Effects of partial substitution of commercial substrates for the production of *Camellia sasanqua*

J.A. Oliveira[1*], E. Afif[2], F. Martínez[3], F.J. Estrada[4] and P. Palencia[1]

[1]Plant Production Area. Department of Organisms and System Biology, Polytechnic School of Mieres, Oviedo University, Mieres, 33600 Asturias, Spain.

[2]Agroforestry Area. Department of Organisms and System Biology, Polytechnic School of Mieres, Oviedo University, 33600 Mieres, Asturias, Spain.

[3]Agroforestry Department, E.T.S.I. 'La Rabida', Huelva University, Palos de la Frontera, 21819 Huelva, Spain.

[4]Plantas del EO Nursery, Finca Riufelle s/n, 32760 Castropol, Asturias, Spain.

[*]Corresponding author's E-mail: oliveira@uniovi.es.

ABSTRACT

Commercial substrates comprising different proportions of peat moss and fermented pine bark and used for container production of ornamental plants are becoming expensive because they are not produced locally. The objective of this study was to determine whether shredded, sieved, locally produced switchgrass (*Panicum virgatum* L.) could at least partly replace commercial substrates. Five test 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 the camellia (*Camellia sasanqua* Thunb.) 'Rainbow' and placed in a polyethylene greenhouse. The plants and substrates were monitored for four months (23 April - 28 August) in 2014. Shredded, sieved (5 mm) switchgrass substrate by itself does not provide physical properties considered ideal for

container camellia plant production. The tallest plants were those grown in the substrates containing between 0 and 50% Switchgrass, possibly 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 commercial container production of camellia plants over 4 months, when mixed in a proportion of no more than 50% by volume with a commercial substrate comprising peat moss and fermented pine bark. Nevertheless, more research is required with different plants in order to confirm the results obtained so far.

Keywords: Biomass, *Camellia sasanqua*, nursery production, ornamental plants, *Panicum virgatum*

INTRODUCTION

Camellia sasanqua Thunb. are a group of evergreen shrubs native to Asia (Sánchez de Lorenzo, 18). This group of fall blooming camellias are gaining popularity for their versatility and ease to grow (Green, 6). Greenhouse production of camellias involves growing the plants in containers with a substrate comprising 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 for use as nursery container substrates, different herbaceous energy crops have been evaluated (Altland and Krause, 2; Altland, 1; Altland and Locke, 3).

Of the many species of herbaceous perennial graminaceous species that could potentially be grown as bioenergy crops (Sanderson *et al*., 19), only miscanthus (*Miscanthus* x *giganteus*) and switchgrass (*Panicum virgatum* L.) have been considered for making potting substrates (Jackson and Wright, 7). On the other hand, rice husk and hazelnut shells were found to be suitable alternatives to peat for the cultivation of *Camellia japonica* (Larcher and Scariot, 10; Larcher et *al.*, 9).

Switchgrass is a graminaceous species native to the North American continent, ranging from northern Mexico to Canada. It is adapted to subtropical and cold temperate climates and is grown as a herbaceous summer crop. It is drought tolerant and displays a high potential for biomass production under diverse soil and climate conditions (Parrish and Fike, 15).

In a two-year-long trial of six switchgrass cultivars carried out in Carreño (Asturias, NW Spain), an average yield of 13.4 t DM/ha and year was obtained (Oliveira et *al*., 14).

The objective of this study was to determine whether shredded, sieved switchgrass could supplement the commercial substrate used for container production of ornamental camellia plants.

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 elevation, 77 m, Spain) and established on an Inceptisol Typic Dystrudept soil (Principado de Asturias, 16) under a temperate oceanic climate (Rivas-Martinez, 17). The experimental trial was carried out 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, elevation, 16 m, Spain).

The SG was harvested at the end of February 2014 and processed in an electric shredder (Viking GE355: Power 2.500 W) before being passed through a sieve of 5 mm mesh size to obtain the material used to make the substrates.

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.

Rooted cuttings of 'Rainbow' camellia (obtained in the nursery from cuttings taken in autumn 2013) were planted in black polyethylene containers (2.5 l) filled with 2.5 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 daily in summer and twice weekly in spring, with the aim of maintaining 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 randomly in the greenhouse.

The physical and chemical characterization of the substrate mixtures was carried out following the methods proposed respectively by Ansorena (4). The following parameters were determined in triplicate: bulk density and real density, air-filled porosity and total porosity, water holding capacity, EC (ds/m) and pH (measured with a SevenMulti™ pH/Conductivity/Ion meter Mettler Toledo®). All measurements were made in the Agroforestry Engineering Laboratory, University of Oviedo.

The first plant reached commercial size and quality 4 months after planting the cuttings. At this point, the response variables of the camellia plants in the different substrate mixtures were measured and recorded: final height of the plants, fresh and dry weights of the aerial plant parts and density of roots in the root ball.

The final height of all of the plants was measured from the surface of the substrate to the apex of the plant. The fresh and dry weights of the aerial plant parts were determined in 3 plants per treatment, after respectively cutting and drying the material in a forced air oven at 70ºC to dry weight. 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 carried out after first washing the samples with deionized water and drying them at 70ºC 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 dilution of samples with 1N HCl. The extract was used to determine Ca, Mg and K by atomic adsorption spectroscopy (PerkinElmer® 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 for 4 hours in a muffle furnace at 450ºC, 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 data were analysed by analysis of variance (ANOVA), with the factor type of substrate (x 5 types) in a completely randomized design. When the ANOVA indicated the substrate factor as significant, the LSD test for comparison of means was applied. Differences between means were considered significant at $P \leq 0.05$. All statistical analyses were carried out with SPSS v. 22.0.

RESULTS AND DISCUSSION

Physical properties. The physical properties of the five substrates were significantly different for all parameters (Table 1). 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 would be difficult to modify them once the crop has been established and therefore their prior characterization is necessary (Cabrera, 5). Adequate values reported by some authors (Ansorena, 4; Yeager *et al*., 21) 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 (Nappi, 13). Bulk density values in the substrates with 75% or more SG were low and not suitable for potting substrates.

Chemical properties. The chemical parameters evaluated mainly affect the plants at establishment, particularly pH and EC (Table 2). The pH has an important influence on the assimilation of nutrients, as it facilitates or hinders dissolution of these elements (Ansorena, 4). The pH of the different substrates did not differ significantly: the mean value was pH 5 at the start and 5.5 at the end of the trial, 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*., 21).

Non-significant differences were observed in the EC of the five substrates, and the values for all substrates were within the usual range (Ansorena, 4). The EC of the substrates decreased as the proportion of SG biomass increased.

Plant growth. Significant differences in the height of the plants were observed in relation to the substrate (Table 3) and the tallest plants were those grown in the substrates containing between 0 and 50% SG, possibly because of the good values for water holding capacity, total porosity and air-filled porosity of those blends.

There were no significant differences between the substrates in the dry weight of the aerial plant parts measured at the end of the study.

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. However, in the experiment carried out by Treder *et al*. (20) growing 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, 2; Altland, 1; Altland and Locke, 3; Locke and Altland, 11), shredded, sieved (5 mm) switchgrass biomass mixed with at least 50% (by volume) of a commercial substrate could be used for container production of ornamental plants to achieve the proper ratio of air-filled porosity to water holding capacity.

Foliar nutrient contents. Regarding the foliar mineral contents in camellia plants grown in different substrates, significant differences were only observed in the Mg contents, and the values were highest in substrates containing 75% or more SG (Table 4).

There were no significant differences between the different substrates in the N, P, Ca, and K contents.

In the *Camellia sasanqua* plants, the foliar mineral contents were within the usual range for Ca (6.9-14.6 g/kg) and lower than usual for N (13.9-35.4 g/kg), P (0.8-1.1 g/kg), Mg (1.4-2.8 g/kg) and K (6.8-11.1 g/kg), according to reports by Mills and Jones (12).

Switchgrass substrate can be used as a substrate component for commercial container production of camellia plants over 4 months, when mixed in a proportion of no more than

50% by volume with a commercial substrate comprising peat moss and fermented pine bark. Nevertheless, more research is required with different plants in order to confirm the results obtained so far.

REFERENCES

1. Altland, J. 2010. Use of Processed Biofuel Crops for Nursery Substrates. Journal of Environmental Horticulture, 28: 129-134.
2. Altland, J.E. and Krause, C. 2009. Use of switchgrass as a nursery container substrate. Hortscience, 44: 1861-1865.
3. Altland, J.E. and Locke, J.C. 2011. Use of ground miscanthus straw in container nursery substrates. Journal of Environmental Horticulture, 29: 114-118.
4. Ansorena, M.J. 1994. Sustratos. Propiedades y caracterización [Substrates. Properties and characterization]. Madrid, Mundi-Prensa.
5. Cabrera, I.R. 1999. Propiedades, uso y manejo de sustratos de cultivo para la producción de plantas en maceta [Properties, use and management of substrates for the production of potted plants]. Revista Chapingo Serie Horticultura, 5: 5-11.
6. Green, B. 2015. You say you want a revolution: reinventing the garden camellia. Act. Hortic. 1085: 405-408.
7. Jackson, B.E. and Wright, R.D. 2009. Pine tree substrate: an alternative and renewable substrate for horticultural crop production. Acta Horticulturae, 819: 265-272.
8. Jones, J.B., Wolf, B., Mill, H.A. 1991. Plant analysis handbook: A Practical Sampling Preparation, Analysis and Interpretation Guide. Athens, Micro-Macro Publishing.
9. Larcher, F., Berruti, A., Gullino, P., Scariot, V. 2011. Reducing peat and growth regulator input in camellia pot cultivation. Horticultural Science, 38: 35-42.
10. Larcher, F., Scariot, V. 2009. Assessment of partial peat substitutes for the production

of *Camellia japonica*. Horticultural Science, 44: 312-6.

11. Locke, J.C. and Altland, J.E. 2012. Use of ground wheat straw in container nursery substrates to overwinter daylily divisions. Journal of Environmental Horticulture, 30: 207-210.
12. Mills, H.A. and Jones J.B. 1997. Plant analysis handbook II. Athens, Micro-Macro Publishing.
13. Nappi, P. 1993. Compost as growing medium: Chemical, physical and biological aspects. Acta Horticulturae, 342: 249-256.
14. Oliveira, J.A., Afif, E., Palencia, P., Gorgoso, J. 2012. Producción y calidad de biomasa del switchgrass (*Panicum virgatum* L.) en Candás (Asturias) [Biomass production and quality of switchgrass (*Panicum virgatum* L.) in Candás (Asturias)]. In: Canals R.M., San Emeterio L. (ed.): Nuevos retos de la ganadería extensiva: Un agente de conservación en peligro de extinción. Pamplona, Sociedad Española para el Estudio de los Pastos: 535-541.
15. Parrish, D.J. and Fike, J.H. 2005. The biology and agronomy of switchgrass for biofuels. Critical Reviews in Plant Sciences, 24: 423-459.
16. Principado de Asturias, 2014. Mapa de evaluación de recursos agroecológicos a escala1:50.000 del Principado de Asturias [Map agroecological resource assessment at 1: 50,000 in Asturias]. Available at: 194.224.34.54/MapaEvaluacionRecursosAgroecologicos/Home.html
17. Rivas-Martínez, S. 2007. Mapa de series, geoseries y geopermaseries de vegetación de España. Memoria del mapa de vegetación potencial de España, Parte I [Map series, geoseries and vegetation geopermaseries Spain. Memory map of potential vegetation Spain, Part I]. Itinera Geobotánica (Nueva serie), 17: 1-436.

18. Sánchez de Lorenzo, J.M. 2001. Guía de las plantas ornamentales [Ornamental plant guide]. Ed. Mundi-Prensa, Madrid, Spain. 686 p.

19. Sanderson, M.A., Martin, N.P., Adler, P. 2007. Biomass, energy, and industrial uses of forages. In: Barnes R.F. et al. (ed.): Forages: The science of grassland agriculture. 6th edition. Ames, Wiley-Blackwell: 635-647.

20. Treder, W., Tryngiel-Gać, A., Klamkowski, K. 2015. Development of greenhouse soilless system for production of strawberry potted plantlets. Horticultural Science, 42: 29-36.

21. Yeager, T.H., Bilderback, T.E., Fare, D., Gilliam, C., Lea-Cox, J.D., Niemiera, A.X., Ruter, J.M., Tilt, K., Warren, S., Whitwell, T., Wright, R.D. 2007. Best management practices: Guide for producing nursery crops. 2nd Ed. Atlanta, Southern Nursery Association.

Table 1. Comparison of physical properties of 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)	Water holding capacity (%)	Air-filled porosity (%)	Total porosity (%)
100%CS+0%SG	0.22(0.01)a[z]	58.3(1,4)a	12.4(0.1)e	70.6(1.2)e
75%CS+25%SG	0.21(0.01)a	49.6(0.7)b	25.2(0.8)d	74.8(0.1)d
50%CS+50%SG	0.16(0.01)b	41.7(0.3)c	36.5(0.1)c	78.2(0.2)c
25%CS+75%SG	0.14(0.01)c	33.7(0.4)d	48.5(0.4)b	82.2(0.1)b
0%CS+100%SG	0.09(0.01)d	25.1(1.6)e	60.5(2.3)a	85.7(0.7)a

[z]Mean values in the same column indicated by the same letter are not statistically different (LSD, $P \leq 0.05$)

Table 2. Comparison of pH and EC (ds/m) 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	pHinitial	pHfinal	ECinitial	ECfinal
100%CS+0%SG	4.4(1.8)	5.1(0.5)	0.08(0.01)	0.22(0.08)
75%CS+25%SG	4.8(0.4)	5.2(0.1)	0.07(0.02)	0.15(0.08)
50%CS+50%SG	5.1(0.6)	5.7(0.4)	0.06(0.03)	0.09(0.04)
25%CS+75%SG	5.2(0.2)	5.8(0.2)	0.03(0.02)	0.07(0.01)
0%CS+100%SG	5.3(0.3)	5.8(0.4)	0.01(0.01)	0.05(0.02)

Table 3. Comparison of mean response variables in camellia 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	Height of plant (cm)	Dry weight of aerial portion (g)	Density of roots in root ball (scale 0-10)
100%CS+0%SG	36.3(6.1)ab[x]	6.6(2.7)	8.7(0.5)a
75%CS+25%SG	38.0(4.3)a	6.8(1.4)	7.6(0.5)b
50%CS+50%SG	36.6(2.5)ab	5.5(2.3)	6.5(0.5)c
25%CS+75%SG	33.6(3.1)b	3.0(1.2)	4.7(0.7)d
0%CS+100%SG	29,0(2.2)c	4.2(0.8)	2.5(0.5)e

[x]Mean values in the same column indicated by the same letter are not statistically different (LSD $P \leq 0.05$)

Table 4. Comparison of foliar nutrient levels in camellia plants grown in substrate 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	N (g/kg)	P (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)
100%CS+0%SG	4.09(0.26)	0.24(0.01)	6.91(5.02)	1.14(0.02)bc[y]	4.36(0.12)
75%CS+25%SG	3.57(0.97)	0.21(0.06)	10.31(1.05)	1.09(0.05)c	4.63(0.22)
50%CS+50%SG	3.08(0.24)	0.18(0.01)	9.67(0.92)	1.13(0.01)bc	4.40(0.08)
25%CS+75%SG	5.13(2.02)	0.30(0.12)	9.35(0.59)	1.22(0.02)a	4.32(0.13)
0%CS+100%SG	6.20(2.78)	0.36(0.16)	9.02(0.88)	1.19(0.04)ab	4.25(0.17)

[y]Mean values in the same column indicated by the same letter are not statistically different (LSD $P \leq 0.05$)