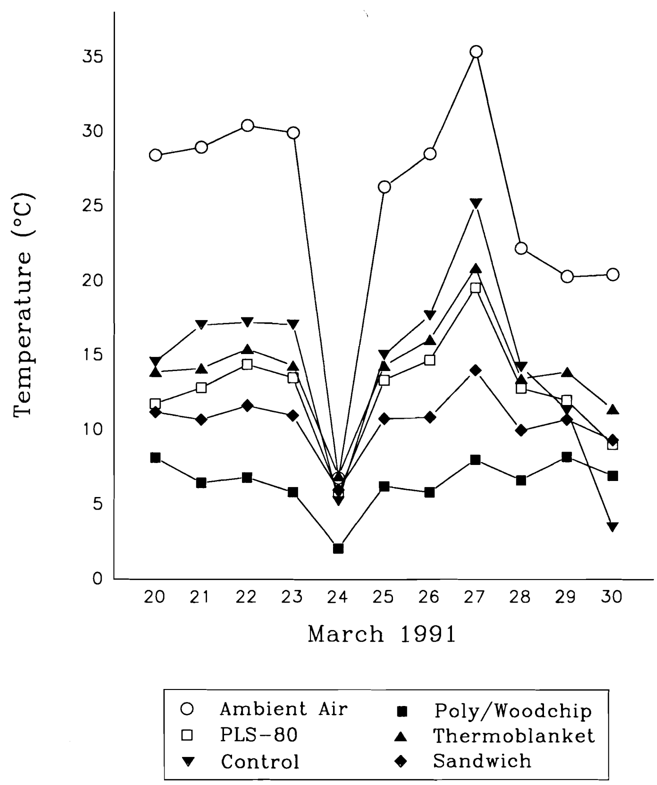

Fig. 3. Comparison of daily maximum ambient air temperatures and medium temperatures of container-grown herbaceous perennials protected by structureless overwintering systems. Each value is the mean of 3 observations × 3 replications. Data presented includes the warmest day of the 1990–91 experiment, March 27, 1991.

Sedum 'Brilliant' demonstrated high survival percentages without any protective covering. Conversely, cold-tender *Geum* 'Mrs. Bradshaw' exhibited specific low-temperature threshold requirements. In 1989-90, polyethylene/woodchip covers that maintained minimum medium temperatures above −4°C (24.8°F) resulted in 78 percent *Geum* survival, whereas only 11 and 0 percent survived under the cooler sandwich and thermoblanket covers, respectively (Table 2). In 1990-91, sandwich, polyethylene/woodchip, and thermoblanket treatments that maintained medium temperatures at −5°C (23°F) and higher resulted in 100 percent *Geum* survival. The PLS-80 cover allowed medium temperatures to slip

Table 2. Effect of 5 structureless overwintering systems on regrowth (shoot dry weight) and percentage (%) survival of 18 species of container-grown herbaceous perennials.

	Treatment									
	Control		PLS-80[z]		Sandwich		Thermoblanket		Poly/Woodchip	
Species/experiment	Shoot Dry wt. (g)[x]	Survival (%)[y]	Shoot Dry wt. (g)	Survival (%)	Shoot Dry wt. (g)	Survival (%)	Shoot Dry wt. (g)	Survival (%)	Shoot Dry wt. (g)	Survival (%)
Achillea 'The Beacon'										
1989–90	12.8 a	89	—	—	16.3 a	100	29.4 b	100	15.5 a	100
1990–91	3.6 a	100	9.4 ab	100	6.8 ab	100	14.8 b	100	13.3 b	100
Coreopsis lanceolata 'Goldfink'										
1989–90	0.0 a	0	—	—	14.6 b	100	11.7 b	100	15.1 b	100
1990–91	—[w]	—	—	—	—	—	—	—	—	—
Coreopsis verticillata 'Moonbeam'										
1989–90	0.1 a	11	—	—	52.9 b	100	51.0 b	100	46.9 b	100
1990–91	0.8 a	22	7.8 ab	89	15.6 b	100	16.6 b	100	10.3 b	100
Coreopsis verticillata 'Zagreb'										
1989–90	0.0 a	0	——	—	42.9 b	100	46.7 b	100	45.6 b	100
1990–91	3.8 a	67	21.4 b	100	19.1 b	100	21.1 b	100	21.8 b	100
Delphinium elatum 'Pacific Hybrid'										
1989–90	0.0 a	0	—	—	21.5 b	56	37.7 c	100	38.4 c	78
1990–91	0.1 a	11	12.4 b	100	17.2 b	100	12.6 b	100	15.2 b	100
Gaillardia x *grandiflora* 'Goblin'										
1989–90	2.1 a	33	—	—	23.4 b	89	20.5 b	100	19.8 b	100
1990–91	0.0 a	0	6.7 ab	100	16.1 c	100	15.9 c	100	9.3 bc	100
Geum quellyon 'Mrs. Bradshaw'										
1989–90	0.0 a	0	—	—	1.3 a	11	0.0 a	0	29.2 b	78
1990–91	0.0 a	0	0.5 a	56	12.4 b	100	6.8 ab	100	10.9 b	100
Heuchera sanguinea 'Bressingham'										
1989–90	0.0 a	0	—	—	15.9 b	100	21.2 b	100	14.5 b	100
1990–91	0.0 a	0	7.3 ab	78	8.5 ab	100	9.0 b	100	11.9 b	100
Heuchera sanguinea 'Splendens'										
1989–90	0.0 a	0	—	—	7.7 ab	89	15.9 b	100	11.9 b	100
1990–91	0.0 a	0	6.9 ab	89	6.1 ab	100	11.2 b	100	10.3 b	100
Physostegia virginiana 'Pink Bouquet'										
1989–90	1.1 a	11	—	—	26.9 b	100	40.4 c	100	25.5 b	100
1990–91	15.6 a	67	53.5 b	100	49.7 b	100	52.1 b	100	54.0 b	100

below −6°C (21.2°F) resulting in only 56 percent survival. These results are similar to those by Still et al. (11) who reported *Geum* to be hardy only to −4.4°C (24°F) in controlled freezing studies.

Regrowth, measured as shoot dry weight, reflects the suitability of winter storage conditions. In general, acceptable regrowth occurred if perennials were protected by any of the structureless systems (Table 2). But, in 1989-90, polyethylene/woodchip covers resulted in higher shoot dry weights for cold-sensitive *Geum* and *Tanacetum*. Yet, regrowth of cold-sensitive *Delphinium* 'Pacific Hybrid' protected by a poorer insulating thermoblanket was superior to those protected by a sandwich cover, because of severe etiolation of plants under the latter cover. Similarly, *Sedum* 'Autumn Joy' and 'Brilliant', and *Physostegia* 'Pink Bouquet' protected by thermoblankets had higher regrowth dry weights than those overwintered under sandwich or polyethylene/woodchip covers. Plants unprotected in control pots in 1989-90 had lower regrowth dry weights.

Because of persistent snow cover, differences in regrowth in 1990-91 occurred mostly between plants in control plots and those protected by structureless overwintering systems (Table 2). Based on shoot dry weight measurements, plants deriving the most benefit from winter covers regardless of covering treatment included *Coreopsis* 'Zagreb', *Delphinium* 'Pacific Hybrid', *Physostegia* 'Pink Bouquet', *Physostegia* 'Summer Snow', *Sedum* 'Autumn Joy' and 'Brilliant', and *Veronica* 'Icicle'. In 1990-91, etiolation was more problematic on perennials protected by a sandwich cover, with effect on regrowth most noticeable on *Sedum* 'Brilliant'. Those protected by a thermoblanket had higher shoot dry weights measured 8 weeks after uncovering than those covered by the sandwich. Finally, cold-sensitive *Geum* 'Mrs. Bradshaw' again demonstrated its need for covers with su-

Table 2. Continued.

Species/experiment	Control Shoot Dry wt. (g)[x]	Control Survival (%)[y]	PLS-80[z] Shoot Dry wt. (g)	PLS-80[z] Survival (%)	Sandwich Shoot Dry wt. (g)	Sandwich Survival (%)	Thermoblanket Shoot Dry wt. (g)	Thermoblanket Survival (%)	Poly/Woodchip Shoot Dry wt. (g)	Poly/Woodchip Survival (%)
Physostegia virginiana 'Summer Snow'										
1989–90	—[v]	—	—	—	—	—	—	—	—	—
1990–91	1.4 a	78	21.9 bc	100	27.5 c	100	18.2 b	100	29.7 c	100
Platycodon grandiflorus 'Fuji Blue'										
1989–90	10.6 a	89	—	—	44.6 c	100	37.2 bc	100	29.0 b	100
1990–91	3.1 a	44	10.9 ab	89	16.7 bc	100	13.7 b	100	24.6 c	100
Salvia x *superba* 'Stratford Blue'										
1989–90	4.2 a	22	—	—	21.8 bc	78	31.6 c	100	20.4 b	78
1990–91	0.9 a	78	15.1 bc	100	17.2 bc	100	20.0 c	100	9.9 b	100
Sedum 'Autumn Joy'										
1989–90	7.3 a	22	—	—	41.5 b	100	62.7 c	100	45.7 b	100
1990–91	23.9 a	100	53.1 b	100	49.7 b	100	50.9 b	100	49.4 b	100
Sedum 'Brilliant'										
1989–90	15.1 a	100	—	—	17.6 a	100	34.5 b	100	14.4 a	100
1990–91	5.2 a	67	40.2 c	100	30.0 b	100	40.2 c	100	36.2 bc	100
Tanacetum coccineum 'Robinson's Mix'										
1989–90	0.0 a	0	—	—	14.1 b	78	23.2 b	89	39.9 c	100
1990–91	0.0 a	0	7.8 ab	78	9.3 bc	100	17.6 c	89	16.2 bc	100
Veronica repens										
1989–90	6.2 a	78	—	—	14.4 ab	100	22.5 b	100	20.6 b	100
1990–91	0.0 a	0	12.6 b	100	12.4 b	100	12.6 b	100	12.8 b	100
Veronica spicata 'Icicle'										
1989–90	—[v]	—	—	—	—	—	—	—	—	—
1990–91	0.9 a	44	23.2 b	100	27.3 b	100	31.0 b	100	31.7 b	100

[z]Treatment not included in 1989–90 experiment.

[y]Percent of container-grown herbaceous perennials surviving (n = 9).

[x]Each value is the mean of 3 observations × 3 replications. Shoot dry weight means across columns followed by the same letter are not signficantly different from each other using LSD (t-test), P = 0.05, LSD = 9.95 (1989–90), LSD = 8.85 (1990–91).

[w]Species unavailable for 1990–91 experiment.

[v]Species unavailable for 1989–90 experiment.

perior insulating abilities, showing poorer regrowth after overwintering in control or PLS-80 plots.

Examining quality of plant regrowth after overwintering is perhaps the best measure of a winter protection system. Plants surviving in control plots usually had poorer regrowth quality ratings than the same plant in any structureless system (Table 3). Notable exceptions to this trend were *Achillea* 'The Beacon' and *Sedum* 'Autumn Joy' and 'Brilliant'. Surprisingly, if perennials survived the 1989-90 winter beneath thermoblanket covers, in most cases their regrowth quality ratings were as high as or higher than treatments providing greater temperature insulation. Because of the translucent character of this material and warm late winter temperatures occurring beneath it, many perennials were saleable immediately following uncovering in April. The same phenomenon occurred with the PLS-80 material after the 1990-91 winter, but, because of persistent snow cover, the insulating abilities of the PLS-80 material remain unproven as evidenced by very poor *Geum* regrowth quality ratings.

Results from this study indicate that polyethylene/woodchip and sandwich covers are effective in moderating temperature extremes and should be favored when overwintering known cold-sensitive species. Alternatively, hardier species can be stored beneath thermoblanket covers. Judging the insulating capabilities of the PLS-80 material was made difficult by snow cover during the winter it was tested. Its effectiveness may be increased if a layer of 4-mil white polyethylene is placed over container-grown-plants first. Although certain cold-tolerant perennial species will survive and grow-on successfully without winter protection, viability will be insured and plants will be saleable sooner in spring if container-grown perennials are protected by these simple structureless systems.

Table 3. Effect of 5 structureless overwintering systems on regrowth quality[z] of 18 species of container-grown herbaceous perennials.

Species/Experiment		Treatment				
		Control	PLS-80[y]	Sandwich	Thermoblanket	Poly/Woodchip
Achillea 'The Beacon'						
	1989–90	3.0 ab[x]	—	3.3 ab	3.9 b	2.9 a
	1990–91	2.3 a	3.2 ab	3.0 ab	4.0 b	3.9 b
Coreopsis lanceolata 'Goldfink'						
	1989–90	1.0 a	—	4.7 c	3.4 b	3.8 bc
	1990–91	—[w]	—	—	—	—
Coreopsis verticillata 'Moonbeam'						
	1989–90	1.1 a	—	5.0 b	4.9 b	4.9 b
	1990–91	1.3 a	3.1 b	3.9 bc	4.2 c	3.7 bc
Coreopsis verticillata 'Zagreb'						
	1989–90	1.0 a	—	4.9 b	4.8 b	4.8 b
	1990–91	2.0 a	4.6 b	4.1 b	4.4 b	4.9 b
Delphinium elatum 'Pacific Hybrid'						
	1989–90	1.0 a	—	2.6 b	3.8 c	3.6 c
	1990–91	1.1 a	4.4 b	4.2 b	3.7 b	4.6 b
Gaillardia x *grandiflora* 'Goblin'						
	1989–90	1.3 a	—	3.7 b	3.8 b	3.3 b
	1990–91	1.0 a	2.9 b	4.2 c	3.9 bc	3.0 b
Geum quellyon 'Mrs. Bradshaw'						
	1989–90	1.0 a	—	1.2 a	1.0 a	4.0 b
	1990–91	1.0 a	1.6 a	3.6 b	3.1 b	4.1 b
Heuchera sanguinea 'Bressingham'						
	1989–90	1.1 a	—	3.4 b	4.6 c	3.6 b
	1990–91	1.0 a	3.4 b	3.6 b	3.8 b	4.3 b
Heuchera sanguinea 'Splendens'						
	1989–90	1.0 a	—	2.7 b	3.4 b	3.2 b
	1990–91	1.0 a	3.1 bc	2.9 b	4.3 d	4.0 cd
Physostegia virginiana 'Pink Bouquet'						
	1989–90	1.2 a	—	4.4 b	5.0 b	4.3 b
	1990–91	2.4 a	5.0 b	4.9 b	4.7 b	4.9 b
Physostegia virginiana 'Summer Snow'						
	1989–90	—[v]	—	—	—	—
	1990–91	1.8 a	3.7 b	3.6 b	3.6 b	4.0 b
Platycodon grandiflorus 'Fuji Blue'						
	1989–90	2.9 a	—	4.3 b	3.8 ab	4.0 b
	1990–91	1.8a	3.4 b	3.6 b	3.8 bc	4.7 c
Salvia x *superba* 'Stratford Blue'						
	1989–90	1.6 a	—	3.4 b	4.4 c	3.2 b
	1990–91	1.8 a	4.2 bc	4.1 bc	4.6 c	3.3 b
Sedum 'Autumn Joy'						
	1989–90	1.6 a	—	4.1 b	4.9 b	4.6 b
	1990–91	3.2 a	4.9 b	4.6 b	4.9 b	5.0 b
Sedum 'Brilliant'						
	1989–90	3.1 a	—	3.8 ab	4.3 b	3.2 a
	1990–91	2.2 a	4.6 b	4.3 b	4.6 b	4.8 b
Tanacetum coccineum						
'Robinson's Mix'	1989–90	1.0 a	—	2.7 b	3.1 bc	3.7 c
	1990–91	1.0 a	3.1 b	4.3 c	4.3 c	4.1 bc
Veronica repens						
	1989–90	2.7 a	—	4.3 b	4.8 b	4.6 b
	1990–91	1.0 a	3.8 b	4.4 b	4.3 b	4.7 b
Veronica spicata 'Icicle'						
	1989–90	—[v]	—	—	—	—
	1990–91	1.4 a	4.3 b	4.2 b	4.4 b	4.8 b

[z]Ratings where 1 = dead plant; 2 = alive, but little top growth; 3–5 = acceptable; 5 = highest quality. Each value is the mean of 3 observations × 3 replications.

[y]Treatment not included in 1989–90 experiment.

[x]Quality ratings across columns followed by the same letter are not significantly different from each other using LSD (t-test), P = 0.05, LSD = 0.94 (1989–1990), LSD = 1.06 (1990–1991).

[w]Species unavailable for 1990–91 experiment.

[v]Species unavailable for 1989–90 experiment.

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Seed Germination of *Rhododendron carolinianum*: Influence of Light and Temperature[1]

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Abstract

Seeds of *Rhododendron carolinianum* Rehd. (Carolina rhododendron) were germinated at 25°C (77°F) or an 8/16 hr thermoperiod of 25°/15°C (77°/59°F) with daily photoperiods of 0, 1/2, 1/2 twice daily, 1, 2, 4, 8, 12, or 24 hr. For both temperatures, no germination occurred during a 30-day period for seeds not subjected to light. At 25°C (77°F) increasing photoperiods increased germination with germination of 26 and 39% occurring by day 30 for the 12 and 24 hr photoperiods, respectively. The alternating temperature of 25°/15°C (77°/59°F) enhanced germination when light was limiting. At this temperature germination ≥58% occurred by day 30 for photoperiods ≥ 4 hr. For photoperiods ≥ 8 hr, 30-day germination ≥ 70% was realized.

Index words: seeds, sexual propagation, Carolina rhododendron, Ericaceae, native plants.

Significance to the Nursery Industry

Quantitative data are presented concerning the influence of light and temperatures of 25°C (77°F) and 25°/15°C (77°/59°F) on seed germination of *R. carolinianum*, an indigenous species with desirable landscape characteristics. Regardless of temperature, seeds required light for germination. However, the photoperiod which maximized germination varied, depending on the temperature. Seeds should not be covered during propagation because of their extremely small size [approximately 825,000 pure seeds per 28 g (1 oz)] and light requirement.

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Introduction

Carolina rhododendron (*Rhododendron carolinianum* Rehd.) is a native evergreen, lepidote (scaly) rhododendron of the southeastern United States. Although the taxonomic treatment of *R. carolinianum* and related taxa is problematical (4,7,9), it occurs at high elevations in the mountains of North and South Carolina and Tennessee (4).

Rhododendron carolinianum is a cold hardy, compact shrub reaching a height of 1 to 2.5 m (4). Flowering occurs in May through June with attractive blooms ranging from pale pink to rose-purple (4). Leaves are dark to paler green in the summer (4) and develop a purplish tinge in winter (5). All of these characteristics have contributed to *R. carolinianum* being a highly desirable landscape plant. Additionally, because of its compact growth habit, outstanding floral display and cold hardiness, it has been used as a parent in many crosses (controlled pollinations). Hybrid selections include Wilson rhododendron (*Rhododendron* X