Expanded Polystyrene as a Substitute for Perlite in Rooting Substrate[1]

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Abstract

Stem cuttings of rose-of-sharon (*Hibiscus syriacus* L. 'Jeanne d'Arc'), barberry (*Berberis thunbergii* DC. 'Crimson Pygmy'), juniper (*Juniperus horizontalis* Moench. 'Plumosa Compacta'), and arborvitae (*Thuja occidentalis* L. 'Woodwardii') were rooted in substrates consisting of 0%, 25%, 50%, 75%, or 100% (by vol) perlite or expanded polystyrene beads with peat. Percentage of rose-of-sharon cuttings rooted and root ratings were lower with polystyrene than with perlite. Statistically, more barberry cuttings rooted with polystyrene (78.8%) than with perlite (78.3%), but the difference in rooting between polystyrene and perlite was not horticulturally significant. More juniper and arborvitae cuttings rooted with 50% perlite than with other perlite concentrations. Percentage of rooted juniper cuttings decreased but percentage of rooted arborvitae cuttings increased as polystyrene concentration in the substrate increased. More roots and longer roots formed on juniper cuttings with perlite than with the same concentration of polystyrene in the substrate. In contrast, arborvitae cuttings had more roots with 25% perlite than with 25% polystyrene, but arborvitae cuttings in 50%, 75%, or 100% polystyrene had more roots than cuttings in the same concentration of perlite. Results indicate expanded polystyrene is a reasonable substitute for perlite in rooting substrate for barberry, juniper, and arborvitae if appropriate ratios of polystyrene to peat are used.

Index words: cuttings, vegetative propagation, styrofoam.

Species used in this study: Rose-of-Sharon (*Hibiscus syriacus* L. 'Jeanne d'Arc'); Crimson pygmy barberry (*Berberis thunbergii* DC. 'Crimson pygmy'); Andorra juniper (*Juniperus horizontalis* Moench. 'Plumosa compacta'); Woodward globe arborvitae (*Thuja occidentalis* L. 'Woodwardii').

Significance to the Nursery Industry

Adoption of practices that reduce production costs while maintaining plant quality helps growers to keep costs down while maintaining their profit margin. Use of by-products from other industries as components of plant growth substrates can reduce production costs if plant quality is maintained because these by-products are often available free of charge or for a nominal fee. Results of this study show that expanded polystyrene beads can be substituted for perlite in rooting substrate during propagation of some woody species.

Introduction

Perlite is an important component in soilless potting substrates. It is often mixed at rates of 30% or greater (by vol) with peat in propagation substrates when rooting cuttings (10). The price of perlite depends on grade and volume ordered. Current perlite prices range from \$35.29/m^3 (\$27.00/yd^3) to \$61.75/m^3 (\$47.25/yd^3) when purchased in quantities of 700 to 800 bags and freight is paid by the nursery. Expanded polystyrene beads are commonly used in media mixes in the greenhouse industry, but they are used less commonly in the nursery industry. Polystyrene beads usually can be acquired at no cost or for a nominal fee of about \$0.44/m^3 (\$0.34/yd^3) if picked up by the user at the source.

Preferred characteristics of a propagation substrate include: a) consistent quality, b) absence of disease and insect pests, c) absence of toxic chemicals, d) ability to hold and supply water, e) light weight, and f) adequate drainage and aeration. Other considerations include compatibility of components when mixing, ability to support the cutting, and ease of inserting the cuttings (9).

The expanded polystyrene industry produces a large amount of waste annually. Some expanded polystyrene waste is used to fill beanbags and similar products, but more waste is produced than can be used; therefore, companies are seeking alternatives for disposing of their waste. Because of the inorganic nature of the product, expanded polystyrene waste should be consistent from a particular source throughout the year. Polystyrene beads are not suitable for use alone for rooting cuttings but are best mixed with peat (9).

Many inorganic materials such as sand, calcined clay, rock wool, perlite, and vermiculite are used commonly in propagation and plant growth substrates (1, 3, 4, 11). Use of polystyrene products has been limited in the nursery industry because of environmental issues. Polystyrene floats, resulting in accumulations in retaining ponds (3), and because of its light weight, polystyrene blows with the wind during mixing. Positive attributes include low cost, good drainage, and light weight (which further saves shipping costs).

The objective of this study was to determine the potential substitution of polystyrene beads for perlite in rooting media for two deciduous broadleaf species ('Jeanne d'Arc' rose-of-sharon and 'Crimson Pygmy' barberry) and two conifer species ('Plumosa compacta' juniper and 'Woodwardii' arborvitae).

Materials and Methods

Substrate properties. A 1:2 mixture (by vol) of substrate to distilled water was prepared for each substrate and allowed to equilibrate for 30 min before testing for pH and electrical

[1]Received for publication May 14, 2001; in revised form September 10, 2001. Approved for publication by the Director, Oklahoma Agricultural Experiment Station. This research was supported under project H-2324. The authors appreciate the support of Greenleaf Nursery Co., Park Hill, OK. Technical assistance of Mary Pritchett and Peggy Reed is greatly appreciated. We thank Dr. P.L. Claypool, Department of Statistics, Oklahoma State University for statistical advice.

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conductivity (EC). The pH of each substrate was determined using a compact pH meter (Twin pH B-213, Spectrum Technologies, Plainfield, IL) and EC was determined with a conductivity meter (Orion, Model 125, Beverly, MA). Total porosity, percent air space, water holding capacity, and bulk density were determined as described by Ingram et al. (5).

Broadleaves. Ten cm (4 in) long terminal softwood cuttings were collected from rose-of-sharon and barberry on September 9, 1999. Leaves were removed from the basal 5 cm (2 in) of each cutting. The basal 1 cm (0.4 in) of rose-of-sharon cuttings was dipped for 5 s in 1250 ppm (0.125%) indolebutyric acid (IBA). The IBA was prepared by dissolving 10 g (0.35 oz) of IBA in 1 liter (0.26 gal) of 70% isopropyl alcohol to make a 10,000 ppm (1%) stock solution. The 10,000 ppm (1%) stock solution was then diluted with a 1:1 (by vol) mixture of 70% isopropyl alcohol and tap water to obtain the final concentration of 1250 ppm (0.125%). Barberry cuttings received no auxin treatment. Cuttings were placed with the lower 4 cm (1.6 in) in the media in 26.5 cm (10.4 in) wide by 51 cm (20 in) long by 7.5 cm (3 in) deep trays with 32 cells per tray. Cell size was 5.7 cm (2.25 in) by 5.7 cm (2.25 in) at the top, 3.8 cm (1.5 in) by 3.8 cm (1.5 in) at the bottom, and 7.5 cm (3 in) deep. One cutting was placed in each cell. Trays contained substrates consisting of 0%, 25%, 50%, 75%, or 100% (by vol) perlite or expanded polystyrene (Insul Bead, Gravette, AR) with peat. About 35% (by vol) of perlite particles was less than 2 mm (0.08 in) in diameter and about 65% (by vol) of perlite particles was between 2 mm (0.08 in) and 8 mm (0.3 in) in diameter. About 80% (by vol) of polystyrene particles was between 2 mm (0.08 in) and 8 mm (0.3 in) in diameter while the remaining 20% (by vol) was primarily larger than 8 mm (0.3 in) in diameter. Cuttings were maintained in a polyethylene-covered greenhouse under natural photoperiod with a maximum photosynthetic photon flux (PPF) of 810 μmol/m^2/s and maximum/minimum air temperatures of 33/10C (92/50F). Trays were placed on black nonwoven groundcover fabric under DGT mist nozzles (A.H. Hummert, St. Louis, MO) with an output of 2 liters/min (0.5 gal/min). Nozzles were positioned 40 cm (15.7 in) above the trays at 90 cm (35.4 in) intervals. Mist cycles were adjusted as necessary, but averaged 6 s duration every 15 min between 0800 and 1800 HR daily. Number of roots on rose-of-sharon and barberry cuttings was rated six and eight weeks after planting, respectively, on a scale of 0 to 4 with 0 = no roots, 1 = 1 to 10 roots, 2 = 11 to 20 roots, 3 = 21 to 30 roots, and 4 = more than 30 roots.

Conifers. The study described above was repeated beginning December 1, 1999, using juniper and arborvitae. Terminal hardwood cuttings from each species were cut to 12 cm (4.7 in) in length. Foliage was removed from the basal 5 cm (2 in), and the basal 1 cm (0.4 in) was dipped for 5 s in 2500 ppm (0.25%) IBA. The IBA was prepared by diluting a 10,000 ppm (1%) stock solution as described above. Cuttings were placed in trays to a depth of 4 cm (1.6 in). Rooting trays and substrates were as described above. Mist was adjusted as necessary, averaging 6 s duration every 30 min between 1000 and 1700 HR daily. Juniper and arborvitae were evaluated 17 and 20 weeks after planting, respectively, for percentage of cuttings rooted. Cuttings were considered rooted when one or more roots were present on the cutting at the time of evaluation. Primary root number and length of the longest root were determined on ten randomly chosen cuttings for each treatment and replication.

Statistics. A randomized complete block design was used for each species with ten replications and 32 subsamples per treatment. Data for percentage of cuttings rooted in each species were transformed using an arcsin transformation. Analysis of variance procedures and trend analyses using perlite or polystyrene concentration in the substrate as the independent variable were performed on percentage of cuttings rooted in all species and on root number and length for juniper and arborvitae. Due its categorical nature, data for root number per cutting of rose-of-sharon and barberry were subjected to analysis of variance using PROC CATMOD, then trend analyses were performed on significant main effects and interactions. The CATMOD procedure analyzes data that can be represented by a contingency table that does not necessarily require transformation of the data for analysis (SAS Institute, Cary, NC).

Table 1. Chemical and physical properties of propagation substrates containing various proportions of perlite or expanded polystyrene with peat.

Component	Rate (%)	pH	Electrical conductivity (dS/m^3)	Air space (%)	Bulk density (g/cm^3)
Peat	100[z]	5.3	5.2	8	0.15
Perlite	25	5.0	1.7	18	0.12
	50	5.4	3.4	24	0.17
	75	5.7	1.9	24	0.16
	100	6.3	1.0	34	0.18
	Linear	***[y]	**	***	*
	Quadratic	**	NS	NS	NS
Polystyrene	25	5.3	4.3	19	0.11
	50	5.4	3.5	21	0.10
	75	5.5	2.4	17	0.05
	100	5.6	0.3	45	0.02
	Linear	NS	***	**	***
	Quadratic	NS	NS	**	*

[z]The 100% peat treatment was used as 0% perlite and 0% polystyrene in trend analyses.
[y]NS, *, **, *** Nonsignificant or significant at $P = 0.05$, 0.01 or 0.001, respectively.

Table 2. **Percentage of rose-of-sharon cuttings rooted and average ranking of number of roots per cutting in various proportions of perlite or expanded polystyrene with peat.**

Component	Rate (% by volume)	Cuttings rooted (%)	Root rating[z]
Peat	100[y]	47.2	1.4
Perlite	25	46.3	1.4
	50	53.1	1.5
	75	65.0	2.3
	100	82.2	2.9
	Linear	***[x]	***
	Quadratic	**	*
Polystyrene	25	23.8	0.6
	50	22.2	0.6
	75	31.3	0.8
	100	57.2	1.4
	Linear	***	NS
	Quadratic	***	*

[z]Rating scale: 0 = no roots, 1 = 1 to 10 roots, 2 = 11 to 20 roots, 3 = 21 to 30 roots, 4 = more than 30 roots.

[y]The 100% peat treatment was used as 0% perlite and 0% polystyrene in trend analysis.

[x]NS, *, **, *** Nonsignificant or significant at P = 0.05, 0.01 or 0.001, respectively.

Results and Discussion

Substrate properties. Component interacted with rate for pH, electrical conductivity, air space, and bulk density (Table 1). Substrate pH increased curvilinearly as perlite concentration increased such that pH was lowest with 25% perlite and highest with 100% perlite (Table 1). In contrast, pH was not affected by polystyrene concentration in the substrate. Electrical conductivity decreased linearly as perlite concentration in the substrate increased. The EC was highest (5.2) with no perlite while 50% perlite was intermediate in pH (3.4) and substrate containing 25%, 75%, or 100% perlite had a lower pH (1.7, 1.9, and 1.0, respectively). Electrical conductivity decreased linearly as substrate polystyrene concentration increased. Air space increased linearly as substrate perlite concentration increased, but air space increased curvilinearly as polystyrene concentration increased. The substrate with no polystyrene contained 8% air space while substrates containing 25%, 50%, or 75% polystyrene were intermediate with 19%, 21%, or 17% air space respectively, and the 100% polystyrene substrate contained 45% air space.

A major physical characteristic of a successful rooting substrate is the percentage air space (6, 8, 12), which depends on the depth and the particle size distribution of a substrate (2). Recommendations for substrate aeration (air space) range from 5% to 30% of the substrate volume, depending on the species and the measurement method (2). In our study, the substrates containing 75% or less perlite or polystyrene were within this recommended range for air space. Air space for 100% perlite was slightly higher (34%) than the recommended range, while air space for 100% polystyrene (45%) was well above the recommended range. Bulk density increased linearly from 0.15 g/cm^3 (9.4 lb/ft^3) to 0.18 g/cm^3 (11.2 lb/ft^3) as perlite concentration increased, but decreased curvilinearly from 0.15 g/cm^3 (9.4 lb/ft^3) to 0.02 g/cm^3 (1.2 lb/ft^3) as polystyrene concentration increased.

Component and rate did not interact for total porosity or water holding capacity (data not presented). Total porosity was higher with perlite (72%) than with polystyrene (64%). Total porosity decreased linearly from 83% with no perlite or polystyrene to 61% with 100% perlite or polystyrene. Substrates containing perlite had a higher water holding capacity (50%) than substrates containing polystyrene (39%). Water holding capacity decreased linearly from 75% with no perlite or polystyrene to 21% in substrates consisting of 100% perlite or polystyrene.

Broadleaves. Component and rate interacted for the percentage of rose-of-sharon cuttings rooted and for rating of root number (Table 2). Percentage of cuttings rooted increased curvilinearly from 47% with no perlite to 82% with 100% perlite. A curvilinear relationship also existed between polystyrene concentration and percentage of cuttings rooted, but percentage of cuttings rooted decreased from 47% with no polystyrene to 22% with 50% polystyrene, and percentage of cuttings rooted increased to 57% with 100% polystyrene. Root rating increased curvilinearly from 1.4 with no perlite and 25% perlite to 2.9 with 100% perlite. In contrast, a curvilinear relationship existed between root rating and polystyrene, but root rating was highest (1.4) with 0% and 100% polystyrene, and lowest with 25%, 50%, and 75% polystyrene (0.6, 0.6, and 0.8, respectively). Although species differ, cuttings with three to five roots are generally considered ready for transplanting. In this study, a rating of one indicated that a cutting had from one to ten roots, so some of these cuttings were ready for transplanting. All cuttings receiving a rating higher than one were well rooted and ready to transplant.

Component and rate did not interact for percentage of barberry cuttings rooted (data not presented). Although statistically a greater percentage of cuttings rooted with polystyrene (78.8%) than with perlite (78.3%), the small difference in percentage of cuttings rooted between polystyrene and perlite was not horticulturally significant. Percentage of cuttings rooted was not affected by concentration of perlite or polystyrene in the growing substrate (data not presented). Similarly, substrate component and rate did not affect the rating of root number per cutting (data not presented).

Conifers. Component and rate interacted for percentage of juniper cuttings rooted, number of roots per cutting and length of the longest root (Table 3). A curvilinear relationship existed between perlite concentration and percentage of cuttings rooted, number of roots per cutting, and length of the longest root for juniper. The most cuttings (98%) rooted with 50% perlite while the largest number of roots and longest roots occurred with 25%, 50%, and 75% perlite. Percentage of cuttings rooted, number of roots per cutting, and root length decreased linearly as polystyrene concentration increased.

Component and rate interacted for percentage of arborvitae cuttings rooted, number of roots per cutting, and length of the longest root (Table 4). A curvilinear relationship existed between perlite concentration and percentage of cuttings rooted such that the fewest cuttings rooted with 0% and 100% perlite (21% and 19% of cuttings rooted, respectively) and the most cuttings (31%) rooted with 50% perlite. A similar trend occurred with number of roots per cutting. A curvilinear relationship existed between perlite concentra-

Table 3. Percentage of cuttings rooted, number of roots per rooted cutting and length of the longest root on juniper cuttings rooted in substrate containing various concentrations of perlite or expanded polystyrene with peat.

Component	Concentration (%)	Cuttings rooted (%)	Number of roots	Length of longest root (cm)
Peat	100[z]	78.8	13.8	8.7
Perlite	25	89.4	14.6	11.0
	50	98.1	14.2	11.2
	75	90.0	14.7	10.5
	100	61.2	8.0	7.7
	Linear	*[y]	***	*
	Quadratic	***	***	***
Polystyrene	25	70.9	12.8	8.5
	50	70.0	9.5	6.9
	75	68.8	9.4	7.4
	100	53.8	5.3	5.2
	Linear	**	***	***
	Quadratic	NS	NS	NS

[z]The 100% peat treatment was used as 0% perlite and 0% polystyrene in trend analyses.

[y]NS, *, **, *** Nonsignificant or significant at P = 0.05, 0.01 or 0.001, respectively.

Table 4. Percentage of cuttings rooted, number of roots per rooted cutting and length of the longest root on arborvitae cuttings rooted in various concentrations of perlite or expanded polystyrene with peat.

Component	Concentration (%)	Cuttings rooted (%)	Number of roots	Length of longest root (cm)
Peat	100[z]	21	7.3	5.7
Perlite	25	29	7.6	7.1
	50	31	7.8	6.6
	75	29	7.4	6.1
	100	19	3.9	5.4
	Linear	NS[y]	**	NS
	Quadratic	***	***	**
Polystyrene	25	19	6.5	4.9
	50	28	9.2	6.1
	75	31	8.6	6.4
	100	26	4.3	4.2
	Linear	*	*	NS
	Quadratic	NS	***	**

[z]The 100% peat treatment was used as 0% perlite and 0% polystyrene in trend analyses.

[y]NS, *, **, *** Nonsignificant or significant at P = 0.05, 0.01 or 0.001, respectively.

tion and root length such that the shortest roots occurred with 0% and 100% perlite (5.7 and 5.4 cm, respectively) and the longest roots (7.1 cm) occurred with 25% perlite. The percentage of arborvitae cuttings rooted was greatest at a polystyrene concentration of 75%. A curvilinear relationship between polystyrene concentration and number of roots occurred. Number of roots increased from 7.3 with no polystyrene to 9.2 with 50% polystyrene, then decreased to 4.3 with 100% polystyrene. A curvilinear relationship also existed between polystyrene concentration and root length. The longest roots occurred with 50% or 75% polystyrene (6.1 and 6.4 cm, respectively).

Loach (7) tested three rhododendron cultivars in six substrates and found divergent results among the substrates. Rooting of the four species in our study was also inconsistent. This inconsistency may have been related to the type of roots produced by each species since rose-of-sharon tends to form thick, coarse roots and barberry tends to form thin, fragile roots. Environmental differences may also explain differences in rooting among our species. Cuttings from the broadleaf species were taken during the fall, whereas both conifer species were taken during the winter when transpiration tends to be lower.

This study suggests that substitution of polystyrene for perlite is feasible and may result in a substantial propagation cost reduction. Rose-of-sharon, a broadleaved species, rooted better with 100% polystyrene than with lower concentrations. The conifer species generally rooted better with lower concentrations of polystyrene. More rooted cuttings and more roots per cutting occurred on junipers when 100% peat (0% polystyrene) or 25% polystyrene were used than with higher rates of polystyrene. More arborvitae cuttings rooted with 50% or 75% polystyrene than with higher or lower concentrations. Individual species should be tested before routinely incorporating polystyrene in propagation substrate.

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