Cowpeat as a Substitute for Peat in Container Substrates for Foliage Plant Propagation

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Summary. This study evaluated the potential for using cowpeat, a composted dairy manure, as a component of container substrates for foliage plant propagation. Using a commercial formulation (20% perlite and 20% vermiculite with 60% Canadian or Florida peat based on volume) as controls, peat was replaced by cowpeat at 10% increments up to 60%, which resulted in a total of 14 substrates. Physical and chemical properties such as air space, bulk density, container capacity, total porosity, pH, carbon-to-nitrogen ratio, and cation exchange capacity of the cowpeat-substituted substrates were largely similar to those of the respective control. However, the electrical conductivity (EC) increased with the increased volume of cowpeat. The 14 substrates were used for rooting single-node cuttings of golden pothos (*Epipremnum aureum*) and heartleaf philodendron (*Philodendron scandens* ssp. *oxycardium*) and three-node cuttings of 'Florida Spire' fig (*Ficus benjamina*) and germinating seeds of sprenger asparagus (*Asparagus densiflorus*) in a shaded greenhouse. All cuttings rooted in the 14 substrates, and the resultant shoot and root dry weights of golden pothos and 'Florida Spire' fig 2 months after rooting did not significantly vary across seven Canadian peat- or Florida peat-based substrates. Shoot dry weights of heartleaf philodendron were also similar across substrates, but the root dry weight produced in the Canadian peat-based control substrate was much greater than that produced in the substrate containing 60% cowpeat. Root dry weight and root length produced in the Florida peat-based control substrate were also significantly greater than those produced in substrates substituted by 60% cowpeat. These results may indicate that cuttings of golden pothos and 'Florida Spire' fig are more tolerant of higher EC than those of heartleaf philodendron, as the substrate with 60% cowpeat had EC ≥ 4.16 dS·m^{-1}. Seed germination rates of sprenger asparagus from cowpeat-substituted Canadian peat-based substrates were greater than or comparable to those of the control substrate. Seed germination rates were similar across the seven Florida peat-based substrates. The root-to-shoot ratios of seedlings germinated from both control substrates were significantly greater than those germinated from substrates substituted by cowpeat. This difference could be partially explained by the higher nutrient content in cowpeat-substituted substrates where shoot growth was favored over root growth. Propagation is a critical stage in commercial production of containerized plants. The success in using up to 60% cowpeat in rooting and seed germination substrates may suggest that cowpeat could be an alternative to peat for foliage plant propagation.

Peat has been a major component of substrates for containerized plant production since the 1960s (Bohlin and Holmberg, 2004) due to its high porosity, high water-holding capacity, and relatively high cation-exchange capacity (CEC). The mining and use of peat has recently been questioned because peat is part of the wetland ecosystem (Barber, 1993; Barkham, 1993). Wetlands have accumulated a vast pool of organic carbon and currently hold about 390 to 455 × 10^{15} g of terrestrial carbon or about one-third of the global soil carbon stock (Freeman et al., 2004). Peat harvesting, particularly draining peatlands, accelerates the decomposition process and results in the carbon stored in the peat being released to the atmosphere as carbon dioxide. Peat also plays an important role in improving groundwater quality, and peat bogs also serve as a special habitat for wild plants and animals (Buckland, 1993; Raviv and Lieth, 2008). Peat mining is currently regulated including Florida peat [Florida Public Health Code Section 403.265 (State of Florida, 2006)]. As a result, peat prices are increasing as regulations are being enforced and supplies decrease (Hanson, 2003; McNally, 2003).

Florida is a leading state in containerized plant production (Hodges and Haydu, 2007). Efforts to use alternative organic materials to partially or completely substitute for peat have been made over the years, including the use of composted biosolids, municipal solid waste, or yard trimmings as components for bedding (Klock-Moore, 1997; Moore, 2005), landscape (Beeson, 1996; Fitzpatrick, 2001), and foliage plant production (Chen et al., 2002, 2003; Conover and Poole, 1990; Fitzpatrick et al., 1998), as well as the use of coconut coir for bedding and foliage plant production (Evans and Stamps, 1996; Meerow, 1995; Stamps and Evans, 1997). However, limited information is available on using composted dairy manure as a sole substitute for peat in containerized plant propagation and production (Chen et al., 1988).

Florida was ranked 15th in the nation in milk production, with 152,000 milk cows (Bronson, 2003). Broadcasting dairy manure onto soil can result in the greatest potential for soluble

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1	meq/100 g	cmol·kg^{-1}	1
1	mmho/cm	dS·m^{-1}	1
28.3495	oz	g	0.0353
1.7300	oz/inch^3	g·cm^{-3}	0.5780
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

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phosphorus and nitrogen loss in runoff (Elliott et al., 2005; Kleinman and Sharpley, 2003; van Horn et al., 1994). Composting manures will significantly minimize the environmental problems and can convert the manures into useful organic materials. The use of composted manure could provide the ornamental plant industry with an alternative to peat, which will in turn reduce peat mining.

This study was intended to formulate container substrates using a composted dairy manure, called cowpeat, to replace Canadian or Florida peat in different percentages by volume, characterize the formulated substrates physically and chemically, and use the substrates for rooting cuttings and germinating seeds of foliage plants. The objective was to determine if cowpeat-substituted substrates could be used for foliage plant propagation.

Table 1. Components in volumetric percentage of Canadian peat- and Florida peat-based substrates substituted by cowpeat.[z]

	Proportion of components by volume (%)				
Substrate	Canadian peat	Florida peat	Cowpeat	Perlite	Vermiculite
C-1 (control)	60	0	0	20	20
C-2	50	0	10	20	20
C-3	40	0	20	20	20
C-4	30	0	30	20	20
C-5	20	0	40	20	20
C-6	10	0	50	20	20
C-7	0	0	60	20	20
F-1 (control)	0	60	0	20	20
F-2	0	50	10	20	20
F-3	0	40	20	20	20
F-4	0	30	30	20	20
F-5	0	20	40	20	20
F-6	0	10	50	20	20
F-7	0	0	60	20	20

[z] Cowpeat is a composted dairy manure; the solids from dairy waste were screened and then composted in a large, rotary horizontal drum digester at a temperature of 65 °C (149.0 °F) for 3 d. The cowpeat used in this study had been cured for 30 d after being discharged from the drum digester.

Materials and methods

Formulation of substrates. Cowpeat is a composted dairy manure produced and named by Agrigy Co. (Clearwater, FL). Solids from dairy waste are screened and composted in a large, rotary horizontal drum digester at temperatures up to 65 °C for 3 d (Nordstedt and Sowerby, 2003). The cowpeat used in this study had been cured for 30 d after being discharged from the Lake Okeechobee facility in Florida; its pH was 6.9 with an EC reading of 4.8 $\text{dS}\cdot\text{m}^{-1}$ and a carbon-to-nitrogen (C/N) ratio of 15.06. Commercial sphagnum peat, perlite, and vermiculite were donated by Fafard, Inc. (Apopka, FL). The sphagnum peat was from Canada, designated as Canadian peat; it had a pH of 3.9, an EC 0.32 $\text{dS}\cdot\text{m}^{-1}$, and a C/N ratio of 56.8. Peat mined in Florida was formed from reeds, sedges, and other associated swamp plants (U.S. Geological Survey, 2008); it is designated as Florida peat and was purchased from Reliable Peat Co. (Winter Garden, FL). The Florida peat had a pH of 6.9, an EC 0.31 $\text{dS}\cdot\text{m}^{-1}$, and a C/N ratio of 18.3. Using a commercial formulation of 20% perlite and 20% vermiculite with 60% Canadian or Florida peat based on volume as controls, Canadian and Florida peats were replaced by cowpeat at 10% increments up to 60%, which resulted in a total of 14 substrates (Table 1) formulated by blending the components in a rotary mixer for 5 min at 50 rpm. A commercial ground dolomite (Ash Grove, Portland, OR) was used to adjust substrate pH to ≈6.0.

Determination of physical and chemical properties. The physical properties of the substrates, including bulk density, total porosity, air space, and container capacity, were measured using the Australian Standard Method (Standards Australia, 1989). EC and pH of the substrates were determined using the pour-through method (Yeager et al., 1983). Samples of the 14 substrates were ground to pass through a screen of 40 mesh (0.42 mm), and the ground samples were analyzed for total N and C using Association of Analytical Communities (AOAC) Method 972.43 (AOAC International, 1997). The CEC of substrates were determined using the ammonium chloride (NH_4Cl) extraction method described by Sumner and Miller (1996). All physical and chemical property determinations were carried out in three replications.

Plant materials and experimental design. Single-node cuttings of golden pothos and heartleaf philodendron and three-node cuttings of ‘Florida Spire’ fig were rooted in 72-cell plug trays filled with the 14 substrates. Seeds of sprenger asparagus were sown singly onto cells of substrate-filled 72-cell trays as well. Each tray was an experimental unit, and the experiments were arranged in a completely randomized block design with six blocks. Rooting and seed germination were carried out in a shaded greenhouse with a maximum photosynthetically active radiation (*PAR*) of 200 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ during the entire course of the experiments. Plants were irrigated two to three times per week by hand watering without any chemical fertilizer application. Rooting percentage, seed germination rate, and root and shoot dry weights were recorded at the end of the experiment (2 months after cuttings were stuck or seeds were sown). Root lengths of golden pothos and heartleaf philodendron were measured using the public domain program National Institute of Health (NIH) Image 1.60 (Rasband and Bright, 1995) modified by Kimura et al. (1999). Briefly, each root image was screened and processed to get the thinned image (skeleton). The numbers of orthogonally and diagonally connected pairs of pixels (No and Nd, respectively) in the skeleton were counted separately and used for length (L) calculation: $L = [Nd^2 + (Nd + No/2)^2]^{1/2} + No/2$. This new length calculation equation has been shown to minimize the errors resulting from root orientations (Kimura et al., 1999).

Data analysis. All results were subjected to analysis of variance using SPSS (release 13.0 for Windows; SPSS, Chicago). Normal distribution was tested by Kolmogorov-Smirnov criterion. Where significant differences occurred, means were separated using Tukey's honestly significant difference (HSD) test at $P = 0.05$. If necessary, regression analysis was conducted to determine how the increased percentage of cowpeat affected substrate physical and chemical properties.

Results

Substrate physical and chemical properties. The substrates formulated with Canadian peat were initially light brown and gradually became dark brown with increased percentages of cowpeat. Bulk density increased linearly as cowpeat volume increased from 0% to 60% ($y = 0.15x + 0.18$, $R^2 = 0.91$, $P = 0.001$; where y is bulk density and x is the percentage of cowpeat). Air space also increased with the increased amount of cowpeat (Table 2). Container capacity had a decreasing trend, and the total porosity did not show any significant difference. The EC values also increased linearly from 0.41 in the control substrate [C-1 (Table 2)] to 4.16 dS·m^{-1} in the substrate containing 60% cowpeat (C-7) ($y = 6.2x + 0.56$, $R^2 = 0.93$, $P = 0.001$; where y is the EC value and x is the percentage of cowpeat). The C/N ratio decreased from 60.3 to 16.9 as the cowpeat percentages increased. The CEC also decreased with the increase of cowpeat volume, but such decreases were not significantly different.

The substrates formulated with Florida peat were primarily dark brown. Increased volume of cowpeat did not result in an increase in bulk density (Table 3). Bulk densities of the control substrate (F-1) to the substrate containing 30% cowpeat (F-4) were significantly greater than the rest. There were no clear trends in air space, container capacity, and total porosity except that the substrate containing 60% cowpeat (F-7) had air space significantly greater than the other substrates and container capacity was significantly less than the control and the substrate containing 50% cowpeat (F-6). The EC values, like those of the Canadian peat-based substrates, increased as cowpeat volume increased. Unlike the Canadian peat, cowpeat substitution of Florida peat did not affect C/N ratios, and CEC were similar across the seven substrates.

Rooting of cuttings. Cuttings, regardless of plant species, rooted 100% in the Canadian peat-based substrates. Shoot dry weights of golden pothos ranged from 0.59 to 0.78 g, root dry weights varied from 0.1 to 0.14 g, and root lengths differed from 116 to 176 cm. However, these variables were not significantly different across the seven substrates. Shoot dry weights of heartleaf philodendron also did not significantly vary across the seven substrates (Table 4). However, the root dry weight produced in the substrate containing 60% cowpeat (C-7) was significantly less than that of the control (C-1) and the substrate containing 10% cowpeat (C-2). Root lengths produced from C-7 were also significantly shorter than those produced from the C-2. 'Florida Spire' fig shoot dry weights ranged from 0.38 to 0.49 g, and root dry weight varied

Table 2. Physical and chemical characteristics of Canadian peat-based substrates substituted by cowpeat.[z]

Substrate[z]	Bulk density (g·cm^{-3})[y]	Air space (%)	Container capacity (%)	Total porosity (%)	EC (dS·m^{-1})[x]	pH	C/N ratio[w]	CEC (cmol·kg^{-1})[w]
C-1 (control)	0.18 b[v]	8.9 b	60.5 a	69.4 a	0.41 e	6.1 a	60.3 a	29.4 a
C-2	0.20 ab	10.1 b	61.3 a	71.3 a	1.12 d	5.9 a	36.8 b	27.6 a
C-3	0.22 ab	10.6 b	60.1 a	70.7 a	1.65 d	5.9 a	28.7 c	27.3 a
C-4	0.22 ab	12.0 b	60.6 a	72.6 a	2.71 c	5.9 a	24.5 c	26.2 a
C-5	0.24 a	11.1 b	57.2 a	68.3 a	3.72 b	5.9 a	20.5 cd	25.1 a
C-6	0.26 a	13.5 ab	57.2 a	70.8 a	3.16 b	6.0 a	18.0 d	25.4 a
C-7	0.26 a	16.7 a	52.1 b	68.8 a	4.16 a	6.2 a	16.9 d	24.8 a

[z] C-1 was the control formulated by mixing 60% Canadian peat with 20% perlite and 20% vermiculite. Substrates C-2 to C-7 were formulated with Canadian peat replaced by cowpeat at 10% increments up to 60%.

[y] 1 g·cm^{-3} = 0.5780 oz/inch^3.

[x] EC = electrical conductivity (1 dS·m^{-1} = 1 mmho/cm); substrate solutions were extracted using the pour-through method (Yeager et al., 1983).

[w] C/N ratio = carbon-to-nitrogen ratio, CEC = cation exchange capacity (1 cmol·kg^{-1} = 1 meq/100 g).

[v] Means within column followed by different letters are significantly different ($P = 0.05$) based on Tukey's honestly significant difference (HSD) test.

Table 3. Physical and chemical characteristics of Florida peat-based substrates substituted by cowpeat.

Substrate[z]	Bulk density (g·cm^{-3})[y]	Air space (%)	Container capacity (%)	Total porosity (%)	EC (dS·m^{-1})[x]	pH	C:N ratio[w]	CEC (cmol·kg^{-1})[w]
F-1 (control)	0.35 a[v]	9.5 b	57.1 a	66.5 a	0.83 d	6.1 a	17.9 a	23.4 a
F-2	0.34 a	11.5 b	53.7 ab	65.3 a	0.90 d	6.4 a	17.3 a	24.2 a
F-3	0.33 a	9.7 b	56.7 ab	66.4 a	1.54 c	6.1 a	17.1 a	24.2 a
F-4	0.35 a	9.2 b	54.4 ab	63.5 a	1.66 c	6.2 a	17.7 a	24.5 a
F-5	0.27 b	8.8 b	53.5 ab	62.3 a	2.32 b	6.4 a	17.3 a	23.4 a
F-6	0.25 b	10.4 b	59.2 a	69.5 a	2.65 b	6.0 a	16.1 a	25.4 a
F-7	0.26 b	16.5 a	52.5 b	68.8 a	4.18 a	6.1a	16.9 a	24.5 a

[z] F-1 was the control formulated by mixing 60% Florida peat with 20% perlite and 20% vermiculite. Substrates F-2 to F-7 were formulated with Florida peat replaced by cowpeat at 10% increments up to 60%.

[y] 1 g·cm^{-3} = 0.5780 oz/inch^3.

[x] EC = electrical conductivity (1 dS·m^{-1} = 1 mmho/cm); substrate solutions were extracted using the pour-through method (Yeager et al., 1983).

[w] C/N ratio = carbon-to-nitrogen ratio, CEC = cation exchange capacity (1 cmol·kg^{-1} = 1 meq/100 g).

[v] Means within column followed by different letters are significantly different ($P = 0.05$) based on Tukey's honestly significant difference (HSD) test.

Table 4. Mean shoot and root dry weights (DW) and root lengths of heartleaf philodendron 2 months after single-node cuttings were rooted in Canadian or Florida peat-based substrates substituted by cowpeat.

Substrate^z	Shoot DW (g)^y	Root DW (g)	Root length (cm)^y	Substrate^z	Shoot DW (g)	Root DW (g)	Root length (cm)
C-1 (control)	0.62 a^x	0.06 a	75 ab	F-1 (control)	0.51 a	0.08 a	139 a
C-2	0.50 a	0.06 a	107 a	F-2	0.46 a	0.05 ab	113 ab
C-3	0.51 a	0.04 ab	73 ab	F-3	0.51 a	0.05 ab	103 abc
C-4	0.46 a	0.04 ab	56 ab	F-4	0.47 a	0.05 ab	118 ab
C-5	0.49 a	0.04 ab	71 ab	F-5	0.50 a	0.04 ab	96 abc
C-6	0.59 a	0.05 ab	91 ab	F-6	0.42 a	0.04 ab	93 abc
C-7	0.47 a	0.03 b	49 b	F-7	0.48 a	0.03 b	49 c

^{z}C-1 and F-1 were the control formulated by mixing 60% Canadian peat or Florida peat with 20% perlite and 20% vermiculite. Substrates C-2 to C-7 or F-2 to F-7 were formulated with Canadian peat or Florida peat replaced by cowpeat at 10% increments up to 60%.

^{y}1 g = 0.0353 oz, 1 cm = 0.3937 inch.

^{x}Means within column followed by different letters are significantly different ($P = 0.05$) based on Tukey's honestly significant difference (HSD) test.

Table 5. Mean germination rates, shoot and root dry weights (DW), and root-to-shoot ratios of sprenger asparagus germinated in Canadian peat-based substrates substituted by cowpeat.

Substrate^z	Germination rate (%)	Shoot DW (g)^y	Root DW (g)	Root-to-shoot ratio
C-1 (control)	63.3 b^x	0.05 c	0.10 a	2.00 a
C-2	76.7 ab	0.14 a	0.14 a	1.00 b
C-3	73.3 ab	0.15 a	0.12 a	0.84 b
C-4	70.0 ab	0.13 ab	0.12 a	0.96 b
C-5	90.0 a	0.13 ab	0.10 a	0.75 b
C-6	76.7 ab	0.11 ab	0.09 a	0.82 b
C-7	76.7 ab	0.14 a	0.08 a	0.57 b

^{z}C-1 was the control formulated by mixing 60% Canadian peat with 20% perlite and 20% vermiculite. Substrates C-2 to C-7 were formulated with Canadian peat replaced by cowpeat at 10% increments up to 60%.

^{y}1 g = 0.0353 oz.

^{x}Means within column followed by different letters are significantly different ($P = 0.05$) based on Tukey's honestly significant difference (HSD) test.

Table 6. Mean germination rates, shoot and root dry weights (DW), and root-to-shoot ratios of sprenger asparagus germinated in Florida peat-based substrates substituted by cowpeat.

Substrate^z	Germination rate (%)	Shoot DW (g)^y	Root DW (g)	Root-to-shoot ratio
F-1 (control)	86.7 a^x	0.11 b	0.13 a	1.10 a
F-2	83.3 a	0.13 ab	0.11 ab	0.84 ab
F-3	93.3 a	0.12 b	0.08 ab	0.68 bc
F-4	76.7 a	0.19 a	0.10 ab	0.52 c
F-5	90.0 a	0.13 ab	0.07 b	0.54 c
F-6	96.7 a	0.13 ab	0.08 ab	0.59 bc
F-7	76.7 a	0.16 ab	0.08 ab	0.50 c

^{z}F-1 was the control formulated by mixing 60% Florida peat with 20% perlite and 20% vermiculite. Substrates F-2 to F-7 were formulated with Florida peat replaced by cowpeat at 10% increments up to 60%.

^{y}1 g = 0.0353 oz.

^{x}Means within column followed by different letters are significantly different ($P = 0.05$) based on Tukey's honestly significant difference (HSD) test.

from 0.02 to 0.04 g. These variables also did not significantly differ across the seven substrates.

Similar to the rooting in Canadian peat-based substrates, all cuttings rooted in the seven Florida peat-based substrates. Shoot and root dry weights of golden pothos produced in the seven substrates did not significantly differ even though shoot dry weights ranged from 0.55 to 0.67 g and root dry weights from 0.07 to 0.12 g. Root lengths of golden pothos produced in the control substrate (F-1) and the substrate containing 60% cowpeat (F-7) were significantly less than those produced from the substrate containing 30% cowpeat. Shoot dry weights of heartleaf philodendron produced in the Florida peat-based substrates were also not significantly different (Table 4). However, root dry weights and root lengths produced in the substrate containing and 60% cowpeat (F-7) were less than 50% of those produced in the control substrate (F-1). Shoot dry weights of 'Florida Spire' fig varied from 0.34 to 0.47 g, and root dry weights ranged from 0.02 to 0.04 g across the seven substrates, but these differences were not statistically significant.

Seed germination. Seed germination rates of sprenger asparagus were higher, ranging from 73.3% to 90%, in substrates containing 10% to 60% cowpeat (C-2 to C-7) than the 63.3% of the control substrate (Table 5). Shoot dry weights of seedlings germinated from the control substrate were substantially less than those germinated from the substrates containing cowpeat. However, root dry weights were not significantly different across the seven substrates. As a result, root-to-shoot ratios of seedlings produced from the control substrate (C-1) were significantly greater than those germinated from the substrates containing cowpeat (C-2 to C-6).

Seed germination rates were similar among the seven Florida peat-based substrates (Table 6). Shoot dry weights of seedlings produced from the control substrate (F-1) were equal to or significantly less than those produced in the substrates substituted by cowpeat (F-2 to F-7). Root dry weights produced from all seven substrates did not significantly differ except that those produced in the substrate containing 40% cowpeat (F-5) were significantly less than those of the control substrate. Root-to-shoot ratios of seedlings produced from the control substrate were significantly greater than those produced from the other substrate except for the substrate containing 10% cowpeat (F-2).

Discussion

The present study showed that all cuttings of golden pothos, heartleaf philodendron, and 'Florida Spire' fig rooted in the formulated 14 substrates. Seed germination rates of sprenger asparagus in substrates containing cowpeat were greater than or comparable to those of the control substrates. The success in rooting and seed germination could be attributed to the appropriate physical and chemical properties of the 14 formulated substrates. In general, a substrate with a bulk density ranging from 0.15 to 0.8 $g \cdot cm^{-3}$ (dry weight), an air space of 10% to 20%, a container capacity between 20% and 60%, and total porosity of 50% to 75% by volume are considered acceptable for rooting or producing containerized plants (Bunt, 1988; Chen et al., 2003; De Boodt and Verdonck, 1972; Evans and Gachukia, 2007; Yu and Zinati, 2006). Comparing the physical properties of the 14 formulated substrates (Tables 2 and 3) to the recommendations, all parameters were within the suggested ranges except for the air space of the Canadian peat-based control substrate and some Florida peat-based substrates that were slightly below 10%. The physical properties demonstrated in this study also concurred with those reported by Nordstedt and Sowerby (2003) where cowpeat-formulated substrates had physical properties well within the recommended ranges. Chemically, substrate CEC varied from 23.4 to 29.4 $cmol \cdot kg^{-1}$, which fell in the suggested range of 2 to 40 $cmol \cdot kg^{-1}$ (Poole et al., 1981). Recommended pH for foliage plant production ranged from 5.5 to 6.5 (Poole et al., 1981). The formulated substrates had a pH range of 5.9 to 6.4. The C/N ratio of the substrates substituted by cowpeat ranged from 16.1 to 36.8, suggesting that most substrates were within maturity range because composts with C/N ratio 25 or less are considered to be mature (Ozores-Hampton et al., 1998).

Although all rooting parameters and germination rates among substrates were comparable, some rooting and seedling establishment parameters varied depending on plant species and substrates. 'Florida Spire' fig, golden pothos, and heartleaf philodendron are commonly propagated through cuttings (Chen and Stamps, 2006). Shoot and root dry weights of golden pothos and 'Florida Spire' fig did not significantly vary across the seven Canadian or Florida peat-substrates. On the other hand, root dry weights and root lengths of heartleaf philodendron produced from the control Canadian and Florida peat-based substrate were much different from those produced from the substrates substituted by 60% cowpeat. This differential response in rooting among the three species may suggest that cuttings of golden pothos and 'Florida Spire' fig are more tolerant of higher EC than those of heartleaf philodendron, as the substrate with 60% cowpeat had EC $\geq 4.16\ dS \cdot m^{-1}$. Additionally, seedling root-to-shoot ratios of sprenger asparagus germinated from both control substrates were significantly greater than those germinated from substrates substituted by cowpeat. This difference could be partially explained by the higher nutrient content in cowpeat-substituted substrates where increased nutrient availability may allow plants to allocate relatively less resource to their roots (Bloom et al., 1985).

Nevertheless, this study showed that container substrates formulated by incorporating 10% to 60% cowpeat had physical and chemical properties similar to the commercial Canadian and Florida peat-based substrates. Biological testing also demonstrated that all tested cuttings rooted and seed germination rates of cowpeat-substituted substrates were greater than or comparable to those of control substrates. The promising results illustrated in this study suggest that there is a potential for using cowpeat for foliage plant propagation and probably for foliage plant production because propagation is the most sensitive stage of plant growth. The use of cowpeat will provide the containerized plant industry with an alternative to peat, which in turn reduces peat mining and encourages composting of dairy manure, thus contributing to the well-being of our environment.

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