Rooting Stem Cuttings of Herbaceous and Woody Ornamentals in Substrates Containing Eastern Redcedar (*Juniperus virginiana*)[1]

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Abstract

Propagation substrates can strongly influence rooting success of stem cuttings. Eastern redcedar (*Juniperus virginiana* L.) chips (ERC) have been suggested as a propagation substrate component. This study investigated ERC as a perlite substitute in a perlite:sphagnum peat moss (3:1 v/v) rooting substrate. Stem cuttings of coleus [*Solenostemon scutellarioides* (L.) Codd], English ivy (*Hedera helix* L.), forsythia (*Forsythia ×intermedia* Zab.), lantana (*Lantana camara* L.), and spreading euonymus (*Euonymus kiautschovicus* Loes.) were rooted in substrates containing increasing concentrations of ERC hammer-milled to pass a 4.8 mm (0.19 in) screen. All species rooted well (≥ 95%) in all substrates except forsythia which rooted poorly in all substrates (8 to 36%). ERC concentration did not affect mean root number or mean root length in any species except spreading euonymus where mean root number peaked at 0 and 100% ERC content and mean root length decreased with increasing ERC content. Bulk density, container capacity, and total porosity increased as ERC replaced perlite. Physical properties of all substrates were suitable for cutting propagation. ERC can effectively replace perlite in rooting substrates for many ornamental species.

Index words: alternative substrate, juniper, perlite, propagation, wood chips.

Species used in this study: spreading euonymus (*Euonymus kiautschovicus* Loes.); forsythia (*Forsythia ×intermedia* Zab.) (cultivar unknown); 'Anne Marie' English ivy (*Hedera helix* L.); eastern redcedar (*Juniperus virginiana* L.); 'Irene' lantana (*Lantana camara* L.); and 'Defiance' coleus [*Solenostemon scutellarioides* (L.) Codd].

Significance to the Horticulture Industry:

Eastern redcedar trees occur as a weed species throughout the eastern half of the United States. Aged wood can be chipped and then hammer-milled to produce a substrate component with aerating properties similar to perlite. Stem cuttings of coleus, English ivy, forsythia, lantana, and spreading euonymus were rooted in substrates containing eastern redcedar chips (ERC) that had been hammer-milled to pass a 4.8 mm (0.19 in) screen. Cuttings of coleus, English ivy, and lantana rooted as well (≥ 95%) in the 100% ERC substrate as they did in a standard rooting substrate [3 perlite: 1 peat (v/v)]. Spreading euonymus rooted well (≥ 95%) in all substrates, but root length decreased as ERC replaced perlite. Forsythia rooted poorly in all substrates (8 to 36%). Growers seeking an alternative to perlite should consider ERC as a rooting substrate component if working with compatible species.

Introduction

Perlite is a key component of most commercial substrates used for cutting propagation. Due to its aerating characteristics, growers commonly incorporate perlite at 30 to 100% by volume of their rooting substrates (Moore 1987). However, perlite dust is an eye and lung irritant. Researchers have investigated many perlite alternatives as rooting substrates. Recent work by Starr (2011) demonstrated that hammer-milled eastern redcedar chips (ERC) could replace peat moss without reducing propagation success for stem cuttings of 'Abelle' chrysanthemum (*Chrysanthemum morifolium* Ramat.), 'Colorcade Cherry Red' ivy geranium [*Pelargonium peltatum* (L.) L'Her.], hibiscus (*Hibiscus rosa-sinensis* L.), 'Golden Vicary' privet (*Ligustrum ×vicaryi* Rehder), and 'Green Giant' arborvitae (*Thuja* L. ×'Green Giant').

Eastern redcedar is native to the Great Plains and the eastern half of the U.S. (Hardin et al. 2001). However, its encroachment into grasslands causes both economic and ecological consequences with a 99% reduction in herbaceous biomass productivity and severe loss of plant species diversity (Briggs et al. 2002). Eastern redcedar trees are occasionally cleared from pasture land and often burned as 'trash' wood. Processing coarsely chipped eastern redcedar through a hammer-mill yields material suitable as a horticultural substrate component.

Recent work has demonstrated the potential of ERC as a substrate amendment in container substrates for production of woody and herbaceous ornamentals (Carmichael et al. 2014; Edwards et al. 2013, 2014; Murphy et al. 2011; Starr et al. 2012, 2013). The reports differ on the total content of ERC that can be incorporated into a substrate and still achieve acceptable growth. However, they all suggest that some ERC can be substituted for traditional substrate components. The objective of this study was to investigate the potential of ERC to substitute for perlite in a propagation substrate for rooting stem cuttings of coleus, English ivy, forsythia, lantana, and spreading euonymus.

Materials and Methods

Rooting. Whole trees (bark and wood) of eastern redcedar were fell and allowed to air dry for one year then chipped. On December 6, 2013, the coarsely chipped eastern redcedar (Queal Enterprises, Pratt, KS) was further hammer-milled (Model 30HMBL, C.S. Bell Co., Tiffin, OH) to pass a 4.8 mm (0.19 in) screen. These chips were used to prepare five substrates of increasing ERC content (0, 25, 50, 75, and 100%,

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by vol). All substrates contained 25% sphagnum peat moss (Ferti-lome, Bonham, TX) except the 100% ERC substrate. The remaining volume of each substrate was coarse perlite (Sun Gro Horticulture, Agawam, MA). Fresh samples of each substrate were collected for physical property analysis.

Clean flats [40 × 40 × 12.7 cm with 5 mm screen bottom (15.75 × 15.75 × 5 in with 0.20 in screen bottom)] (AFlat5, Anderson Die and Manufacturing Inc., Portland, OR) were dipped in a sterilizing solution [3.96 ml·L^{-1} (0.5 fl oz·gal^{-1}) Green-Shield, Whitmire Micro-Gen Research Laboratories, Inc., St. Louis, MO] before each was filled with one of the five substrates. Three days before the first cuttings were inserted, all flats were placed under intermittent mist (8 s every 4 min during natural daylight hours) [Flora-Mist #300A, 0.25 L·min^{-1} (0.066 gal·min^{-1}), Hummert International, St. Louis, MO] in a glass greenhouse with natural photoperiod and constant temperature set at 29 C (84 F).

Woody cuttings of spreading euonymus and forsythia were harvested December 16, 2013, from the Kansas State University campus, Manhattan, KS. Stem tissue from the most recent year was selected, and cuts were made above nodes to form 10 to 15 cm (4 to 6 in) stem cuttings. Any remaining leaves were stripped from dormant forsythia cuttings and from the basal half of euonymus cuttings. The bottom 1 cm (0.4 in) of each cutting was dipped 5 s in a 1,000 ppm (0.1%) solution of the potassium (K) salt of indole-3-butyric acid (K-IBA) (7012I, Research Organics, Inc., Cleveland, OH) dissolved in distilled water. Cuttings were allowed to air dry 5 min, then were inserted 5 cm (2 in) deep into the substrate. Intermittent mist was initially set at 6 s every 8 min, 24 h·d^{-1}, but was increased to 6 s every 4 min after 1 week.

Stem cuttings were purchased from a commercial unrooted cutting supplier (North Carolina Farms Inc., Indian Trail, NC) on January 4, 2014. Single node softwood stem cuttings of English ivy were 2 to 4 cm (0.8 to 1.6 in) in length and had been trimmed just above a node at both ends by the supplier. Herbaceous cuttings of lantana and coleus both arrived as 2 to 4 cm (0.8 to 1.6 in) stem tip cuttings. The basal 1 cm (0.4 in) of English ivy and lantana cuttings was dipped in a 1,000 ppm (0.1%) K-IBA solution for 5 s and allowed to air dry for 5 min. Coleus cuttings were not treated with auxin. Six cuttings of each species were inserted 1 to 2 cm (0.4 to 0.8 in) deep into dibbled holes in each substrate which was gently firmed around cuttings to ensure good stem to substrate contact. Seventeen days after the herbaceous cuttings were inserted, intermittent mist frequency was reduced to 6 s every 8 min to begin hardening-off the rooted cuttings. At 21 d, mist frequency was further reduced to 6 s every 16 min to prevent rot of herbaceous cuttings.

Cuttings were destructively harvested for data collection. Percent rooting, mean root number per rooting cutting, and mean primary root length of each root were measured by hand. Coleus, forsythia, English ivy, lantana, and spreading euonymus cuttings were harvested at 25, 59, 32, 32, and 51 d, respectively, after initial insertion into the substrates. Roots were defined as any linear root growth longer than 2.0 mm (0.08 in) to distinguish roots from callus tissue.

The experimental design was a randomized complete block design with five substrate treatments and six cuttings (subsamples) per species per treatment. Each substrate treatment was replicated (block) six times. Data were subjected to analysis of variance and regression analysis (SAS, Version 9.2, SAS Institute Inc., Cary, NC). Each species was treated as a separate experiment; therefore, no statistical comparisons were made between species.

Physical properties. Substrate samples were adjusted to 35% volumetric water content and four replications of each were measured using the procedure described by Fonteno and Harden (2003) to determine air space, container capacity, total porosity, and bulk density. Particle size distribution was determined from 100 g (3.53 oz) samples of oven dried [24 h at 105 C (221 F)] substrate separated on a sieve shaker [278 oscillations·min^{-1}; 159 tap·min^{-1} (Ro Tap RX-29, W.S. Tyler, Mentor, OH)] with 12 sieve opening sizes of 12.7, 9.5, 6.3, 3.35, 2.36, 2.00, 1.40, 1.00, 0.50, 0.25, 0.106, and 0.053 mm (0.5, 0.375, 0.248, 0.132, 0.093, 0.079, 0.055, 0.039, 0.020, 0.010, 0.004, and 0.002 in) plus a catch pan. Sieves were divided into two sets — the largest six and the smallest six, and samples were run for 3 min on each. Mass of material caught in each sieve was measured and the value was divided by 100 g (3.53 oz) to determine its proportion of the original substrate.

Sieve shaker results showed that particle size varied among substrates in three distinct ranges. These ranges were based on particle diameter and were defined as coarse [> 2.36 mm (> 0.093 in)], medium [2.36 to > 0.5 mm (0.093 to > 0.020 in)], and fine [≤ 0.5 mm (≤ 0.020 in)]. Substrates were analyzed using these three categories. Differences in physical properties were tested for significance using a protected means separation [Waller-Duncan K ratio t-test (α=0.05)].

Results and Discussion

Percent rooting was high for all species (≥ 95%) except forsythia (25.6%) and unaffected by substrate ERC content (Data not shown). These results are similar to those of Witcher et al. (2014) who reported no effect of whole pine tree substrates on rooting percent of various species. Mean root number per rooted cutting and mean root length were also unaffected by substrate ERC content (Data not shown), with the exception of spreading euonymus (Table 1). Physical properties of the five substrates were generally within recommended ranges with total porosity slightly above recommendations and bulk density below recommendations (Tables 2 and 3).

Rooting. Shoot tip cuttings of spreading euonymus rooted at 96.1%, and rooting was unaffected by substrate ERC content (Table 1). This agrees with Dirr (2009) who stated that cuttings of spreading euonymus root easily. Cuttings in the standard substrate [3 perlite: 1 sphagnum peat moss (v/v)] rooted well (97.2%) with a mean of 36.3 roots per rooted cutting and a mean root length of 7.1 cm (2.8 in). This confirms that cuttings of spreading euonymus used in this experiment were capable of rooting successfully and shows that incorporating ERC in propagation substrates does not negatively influence their percent rooting. The response of mean root number of spreading euonymus to increasing ERC content was quadratic in nature (Table 1). Root number peaked at 0 and 100% ERC with means of 36.3 and 25.6 roots, respectively. Substrates with intermediate ERC contents produced the lowest mean root number (approximately 20). No single substrate component or physical property entirely explains this quadratic trend, which reflects the combined effects of several factors.

Root length of spreading euonymus declined linearly with increasing ERC content (Table 1), suggesting ERC slowed

Table 1. Percent rooting, mean root number, and mean root length of stem cuttings of spreading euonymus (*Euonymus kiautschovicus*) inserted into substrates containing eastern redcedar (*Juniperus virginiana*) chips (ERC).

ERC[z] (% vol)	Perlite (% vol)	Peat moss (% vol)	Rooting[y] (%)	Root no.	Root length (cm)
0	75	25	97.2	36.3	7.1
25	50	25	100.0	20.1	5.9
50	25	25	97.2	20.7	4.1
75	0	25	88.9	20.2	2.6
100	0	0	97.2	25.6	2.3
		Significance	$P = 0.32$	$P = 0.02$	$P \leq 0.0001$
		Linear	NS[x]	NS	**
		Quadratic	NS	**	NS

[z]Hammer-milled to pass a 4.8 mm (0.19 in) screen. All substrates contained 25% peat by volume except the 100% ERC treatment. Perlite filled the remaining volume.
[y]n = 36 stem cuttings per treatment.
[x]Not significant (NS) at $P \leq 0.05$ or (**) Significant at $P \leq 0.01$.

root initiation or subsequent root growth. Maximum mean root length [7.1 cm (2.8 in)] occurred in the 0% ERC substrate. Witcher et al. (2014) also reported a general decrease in root length as wood from whole pine trees was added to the rooting substrate. Others have also reported a slight decline in root growth with increasing ERC substrate content (Carmichael et al. 2014; Starr et al. 2012). However, that decline appeared to be species dependent. In the current study, substrate bulk density increased as ERC content increased. Chong (1999) observed a similar inverse relationship between root length and substrate bulk density after growing burning bush [*Euonymus alatus* (Thunb.) Seibold] in substrates

Table 2. Particle size distribution[z] of substrates containing eastern redcedar (*Juniperus virginiana*) chips (ERC).

Particle size category	Sieve opening (mm)	Substrate				
		0% ERC[y]	25% ERC	50% ERC	75% ERC	100% ERC
Coarse	> 2.36	37.7[x]a[w]	22.8b	14.7c	10.1d	9.6d
Medium	2.36 to > 0.5	32.5e	50.9d	59.5c	67.3b	70.7a
Fine	≤ 0.5	28.1a	25.9b	25.4b	22.3c	19.2d

[z]From 100.0 g (3.53 oz) samples dried at 105 C (221 F) and separated on sieve shaker for 3 minutes (278 oscillations·min^{-1}, 159 taps·min^{-1}) (Ro Tap RX-29, W.S. Tyler, Mentor, OH).

[y]Percent volume of total substrate. ERC were hammer-milled to pass a 4.8 mm (0.19 in) screen. All substrates contained 25% peat by volume except the 100% ERC treatment. Perlite filled the remaining volume.

[x]Percent of total sample weight collected from sieve. Column totals do not equal 100% because of particle losses due to static electricity.

[w]Means separated within row using Waller-Duncan K-ratio t test (n = 3, α = 0.05).

Table 3. Physical properties[z] of substrates containing eastern redcedar (*Juniperus virginiana*) chips (ERC).

ERC[y] (% vol)	Air space[x] (% vol)	Container capacity[w] (% vol)	Total porosity[v] (% vol)	Bulk density[u] g·cm^{-3}
0	26.0NS[t]	53.2bc[s]	79.2c	0.09e
25	29.7	51.1c	81.3bc	0.11d
50	30.1	55.1ab	85.2ab	0.13c
75	31.4	57.6a	88.9a	0.16b
100	35.4	50.8c	86.2ab	0.17a
Recommended range[r]	15–40	20–60	40–60	0.3–0.8

[z]Measured according to procedures described by the Horticultural Substrates Laboratory at North Carolina State University (Fonteno and Harden, 2003).

[y]Hammer milled to pass a 4.8 mm (0.19 in) screen. All substrates contained 25% peat by volume except the 100% ERC treatment. Perlite filled the remaining volume.

[x]Air space = (volume of water drained) ÷ (initial volume of sample).

[w]Container capacity = [(wet weight) – (oven dry weight)] ÷ (initial volume of sample).

[v]Total porosity = (air space) + (container capacity).

[u]Bulk density = (oven dry weight) ÷ (initial volume of sample).

[t]Differences not significant (NS) at α = 0.05.

[s]Mean separation within columns using Waller-Duncan K-ratio t test (n = 4, α = 0.05).

[r]From Maronek et al. 1985.

containing composted municipal solid waste. Kirkham (2005) demonstrated that increasing bulk density increases the energy roots must expend to elongate. Although bulk densities observed in the current study [0.09 to 0.17 $g \cdot cm^{-3}$ (5.6 to 10.6 $lb \cdot ft^{-3}$)] are much lower than typical landscape soil conditions, differences in bulk density were strongly significant and similar in magnitude to differences in mean root length. This strongly suggests that bulk density was the main factor influencing mean root length of euonymus cuttings in this study.

Allelopathic chemicals found in eastern redcedar are not likely responsible for the reduced root growth. Work by Smith (1986) shows that most of the allelopathic effects of eastern redcedar influence seedling germination and not general plant growth. Additionally the other species in the current study did not show a similar response. Therefore, an allelopathic effect is either unlikely or species specific.

Overall, forsythia cuttings rooted poorly. Most cuttings flowered and developed leaves shortly after being placed under intermittent mist. Warm greenhouse conditions likely forced forsythia cuttings to initiate shoot growth before adventitious root initiation. Cooler air temperature and bottom heat may have induced rooting prior to bud expansion and growth. Differences among treatments were not significant with 25.6% mean rooting ($P = 0.20$), a mean of 3.6 roots per rooted cuttings ($P = 0.48$), and a mean root length of 1.5 cm (0.59 in) ($P = 0.80$) (data not shown).

Herbaceous cuttings rooted well and without significant differences among treatments (data not shown). Average rooting of all treatments of stem cuttings of English ivy was 98.9% ($P = 0.16$) with a mean of 11.8 roots per rooted cutting ($P = 0.24$) and a mean root length of 4.5 cm (1.8 in) ($P = 0.40$). Cuttings of lantana rooted at 97.2% ($P = 0.41$) with a mean root number of 7.8 ($P = 0.06$) and mean root length of 3.5 cm (1.4 in) ($P = 0.49$). Similarly, cuttings of coleus rooted at 94.7% ($P = 0.33$), with a mean root number of 12.3 ($P = 0.76$), and mean root length was 5.5 cm (2.2 in) ($P = 0.35$). These results suggest that cuttings of many species may root successfully in ERC substrates.

The species selected for this project typically root reliably. They were chosen to demonstrate the feasibility of rooting cuttings in ERC substrates. Future research ought to focus on identifying the rooting substrate preferences of individual species, especially those that are more difficult to root.

Physical properties. During particle size analysis, no particles were caught on the two largest sieves [12.7 and 9.5 mm (0.5 and 0.375 in) openings]. Although a fine dust accumulated in the pan below the smallest sieve for each substrate, the quantity was insufficient to register on a scale accurate to 0.1 g (0.004 oz). Dividing particle size distribution into categories of coarse [> 2.36 mm (> 0.079 in)], medium [2.36 mm to > 0.5 mm (0.093 to > 0.020 in)], and fine [≤ 0.5 mm (≤ 0.020 in)] clarified the results (Table 2). Coarse particle content decreased as ERC replaced perlite. Medium particles increased whenever ERC content increased. Fine particles decreased as the ERC increased from 0 to 100%. Considering substrate components based on their particle size distributions helps to explain their interaction with other substrate components. This leads to a greater understanding of how each component influences substrate physical properties.

Significant differences ($\alpha = 0.05$) among substrates were observed for all physical properties (Table 3) except air space, which averaged 30.5% of substrate volume. Container capacity generally increased as ERC content increased, reaching 57.6% of volume at 75% ERC before dropping to 50.8% when ERC replaced peat moss in the 100% ERC substrate. The increase in container capacity as ERC rose from 25 to 75% seems largely due to the uniform particle size of ERC, which were 70.7% medium-sized particles. These particles nested closely together, increasing the water holding capacity of the substrate. Bilderback and Lorscheider (1995) observed a similar result in a substrate containing double-processed pine bark with uniformly sized particles. The decrease in container capacity between 75 and 100% ERC substrates is clearly due to the decrease in sphagnum peat moss, which has a higher water holding capacity than ERC. The corresponding increase in air space demonstrates that peat moss, which was contributing mostly fine particles, had been nesting between the ERC particles in other substrates. When peat moss was removed, the volume of these pores increased. Thus, air space increased and container capacity decreased when peat moss was replaced by ERC.

Total porosity rose steadily from 79.2% of volume at 0% ERC to 88.9% of volume at 75% ERC. However, when ERC content increased to 100%, porosity decreased slightly. This trend was a direct result of the changes in air space and container capacity. Both air space and container capacity generally increased from 0 to 75% ERC content. Although air space increased again when ERC content reached 100%, container capacity dropped sharply with the loss of peat moss. Combined, these factors caused the slight decrease in total porosity at 100% ERC. Bulk density rose steadily from 0.09 $g \cdot cm^{-3}$ (5.6 $lb \cdot ft^{-3}$) at 0% ERC to 0.17 $g \cdot cm^{-3}$ (10.6 $lb \cdot ft^{-3}$) at 100% ERC. Clearly, ERC is a denser substrate component than either perlite or sphagnum peat moss.

Maronek et al. (1985) provide recommended ranges for physical properties of propagation substrates (Table 3). In the current experiment, all substrates were within the recommended ranges for air space and container capacity. Total porosity was above the recommended range of 40 to 60% porosity in all cases, but was closest in the control substrate (79.2%). High porosity can lead to poor contact between substrate and the cuttings to be rooted (Maronek et al. 1985), but in this experiment, high porosity did not seem to be a problem as most species rooted well. Bulk density was also outside the recommended range of 0.3 to 0.8 $g \cdot cm^{-3}$ (18.7 to 49.9 $lb \cdot ft^{-3}$) and only reached 0.17 $g \cdot cm^{-3}$ (10.6 $lb \cdot ft^{-3}$) at the highest ERC content. Similarly, Starr (2011) determined the bulk density of his 100% ERC substrate to be 0.18 $g \cdot cm^{-3}$ (11.2 $lb \cdot ft^{-3}$). The range for bulk density recommended by Maronek et al. (1985) is influenced by the ballast needed in substrates used for liner production. Though substrates from this experiment may not be dense enough for container production, they appear suitable as propagation substrates.

ERC substrates have shown potential for cutting propagation. Although roots of certain species such as spreading euonymus and possibly forsythia may develop poorly in ERC substrates, other species including English ivy, lantana, and coleus root well in substrates containing up to 100% ERC. Propagators seeking alternatives to perlite should consider ERC as a component of their propagation substrate.

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