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SWITCHGRASS BIOMASS AS A SUBSTRATE FOR *Camellia* AND *Cuphea* PRODUCTION IN CONTAINER

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Abstract

In Spain, most substrates used in the production of plants in containers, are composed of peat in combination with other components such as pine bark, perlite or vermiculite. In order to find alternatives to the use of peat, shredded switchgrass (*Panicum virgatum* L.) biomass was evaluated as a component of the substrates. Five substrates were prepared with the following proportions, by volume, of commercial substrates:switchgrass: 100/0, 75/25, 50/50, 25/75 and 0/100. Pots were filled with the substrates, planted with rooted cuttings of camellia (*Camellia sasanqua* Thunb.) 'Rainbow' and *Cuphea* (*Cuphea hyssopifolia* Kunth.) and placed in a polyethylene greenhouse. The plants and substrates were monitored from April 23rd to August 28th for camellia and from April 23rd to July 23rd for *Cuphea*, until they reached marketable size in 2014. Data were analysed using ANOVA independently for each plant species and the types of substrates were compared with LSD test ($p \leq 0.05$). The tallest plants were those grown in the substrates containing between 0 and 50% Switchgrass in camellia and between 0 and 25% in *Cuphe*a, probably because of the good values for water holding capacity, total porosity and air-filled porosity of those blends. The density of roots decreased as the proportion of Switchgrass in the substrate increased. Switchgrass substrate can be used as a substrate component for container production of camellia and *Cuphea* plants, when mixed in a proportion of no more than 50% in *Camellia* and no more than 25% in *Cuphea* plants.

Keywords: biomass, nursery production, ornamental plants, *Panicum virgatum*

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1. Introduction

Camellia sasanqua Thunb. (Fig. 1) (*Theaceae* family) is an evergreen shrub native to Asia (Sánchez de Lorenzo, 2001). This group of fall blooming *Camellias* have gained popularity for their versatility and ease to grow (Green, 2015).

Cuphea hyssopifolia Khunt (Fig. 2), commonly called the Mexican heather, a perennial small shrub native of Mexico and Guatemala is covered with small pink, purple or white flowers for most of the year and makes an excellent plant for borders and in containers (Sánchez de Lorenzo, 2001). *Cuphea* is the largest of the 32 genera of *Lythraceae* family with about 260 species of annual or perennials herbaceous and small shrubs (Graham et al., 2006).

Greenhouse production of *Camellias* and *Cupheas* involves growing the plants in containers with a substrate with different proportions of peat moss, fermented pine bark and, sometimes, small amounts of other components. However, peat moss and pine bark materials are becoming expensive because they are not produced locally. In the search for alternative materials to use as nursery container

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substrates, several herbaceous energy crops have been evaluated (Altland and Krause, 2009; Altland, 2010; Altland and Locke, 2011). Biomass resources are divided into four general categories: wastes, forest products, energy crops and aquatic plants including algae (Blaga et al., 2018; Ciubota-Rosie et al., 2008).

Many species of herbaceous perennial graminaceous species can be grown as energy crops (Akhtar et al., 2019; Sanderson et al., 2007), but only miscanthus (*Miscanthus* x *giganteus*) and switchgrass (*Panicum virgatum* L.) are considered for potting substrates (Jackson and Wright, 2009). Besides, rice husk and hazelnut shells are suitable alternatives to peat for *Camellia japonica* cultivation (Larcher and Scariot, 2009; Larcher et al., 2011).

Switchgrass is a North American native graminaceous species, distributed from northern Mexico to Canada. It is adapted to subtropical and cold temperate climates and is grown as an herbaceous summer crop. It is drought tolerant and displays a high potential for biomass production under diverse soil and climate conditions (Parrish and Fike, 2005). In a four-year-long trial of three switchgrass cultivars and one clone of miscanthus performed in Candás (Asturias, NW Spain), an average annual yield of 13.3 t DM ha^{-1} was obtained for cultivar 'Kanlow' (Oliveira et al., 2017). Therefore, the objective of this study was to determine whether shredded, sieved switchgrass could supplement a commercial substrate used for container production of ornamental *Camellia* and *Cuphea* plants.

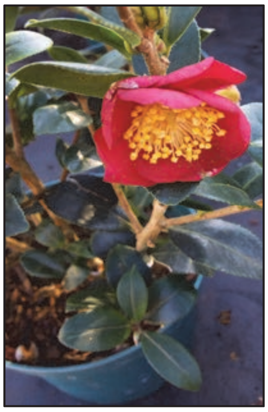

Fig. 1. *Camellia sasanqua* (Plantas del Eo Nursery, Castropol, Asturias, Spain)

Fig. 2. *Cuphea hyssopifolia* (Plantas del Eo Nursery, Castropol, Asturias, Spain)

2. Material and methods

The switchgrass cultivar 'Kanlow' (SG) was obtained from a field trial carried out in Candás (43º 35' 03.95'' N, 5º 46' 56.32'' W, altitude of 77 m, Spain) and established on an Inceptisol Typic Dystrudept soil under a temperate oceanic climate (Rivas-Martínez, 2007).

The experimental trial was conducted in the "*Plantas del EO*" nursery (a producer of forest and ornamental plants) in Castropol, Asturias (43º 31' 25.28'' N, 7º 00' 45.87'' W, altitude of 16 m, Spain) under a temperate maritime climate.

The SG was harvested at the end of February 2014 and processed in an electric shredder (Viking GE355: Power 2500 W) before being passed through a sieve of 5 mm mesh size to obtain the material to make the substrates (Fig. 3).

Fig. 3. Switchgrass biomass shredded and sieved (Plant Production Laboratory, Mieres, Asturias, Spain)

The commercial substrate (CS) routinely used in the nursery is composed of 70% peat moss (fibrous, particle size 20-40 mm, pH 5.5), 30% fermented pine bark, and clay (bulk density 40 kg m^{-3}). The CS and SG were mixed in five different proportions, by volume, to make the test substrates (CS/SG): 100/0, 75/25, 50/50, 25/75 and 0/100.

Controlled release fertilizer (14N-5.9P-10.8K, Osmocote®, KB, Scotts France SAS, Bourth, France), effective for 6 months, was incorporated into the substrate at a rate of 4 kg m^{-3}. Ten cm rooted cuttings of 'Rainbow' *Camellia* (obtained in the nursery from cuttings taken at the beginning of autumn 2013) were planted in black polyethylene containers (2.5 l) filled with 2.5 l of the different substrates. Five cm rooted cuttings of *Cuphea* (obtained in the nursery from cuttings taken at the beginning of autumn 2013) were planted in black polyethylene containers (1 l) filled with 1 l of the different substrates.

The containers were placed in a polyethylene greenhouse without temperature or light control, in March 2014. The containers were watered throughout the trial by micro-spray irrigation, for 20 minutes a day in summer and twice a week in spring, in order to keep the pots at field capacity.

Ten individual plants (one cutting per container) were considered as replicates for each treatment (substrate mixture) and the containers were placed in the greenhouse at random.

The physical and chemical characterization of the substrate mixtures was performed following the methods proposed by Ansorena (1994). The following parameters were determined in triplicate: bulk density and real density, air-filled porosity and total porosity, water holding capacity, EC (ds m^{-1}) and pH (measured with a SevenMulti™ pH/Conductivity/Ion meter Mettler Toledo®). Soil pH was measured in a suspension of soil and water 1:2.5 and EC was measured in the same extract diluted 1:5. All measurements were done in the Agroforestry Engineering Laboratory, University of Oviedo.

It took four months for the first plant of *Camellia* to reach commercial size and quality since the cuttings were planted, while for the plants of *Cuphea* it took three months. At this point, the response variables of the *Camellia* and *Cuphea* plants in the different substrate mixtures were measured and recorded: final height of the plants, dry weights of the aerial plant parts and density of roots in the root ball.

The final height of every plant was measured from the surface of the substrate to the apex of the plant. The dry weights of the aerial plant parts were determined in three plants per treatment, after cutting and drying the material in a forced air oven at 70ºC. The density of roots in the root ball was determined in all plants, on a scale of 0-10, where 0 = no roots observed on the exterior surface of the root ball and 10 = root ball totally covered by roots.

At the end of the study, foliar analysis of 3 plants per treatment was performed after washing the samples with deionized water and drying them at 70 ºC to constant weight. The dried samples were ground in an ultracentrifuge mill ZM 100 Retsch® (Retsch GmbH & Co. KG, Haan, Germany) and sieved (1 mm). Foliar analysis was carried out after wet extraction with perchloric acid and nitric acid (Jones et al., 1991), followed by the dilution of the samples with 1N HCl. The extract was used to determine Ca, Mg and K by atomic absorption spectroscopy (Perkin Elmer® AAnalyst™ 200, Shelton, CT, USA). The concentrations of P were determined by colorimetric analysis (PerkinElmer® Lambda™ 35 UV/VIS Spectrophotometer, Shelton, CT, USA) after combustion in a muffle furnace at 450ºC for 4 hours, and dissolution of the ashes with 6 N HCl.

The N was determined in a PerkinElmer® spectrophotometer Lambda 35 UV/VIS (Shelton, CT, USA) after mineralization of the samples in a Foss Tecator™ 2020 digester (Hillerød, Denmark) with concentrated sulphuric acid at 350ºC for 2 h, by the Kjeldahl method. The experimental design was completely randomized with the factor type of substrate (x 5 types). Data were analysed using ANOVA, independently for each plant species, and treatments were compared with LSD test ($p \leq 0.05$). All statistical analyses were carried out with SPSS v. 23.0.

3. Results and discussion

3.1. Weather conditions

The area of this study is within the warm zone of the Northern Hemisphere and in a western maritime facade, which determine a typical humid, temperate, maritime climate, with generally moderate temperatures and high humidity (Table 1). Data were obtained from the weather station closest to the study site, in Pedro Murias, Ribadeo (43° 32' 26.52'' N, 7° 04' 58.87'' W, and altitude of 51 m). It has been found that the growth of *Camellia* as well as *Cuphea* is at its best when grown in greenhouses at temperatures between 15ºC and 18ºC at night and between 21ºC and 26ºC during the day (Gesch et al., 2002; Warley, 2009).

3.2. Physical properties

The physical properties of the five substrates were significantly different for all parameters (Table 2). Bulk density and water holding capacity decreased and the air filled porosity increased as the percentage of SG increased. The total porosity and its components, air-filled porosity and water holding capacity, are very important for container production of plants: if these physical properties are inadequate, it is difficult to modify them once the crop is established and therefore their prior characterization is necessary (Cabrera, 1999). Adequate values reported by some authors (Ansorena, 1994; Yeager et al., 2007) are 60-80% (by volume) for total porosity, 10-30% for air-filled porosity, and 40-60% for water holding capacity.

On the basis of these values, only those substrates comprising 50% or less SG can be considered adequate for water holding capacity and total porosity, whereas for air-filled porosity, only substrates with 25% or less SG are adequate. The bulk density of substrates containing 50% or less SG was in the optimal range of 0.15 to 0.60 g mL^{-1} (Nappi, 1993). Bulk density values in the substrates with 75% or more SG were low and not suitable for potting substrates.

Table 1. Average temperature, relative humidity and solar irradiance during the study in 2014 at Castropol, Asturias, Spain

Month	*Average temperature (ºC)*	*Relative humidity (%)*	*Solar irradiance (kWh m^{-2}. d^{-1})*
April	13.5	82.6	3.5
May	13.7	80.5	5.5
June	17.1	83.0	5.2
July	19.1	83.1	5.3
August	19.2	79.2	4.5

Table 2. Comparison of physical properties of the substrates composed of different proportions of commercial substrate (CS) and shredded, sieved switchgrass (SG), measured at the start of the study. Standard deviation in parentheses

Substrate	***Bulk density (g mL^{-1})***	***Water holding capacity (%)***	***Air-filled porosity (%)***	***Total porosity (%)***
100%CS+0%SG	0.22(0.01)a	58.3(1.0)a	12.4(0.1)e	70.6(0.9)e
75%CS+25%SG	0.21(0.01)a	49.6(0.5)b	24.9(0.8)d	74.5(0.6)d
50%CS+50%SG	0.16(0.01)b	41.7(0.3)c	36.5(0.1)c	78.3(0.2)c
25%CS+75%SG	0.14(0.01)c	33.7(0.3)d	48.7(0.4)b	82.4(0.8)b
0%CS+100%SG	0.09(0.05)d	25.1(1.1)e	60.9(1.8)a	86.0(0.8)a

$^{a, b, c, d}$*Values with different letter in a column are statistically different (LSD, p ≤ 0.05)*

Table 3. Comparison of pH and EC (ds m^{-1}) of the substrate composed of different proportions of commercial substrate (CS) and shredded, sieved switchgrass (SG), measured at the start and at the end of the study. Standard deviation in parentheses

Substrate	***Plants***	***Initial pH***	***Final pH***	***Initial EC***	***Final EC***
100%CS+0%SG	*Camellia* *Cuphea*	4.4(1.8)	5.1(0.5) 5.2(0.5)	0.08(0.06)	0.22(0.08) 0.18(0.05)
75%CS+25%SG	*Camellia* *Cuphea*	4.8(0.4)	5.2(0.1) 5.3(0.1)	0.07(0.05)	0.15(0.11) 0.15(0.12)
50%CS+50%SG	*Camellia* *Cuphea*	5.1(0.6)	5.7(0.4) 5.7(0.5)	0.06(0.05)	0.09(0.04) 0.07(0.04)
25%CS+75%SG	*Camellia* *Cuphea*	5.2(0.2)	5.8(0.2) 5.8(0.2)	0.03(0.03)	0.07(0.01) 0.06(0.07)
0%CS+100%SG	*Camellia* *Cuphea*	5.3(0.2)	5.8(0.4) 5.8(0.3)	0.01(0.01)	0.05(0.02) 0.04(0.03)

SG substrates usually have a higher air-filled porosity and lower water holding capacity than peat moss substrates. Over time, SG substrates are more likely to suffer a reduction in volume (shrinkage) than peat moss substrates. This leads to a decrease in air-filled porosity and a slight increase in water-holding capacity (Altland and Krause, 2012). However, for these improvements to take place, it is necessary that the substrate components have a desirable particle size. For the elaboration of substrates, most of the particles should range from 0.5 to 4 mm, with no more than 20% of particles finer than 0.5 mm (Barrett et al., 2016; Bunt, 1988).

3.3. Chemical properties

The chemical parameters evaluated affect the plants at establishment, in particular pH and EC (Table 3). The pH has an important influence on the assimilation of nutrients, as it facilitates or hinders their dissolution (Ansorena, 1994). The pH of the different substrates did not differ significantly: the initial mean value was pH 5 and increased at the end of the trial to 5.5 in *Camellia* and 5.6 in *Cuphea*, indicating that the SG substrate tended to cause an increase in pH when added to CS. Although the ideal pH depends on the type of crop, the values obtained in this study can be considered adequate (desirable pH between 5.0 and 6.5) for this type of plant (Yeager et al., 2007).

Non-significant differences were observed in the EC of the five substrates, and the values for all substrates were within the usual range (Ansorena, 1994). The EC of the substrates decreased as the proportion of SG biomass increased.

3.4. Plant growth

Significant differences in the height of the plants related to the substrates were observed (Table 4) and the tallest plants were those grown in the substrates containing between 0 and 50 % SG, possibly attributed to the significant soil physical properties, such as the water holding capacity, total porosity and air-filled porosity of the mixtures of the substrates.

There were no significant differences between the substrates for the dry weight of the aerial plant parts measured at the end of the study for *Camellia*, but significant differences were obtained for *Cuphea.* Higher dry aerial weight was recorded in *Cuphea* plant without additional SG in the substrate to 25% SG.

There were significant differences in the density of roots in the root ball of the plants grown in the different substrates. The density of roots decreased as the proportion of SG in the substrate increased. Therefore, SG substrates may not be suitable for the production of slow-rooting crops (Altland and Krause, 2012). However, in the experiment performed by Treder et al. (2015) growth media did not influence the dynamics and quality of plantlet rooting.

As reported in other studies evaluating energy crops as substrates for container production of plants (Altland and Krause, 2009; Altland, 2010; Altland and Locke, 2011; Locke and Altland, 2012), shredded, sieved (5 mm) switchgrass biomass mixed with at least 50% (by volume) of a commercial substrate could be added for container production of ornamental plants to maintain the proper ratio of air-filled porosity to water holding capacity, similar with the common substrates used for container gardening.

Table 4. Comparison of the mean values of the response variables in *Camellia* and *Cuphea* plants grown in substrates composed of different proportions of commercial substrate (CS) and shredded, sieved switchgrass (SG), measured at the end of the study. Standard deviation in parentheses

Substrate	*Plants*	*Height of plant (cm)*	*Dry weight of aerial portion (g)*	*Density of roots in root ball (scale 0-10)*
100%CS+0%SG	*Camellia*	36.3(6.1)ab	6.6(2.7)	8.7(0.5)a
	Cuphea	17.5(1.8)a	7.9(0.6)a	9.1(0.9)a
75%CS+25%SG	*Camellia*	38.0(4.3)a	6.8(1.4)	7.6(0.5)b
	Cuphea	15.5(2.1)b	7.2(0.3)a	8.0(0.8)b
50%CS+50%SG	*Camellia*	36.6(2.5)ab	5.5(2.3)	6.5(0.5)c
	Cuphea	13.4(1.5)c	3.9(1.1)b	7.0(0.8)c
25%CS+75%SG	*Camellia*	33.6(3.1)b	3.0(1.1)	4.7(0.7)d
	Cuphea	14.2(2.0)c	3.5(0.9)b	6.2(0.9)d
0%CS+100%SG	*Camellia*	29.0(1.5)c	4.2(0.8)	2.5(0.5)e
	Cuphea	10.6(1.7)d	1.4(1.2)c	5.4(0.8)d

Mean values (independently for each plant species) in the same column indicated by the same letter are not statistically different (LSD p ≤ 0.05)

Table 5. Comparison of foliar nutrient levels in *Camellia* and *Cuphea* plants grown in the substrates composed of different proportions of commercial substrate (CS) and shredded, sieved switchgrass (SG), measured at the end of the study. Standard deviation in parentheses

Substrate	*Plants*	*N (g kg^{-1})*	*P (g kg^{-1})*	*Ca (g kg^{-1})*	*Mg (g kg^{-1})*	*K (g kg^{-1})*
100%CS+0%SG	*Camellia*	4.09(0.26)	0.24(0.01)	6.91(5.02)	1.14(0.02)bc	4.36(0.12)
	Cuphea	5.89(2.02)	0.26(0.02)b	6.78(0.77)	1.08(0.04)b	4.96(0.12)
75%CS+25%SG	*Camellia*	3.57(0.97)	0.21(0.06)	10.31(1.05)	1.09(0.05)c	4.63(0.22)
	Cuphea	4.42(2.75)	0.24(0.01)b	7.67(0.67)	1.04(0.01)bc	4.92(0.11)
50%CS+50%SG	*Camellia*	3.08(0.24)	0.18(0.01)	9.67(0.92)	1.13(0.01)bc	4.40(0.08)
	Cuphea	5.86(1.76)	0.20(0.02)b	8.35(0.71)	0.99(0.03)c	5.03(0.22)
25%CS+75%SG	*Camellia*	5.13(2.02)	0.30(0.12)	9.35(0.59)	1.22(0.02)a	4.32(0.13)
	Cuphea	4.96(1.73)	0.37(0.04)a	7.67(0.57)	1.09(0.03)b	4.96(0.12)
0%CS+100%SG	*Camellia*	6.20(2.78)	0.36(0.16)	9.02(0.88)	1.19(0.04)ab	4.25(0.17)
	Cuphea	5.78(2.80)	0.43(0.06)a	8.61(0.75)	1.21(0.03)a	4.99(0.27)

Mean values (independently for each plant species) in the same column indicated by the same letter are not statistically different (LSD p ≤ 0.05)

3.5. Foliar nutrient contents

Regarding the foliar mineral contents in *Camellia* plants grown in different substrates, significant differences were observed only in the Mg contents, and the values were highest in substrates containing 75% or more SG (Table 5) for *Camellia*. Significant differences between the different substrates were found only in the mineral contents of Mg in *Camellia* and *Cuphea* and of P in *Cuphea,* with higher values found in substrates containing 75 % or more of SG. In the *Camellia* plants, the foliar mineral contents were within the usual range for Ca (6.9-14.6 g kg^{-1}) and lower than usual for N (13.9-35.4 g kg^{-1}), P (0.8-1.1 g kg^{-1}), Mg (1.4-2.8 g kg^{-1}) and K (6.8-11.1 g kg^{-1}), according to reports by Mills and Jones (1997).

In the *Cuphea* plants, the foliar mineral contents were lower than usual for N (44.4 g kg^{-1}), P (5.6 g kg^{-1}) and K (43.6 g kg^{-1}), according to reports by Newman (2014). The low nitrogen values obtained were possibly a result of the nitrogen fixation process, due to decomposer microorganisms, which typically reduces the availability of nitrogen to plants (Bunt, 1988; Ansorena, 1994). Nevertheless, low levels in N, P and K can be managed by fertilization.

4. Conclusions

Switchgrass substrate can be used as a substrate component for commercial container production from rooted cuttings of *Camellia* and *Cuphea* to market size plants in 2.5 L and 1 L containers, when mixed in a proportion of not more than 50% by volume for *Camellia* and no more than 25% for *Cuphea*, with a commercial substrate comprising peat moss and fermented pine bark. Nevertheless, in order to recommend shredded switchgrass as a component of substrates for commercial use, further research is needed on long-term physical stability and plant performance in different ornamental plants.

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