A Comparison of Distilled Cedar, Perlite, and Rice Hulls as Substrate Components in the Production of Greenhouse-Grown Annuals©

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Perlite is a standard greenhouse component whose function is to add necessary porosity to peatmoss based substrates allowing for flow of gas and water through containers. Perlite requires high amounts of energy for both the production and shipping processes. This high-energy input is one of the main reasons for interest in discovering alternatives. The objective of this study was to mimic the beneficial characteristics of perlite in substrates by adding varying percentages of distilled cedar (DC) and rice hulls (RH) to peat moss and comparing them to Peatlite mixes of concordant percentages. Treatments were amended at 10, 20, and 30% for each component. The species used included petunia and marigold. Results for petunia indicated that PL treatments performed marginally better than substrates containing percentages of DC and RH. However, for marigold, no significant difference was observed between treatments in almost all growth parameters. The conclusive data indicates that growers could amend their substrates with up to 30% DC or RH and yield viable annual crops.

INTRODUCTION

Peat moss and perlite are the main components found in soilless greenhouse substrates today and are thus in high demand commercially. Perlite is a naturally occurring volcanic rock, which expands when heated. It lends air-filled porosity to substrates; an important physical property that growers desire in greenhouse mixes. This porosity allows for gas exchange and drainage to occur between the roots of the plant and the atmosphere outside (Bunt, 1988). Perlite is not only expensive to produce; there are also high amounts of energy required for both the production and shipping processes. In its dry state perlite produces a siliceous dust that is considered a nuisance, causing lung and eye irritation in cases involving over-exposure (Du et al., 2010). Due to these concerns, growers have been engrossed in finding replacement substrate options for perlite. In recent years research regarding alternative substrates has steadily increased; with an emphasis on local and regional sources of materials which are considered to be more sustainable. Numerous types of alternative substrates have been tested in greenhouse crops. A few of those alternatives include: rice hulls, cedar, corncob, rock wool, and polystyrene beads.

Rice hulls are a waste product of the rice milling industry. It has been estimated that almost 34 million tons of fresh rice hulls were produced annually in the United States (Kamath and Proctor, 1998). Rice hulls are generally considered an agricultural waste and, thus, could potentially have a lower market value in comparison to perlite. A study performed by Evans and Gachukia (2004), compared peat-based substrates containing volumetric percentages of rice hulls and perlite that ranged from 20 to 60%. The study indicated that all plants grown in parboiled fresh rice hulls (PFH) substrates were of marketable value. Therefore, PFH could be used as a lower cost substitute to perlite in greenhouse substrates.

In recent years an interest in using *Juniperus virginiana* (L.) as an alternative substrate component has risen. Research has shown that plants grown in substrates amended with cedar tended to be equivalent to those grown in a traditional peatlite mix. Murphy et al. (2011) indicated greenhouse producers could amend standard greenhouse substrates with up to 50% cedar with little to no difference in plant growth. Starr et al. (2011) indicated that *J. virginiana* chips could be used as a substrate for container-grown Rudbeckia, with chips at 0.476-cm screen size performing the best when compared to a pine bark substrate. In addition to the replacement of peat moss, the physical nature of cedar tends to add substrate porosity normally achieved with the addition of perlite. Therefore, we believed a reduction or elimination in the need for perlite might be realized with the use of cedar as a substrate component.

The cedar used in this study was obtained from CedarSafe, a company located in Huntsville, AL. It is unlike cedar found in other substrate research projects. This cedar is a by-product of cedar oil production at the CedarSafe facilities. The cedar logs (*J. virginiana*) are first debarked and shaved and then sent through a hammer mill (1.27 cm screen size). It is then conveyed to a set of boilers, where the material undergoes a steam distillation process, which extracts a percentage of the cedar oil. CedarSafe currently has limited market for the post-distilled cedar biomass.

The objective of this study was to incorporate rice hulls (Riceland Foods Inc. Stuttgart, Arkansas), distilled cedar and perlite (Premium Coarse Grade, Sun Gro Horticulture Distribution Inc. Bellevue, Washington) into a peat substrate at proportional percentages. The varying substrates would be analyzed and compared as to their abilities to promote growth of greenhouse annuals.

MATERIALS AND METHODS

The experiment was installed March 16, 2012 at the Paterson Greenhouse Complex located in Auburn, Alabama. The study evaluated nine treatments. The treatments were mixed by adding RH, DC, or PL at 10, 20, and 30% (by volume) to a peat substrate. Treatments had the following amendments added per cubic meter at mixing: 2.26 kg lime; 0.907 kg starter nutrient charge (7-3-10, Greencare Fertilizers Inc. Kankakee, Illinois), 0.45 kg Micromax (The Scott's Company LLC. Marysville, Ohio), and 2.72 kg slow release fertilizer (13-6-16, Harrell's LLC. Lakeland, Florida). Aqua-Gro L was added at 118.3 mL per cubic meter. Containers (1.8 L) (Dillen Products Middlefield, Ohio) were filled with the substrates and 2 plugs (200 cell flats) of either (*Petunia* × *hybrida* Dream Series, Sky Blue) or marigold (*Tagetes erecta* Antigua Series, Yellow) were planted into each container. Containers were placed in a twin wall polycarbonate greenhouse on elevated benches and hand watered as needed. Containers were arranged in a randomized complete block with 12 blocks per treatment. Species were arranged as separate experiments.

Data collected included pH and EC using the pour-through method (Wright, 1986). At termination all plants were measured for growth index (GI), and bloom count (BC). Roots were visually inspected and rated on a scale of 0 to 5 (RR). At termination shoots were removed at substrate surface, oven dried, and weighed to determine shoot dry weight (SDW). Initial substrate airspace (AS), container capacity (CC), total porosity (TP), and bulk density (BD) were determined using the NCSU Porometer method, as well as particle size distribution (PSD) (Fonteno and Harden, 1995). Data was analyzed using Tukey's studentized range test ($P \leq 0.05$) (SAS Institute version 9.1, Cary, North Carolina).

RESULTS AND DISCUSSION

Results for physical properties indicate that RH had a significantly higher AS than DC and PL at 30%. However, at 10 and 20% no significant difference was observed (Table 1). For CC there was a significant difference at 10, 20, and 30% with DC having significantly higher CC than RH and PL. At 30%, it was observed that PL had 15% lower TP than DC. For treatments amended at 10% there was an 8% difference in TP between DC and PL. There was no significant difference in BD found between treatments with concordant percentages. However, 30% PL had a higher BD than RH and DC at volumes of 10 and 20%.

Table 1. Physical properties of amended substrates.[z]

Substrates	Air space[y]	Container capacity[x]	Total porosity[w]	Bulk density[v]
		(% vol)		(g/cm^3)
10% RH	6.6 b[u]	77.6 bc	84.3 ab	0.12 b
10% DC	5.4 b	82.4 a	87.8 a	0.11 b
10% PL	4.3 b	76.2 c	80.4 b	0.13 ab
20% RH	8.4 ab	77.4 c	85.7 a	0.14 ab
20% DC	5.0 b	83.1 a	88.1 a	0.12 b
20% PL	6.4 b	77.5 c	83.9 ab	0.11 b
30% RH	11.2 a	75.0 c	86.2 a	0.13 ab
30% DC	5.1 b	82.0 ab	87.1 a	0.14 ab
30% PL	6.1 b	67.7 d	73.8 c	0.17 a

[u] Tukeys studentized range test ($P \leq 0.05$, n=3).
[v] Bulk density after forced-air drying at 105°C (221°F) for 48 h (g/cm^3 = 62.4274 lb/ft^3).
[w] Total porosity is container capacity ÷ air space.
[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample.
[y] Air space is volume of water drained from the sample ÷ volume of the sample.
[z] Analysis performed using the NCSU porometer.

Results for pH and EC indicate that at 0 days after planting (DAP) pH levels varied among treatments. The EC readings for 0 DAP were similar at 20%; however, at a rate of 30%, DC had the higher EC values. Also, at 10% DC had significantly lower EC values, which we have seen in previous studies and contribute to the larger particle size associated with DC. At 14 DAP an increase in EC levels was seen throughout all treatments. At 28 DAP EC values dropped to an acceptable range and remained at those levels throughout the rest of the experiment. There was no significant difference between EC values at 35 and 42 DAP. The pH readings varied throughout the study, but remained within a range of 3 to 5; which applied for all treatments (Table 2).

At termination GI for petunia was the highest for substrates containing PL. Treatments containing DC had about 8% lower GI when compared to all PL treatments. Substrates containing RH had 5% lower GI values when compared to DC treatments at 10% and 20%; however, at 30%, RH GI were 16% lower than DC. For petunia BC there were variations observed among treatments. Substrates containing PL, again, had the highest values. For 10% DC a 22% lower BC was observed when compared to 10% PL. A similar difference was observed for treatments containing 20 and 30% DC. A 45% lower BC was noted for 30% RH when making a comparison to PL at its concordant percentage. Petunia RR were similar amongst all treatments at 10 and 20%. However, at 30%, RR values were highest for PL substrates. Values for DC were 12% higher than RH substrates. For marigold GI there was no significant difference observed at 10 and 20% for all treatments. However, at 30%, DC had an 8% higher GI than PL. Termination values for BC, RR, and SDW of marigold were similar among all treatments (Table 3).

The data provided indicates, for petunia, that substrates containing PL would yield the largest crops. However, growing plants in substrates containing 10 and 20% of RH, DC, or PL would yield a viable crop. Data for marigold indicates that plants would grow well in any of the nine substrate treatments. We can compare this to previous research performed by Murphy et al. (2011) where it was concluded that growers could amend greenhouse mixes with up to 50% cedar and have equally successful yields of annual crops when compared to a standard peatlite mix.

Table 2. Effects of substrate on pH and electrical conductivity of greenhouse grown *Petunia ×hybrida.*

Substrates	0 DAP[z]		7 DAP		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
10% RH	3.97 abc[x]	4.38 a	3.85 bc	10.02 abcd	3.89 bc	10.63 ab	3.83 bc	9.22[NS]	4.53 ab	1.85 ab	4.61 a	2.62[NS]	4.19 b	1.87[NS]
10% DC	3.97 abc	2.78 b	3.74 c	10.08 abcd	3.72 de	10.31 ab	3.75 c	7.89	3.90 ef	2.54 ab	4.24 bcd	2.60	3.80 bc	2.83
10% PL	3.81 c	4.43 a	3.73 c	11.57 a	3.70 e	11.03 ab	3.70 c	9.42	3.75 f	2.35 ab	3.93 de	3.01	3.70 c	2.60
20% RH	3.88 bc	4.52 a	3.91 bc	9.28 bcd	3.87 bc	9.21 ab	3.83 bc	9.34	4.27 bcd	2.76 a	4.40 ab	3.10	4.22 b	2.14
20% DC	4.07 ab	4.02 a	4.16 a	9.07 cd	3.98 bc	9.88 ab	4.07 a	7.49	4.47 abc	1.28 b	4.26 bc	2.40	4.24 b	1.35
20% PL	3.86 bc	4.64 a	3.90 bc	11.31 ab	3.85 cd	10.31 ab	3.98 ab	7.29	3.94 def	2.06 ab	3.85 e	2.33	3.90 bc	2.27
30% RH	4.15 a	3.51 ab	4.24 a	8.35 d	4.19 a	7.98 b	4.10 a	8.80	4.80 a	2.64 ab	4.59 a	2.91	4.73 a	1.53
30% DC	4.12 a	4.09 a	4.02 ab	10.68 abc	3.97 bc	9.18 ab	4.03 ab	8.12	4.15 cde	2.55 ab	4.02 cde	2.73	4.03 bc	2.47
30% PL	4.12 a	3.43 ab	4.08 ab	10.75 abc	3.99 b	11.87 a	4.06 a	9.82	4.17 cde	1.66 ab	3.99 cde	2.00	4.15 bc	1.24

[x] Tukeys studentized range test ($P \leq 0.05$, $n=4$).
[y] Electrical conductivity (dS/cm) of substrate solution using the pour through method.
[z] Days after planting.

Table 3. Use of rice hulls, distilled cedar and perlite as substrate components.[z]

Substrates	Growth index[y]	Bloom counts[x]	Root rating[w]	Shoot dry weight[v]
		Petunia ×hybrida		
10% RH	31.5 d[u]	29.6 bc	2.6 ab	11.7 cd
10% DC	32.8 bcd	30.5 abc	2.6 ab	13.3 bc
10% PL	35.7 a	38.8 a	3.3 ab	16.8 a
20% RH	30.2 d	25.8 cd	2.6 ab	9.9 d
20% DC	32.3 bcd	30.3 bc	2.8 ab	11.6 cd
20% PL	35.0 ab	36.5 ab	3.4 ab	15.9 ab
30% RH	26.7 e	20.0 d	2.3 b	7.6 e
30% DC	31.9 cd	32.8 abc	2.6 ab	14.6 abc
30% PL	34.4 abc	36.7 ab	3.6 a	15.9 ab
		Tagetes erecta		
10% RH	21.4 ab	7.3 a	2.8 a	9.3 a
10% DC	21.3 ab	7.2 a	3.4 a	9.0 a
10% PL	21.3 ab	7.7 a	3.1 a	8.5 a
20% RH	20.4 ab	6.8 a	2.9 a	8.5 a
20% DC	20.3 ab	6.8 a	2.8 a	8.0 a
20% PL	21.0 ab	7.0 a	3.4 a	9.0 a
30% RH	19.1 b	7.5 a	3.1 a	8.4 a
30% DC	22.6 a	6.6 a	3.3 a	9.3 a
30% PL	20.7 ab	6.7 a	3.5 a	9.2 a

[u] Tukeys Studentized Range Test ($P \leq 0.05$).
[v] Shoot dry weight measured in grams (n=8).
[w] Root ratings 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface) (n=8).
[x] Bloom count = number of blooms or buds showing color at 42 days (n=12).
[y] Growth index = [(height+width1+width2)/3] (n=12).
[z] Experiment installed at the Paterson Greenhouse Complex on March 12, 2012.

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