Evaluation of composted green waste in ornamental container-grown plants: effects on growth and plant water relations

Compost Science & Utilization, (2007), Vol. 15, No. 4, 283-287

Evaluation of Composted Green Waste In Ornamental Container-Grown Plants: Effects on Growth and Plant Water Relations

Sergio Mugnai, Tommaso Pasquini, Elisa Azzarello, Camilla Pandolfi and Stefano Mancuso
Department of Horticulture, University of Florence, Italy

Ornamental nurseries extensively utilize peat in commercial soilless potting media, but its use as an organic amendment with a superior water holding capacity is challenged by economic and environmental pressures so potential alternatives to peat need to be investigated. In our experiment, commercially available peat-based soilless mixes were amended with increasing composted green waste (CGW) percentages. Results on *Photinia X fraseri* and *Viburnum tinus* suggest that CGW could partially substitute peat in containerized nursery production, with a different effectiveness related to species behavior. *Viburnum* seemed to be less affected by CGW addition (only CGW-based media, T_{100}, showed a significant difference compared to peat-based media, used as control), which on the contrary hardly affected *Photinia* growth in terms of biomass production and quality. On the other hand, a higher CGW content (75% or 100%) also improved plant susceptibility to water shortage. Concluding, peat-based media partially amended with CGW may have positive agronomic and economic consequences for commercial ornamental nursery production.

Introduction

The ornamental nursery industry extensively uses peat as a primary component in commercial soilless potting media due to its organic composition and superior water holding capacity. Increased commercial interest has been directed towards developing complete or partial alternatives for peat utilized in traditional potting media within nursery production, both for environmental and economical implications, resulting in the development of new substrate substitutes, most of which use waste by-products. Over the past decade, compost facilities have also dramatically improved their products to a degree that is acceptable both in terms of quality, quantity and economical feasibility. Compost can provide a valuable source of nutrients within a nursery substrate (Hue and Sobieszczyk 1999), and generally improve its physical, chemical and biological properties. In efforts to use organic waste materials, compost derived from municipal biosolids (composted green waste, CGW) have been utilized to successfully grow a wide range of nursery crops including bedding annuals (Klock-Moore 1999), perennials (Wilson *et al*. 2002), woody shrubs and trees (Wilson *et al.* 2006; Ferrini and Nicese 2003). On the contrary, there is a lack of information about the indirect role of CGW in affecting physiological response of container-grown plants to environmental stresses, such as water shortage.

The objectives of this investigation were to: a) study physical, chemical and hydrological characteristics of some peat and CGW mixtures as viable potting media alternatives to a traditional, commercially available peat-based potting substrate; b) evaluate the growth of two ornamentals, *Viburnum tinus* L. and *Photinia X fraseri* Dress., characterized by different growth status and behaviors, and c) attest the effect of CGW on the plant water relations during the onset of a water stress event.

Materials And Methods

Plant Material and Media Composition

Experiments were conducted from May to October at the Ce.Spe.Vi. (Experimental Station for Nursery Production) located in Pistoia, Italy. One-year-old *Photinia* X *fraseri* Dress. and *Viburnum tinus* L. rooted cuttings were transplanted into 2.6 L pots (Ø16 cm) filled with substrates with different CGW and peat ratios. CGW derived from municipal waste biosolids was supplied by Azienda Quadrifoglio SpA (Florence, Italy). The CGW parameters' values did not exceed Italian standards (D.L. 217/2006) (Table 1). A peat-based soilless media (75% peat and 25% pumex, v:v) was established as control (T_0). Treatments were amended with 25% (T_{25}), 50% (T_{50}), 75% (T_{75}) or 100% (T_{100}) CGW in the amendment fraction. A 5 to 6-month

TABLE 1.
Physical and chemical analysis of the CGW supplied by Azienda Quadrifoglio (Florence, Italy) at the beginning of the experiment.

Parameters		Values
Inerts < 3,33mm	%	0,13
Plastic < 3,33mm	%	0,10
10mm < Inerts > 3,33mm	%	0,01
10mm < Plastic > 3,33mm	%	0,13
pH (1:10)		7,60
Humidity	%	32
Residues at 550° C	% S.S.	44
Total carbon	% S.S.	33
Humic and fulvic acid	% S.S.	13,6
Total nitrogen	% S.S.	1,4
Organic nitrogen	% S.S.	1,4
C/N ratio		28
Total phosphorus (P_2O_5)	% S.S.	0,36
Potassium (K_2O)	% S.S.	0,86
Cadmium	mg/Kg S.S.	0,20
Total chromium	mg/Kg S.S.	21
Exavalent chromium	mg/Kg S.S.	0,00
Mercury	mg/Kg S.S.	0,19
Nichel	mg/Kg S.S.	35
Lead	mg/Kg S.S.	70
Copper	mg/Kg S.S.	76
Zinc	mg/Kg S.S.	204

controlled release granular fertilizer 15-9-9 (N-P-K) + 3MgO (Osmocote Exact Standard®, The Scotts Company, Marysville, Ohio) was incorporated in the substrate at a rate of 3 g L^{-1}. Plants were placed outdoor (average temperature: 20.8°C; average RH: 62.8%, average solar radiation 5.1 KWh m^{-2}), and were daily irrigated by a computer-controlled drip irrigation system with one 2 L h^{-1} emitter until water-holding capacity.

Each mixture was evaluated at the beginning of the experimental period for major physical, chemical and hydraulic media components consisting of bulk density (BD), air-filled porosity (AFP) and available water (AW), pH and electrical conductivity (EC). Hydraulic parameters were determined by using the De Boodt method (De Boodt *et al*. 1974). Physico-chemical parameters were measured after preparing a saturated media extract: electrical conductivity (EC) was determined by a conductance meter (GLP31, Crison Instruments, Spain) and pH was measured by a pH meter (HI 9025, Hanna Instruments, Italy).

Plant Growth and Development

Five plants for each treatment were randomly collected at the end of the experiment. Data recorded included height, maximum canopy width, number of leaves, total dry weight, and leaf area. Dry weight was obtained after drying the samples in an oven at 70°C for 48 h. Leaf area was calculated using the Image Tool® software (available freeware at ddsdx.uthscsa.edu/dig/itdesc.html) on leaf images obtained by a CanoScan D660U scanner.

Water Stress Experiment

Water stress experiment was conducted during September by placing the plants into a climate-controlled growth chamber (25°C/18°C day/night, 70% relative humidity, 16h/8h photoperiod, 1200 μmol m^{-2} s^{-1} PAR). Thirty plants from each treatment were split into two groups: control plants (daily irrigated) and stressed plants (water deprived for 7 days). During the experiment both substrate water content (SWC) and midday xylem water potential (Ψ_{xyl}) were measured. SWC was determined by the gravimetric method, as reported by Miller and Donahue (1990), whereas Ψ_{xyl} was measured at noon on detached young shoots by a pressure chamber, according to Pardossi *et al.* (1991).

Statistical Analysis

Experimental design refers to five randomized blocks for each species, each treatment representing a block. All data were subjected to one-way ANOVA with means separated by Tukey's test (n=5, each plant representing one replicate; P≤0.05) using a specific software (GraphPad Prism 4.0, GraphPad Software Inc.). Data from water stress experiment were analyzed one at time, comparing each rate to the control by the same statistical procedure previously described.

Results and Discussion

Properties of CGW Based Media

The pH and electrical conductivity (EC) of CGW-based media at the onset of the experiment were significantly higher than that of peat-based medium (Table 2). Media pH ranged from 4.1 in the T_0 to 7.2 in the T_{100}, with intermediate values in the other treatments. The ideal pH interval reported for *Photinia* and *Viburnum* is considered to be between 5.5 and 6.5 (Rosen *et al.* 1998). Higher pH values can significantly lead to the immobilization of some important micronutrients, such as iron and aluminum, with the onset of leaf chlorosis, as detected in *Photinia* (Figure 1). EC values also increased when compost was added to the substrate (Table 2). Media with a high salt content can have deleterious effects on plant growth and develop-

TABLE 2.
Effect of different CGW content on physical, chemical and hydraulic parameters of the substrates.

Treatments	EC[1]	pH	BD[2]	AFP[3]	AW4
T_0	0.5 b	4.1 c	0.28 a	45.5 b	16.4 a
T_{25}	0.55 ab	5.6 b	0.30 ab	48.2 ab	13.4 b
T_{50}	0.6 ab	5.9 b	0.32 ab	46.4 b	10.5 c
T_{75}	0.65 a	7.0 a	0.33 ab	49.8 a	8.6 c
T_{100}	0.65 a	7.2 a	0.35 b	51.9 a	5.2 d

[1]EC=Electrical Conductivity (mS*cm^{-1}), [2]BD=Bulk Density (g*L^{-1}), [3]AFP=Air-Filled Porosity (%), 4AW=Available Water (%). Data are reported as means (n=5), separated by Tukey's test. Different letters in a single column show statistically significant differences for P<0.05 (n=5).

FIGURE 1. Onset of leaf chlorosis on *Photinia* grown with 75% CGW in the amendment fraction of the substrate.

ment (Sanderson 1980), particularly for salt-sensitive species, for which no more than 20% of compost containing high levels of soluble salts should be incorporated in a soil mix for production (Alexander 2001). However, in our experiment CGW-based media ECs are all under the tolerance limit for the ornamentals (Hanlon *et al.* 1993). Air-filled porosity significantly increased from 45.5% (T_0) to 51.9% (T_{100}) and available water percentage significantly decreased from 16.37% (T_0) to 5.26% (T_{100}, Table 2). Wootton *et al*. (1981) previously reported that as particle size of compost-based substrate increased, air-filled porosity also increased. In our case, compost-based media with high compost levels (T_{75} and T_{100}) had higher bulk density than that the peat-based substrate, but in the range suggested by Poole *et al.* (1981), which recommended that compost amended media for container-grown plants have a bulk density of 0.30 g cm^{-3}, indicating that gas exchange should be sufficient in the root zone (Agnew and Leonard 2003) Similar results have been previously found by Wilson *et al*. (2001) suggesting that, although the higher density of the compost increased total porosity, it may simultaneously reduce water retention of the substrate, as shown by decreased values in available water percentages.

Plant Growth and Development

In *Viburnum*, T_{25} increased both total dry weight and leaf area compared to control and the other treatments (Table 3). At T_{50} and T_{75} CGW levels total dry weight, leaf area and number of leaves were similar to control treatment. These plants had more compacted canopies due to reduced height and width values (Table 3). *Viburnum* growth was reduced at T_{100} level. *Photinia* control plants had the highest values for both total dry weight and leaf area values among all the treatments. The reduction in plant height reported in higher CGW content treatments led to shorter and thinner shoots. Consequently, plants grown in T_{75} and T_{100} were characterized by a poor quality and were less attractive. Previous works already highlighted the role of low percentages of CGW in improving plant growth compared to a pure compost-based media,

TABLE 3.
Effect of different CGW percentages on total dry weight (g), leaf area (cm2), height (cm), width (cm) and number of leaves in *Photinia X fraseri* and *Viburnum tinus* container-grown plants.

	Photinia				*Viburnum*				
Treatments	Total Dry Weight	Leaf Area	Height	N° Leaves	Total Dry Weight	Leaf Area	Height	Width	N° Leaves
T_0	75.91 a	1518 a	82 a	52 ab	69.92 b	1258 b	45 ab	21 b	44 a
T_{25}	57.19 b	1244 b	85 a	42 b	77.60 a	1841 a	49 a	25 a	44 a
T_{50}	57.21 b	1342 b	80 a	47 b	66.34 bc	1504 b	44 b	20 b	43 a
T_{75}	64.94 b	1370 b	75 b	58 a	64.95 b	1505 b	38 c	18 c	47 a
T_{100}	58.41 b	1374 b	72 b	55 a	34.75 c	976 c	38 c	17 c	47 a

Data are reported as means (n=5), separated by Tukey's test. Different letters in a single column show statistically significant differences for P<0.05 (n=5).

both in perennial (Wilson *et al.* 2002) and herbaceous plants (Hartz *et al.* 1996). However, the role of compost in the growth of container-grown plants is still controversial, as plant response is strongly affected both by the origin of compost and the species behavior. For example, Gils *et al.* (2005) showed a different pattern in the growth of *Physocarpus opulifolius* plants in the presence of municipal solid waste compost or turkey litter compost. Chong and Rinker (1991) showed the species-affected effect of increasing percentages of spent mushroom compost mixed with bark on top dry weight response of eight container-grown deciduous ornamental shrubs (*Physocarpus opulifolius*, *Forsythia X intermedia*, *Rosa* spp., *Cornus alba*, *Weigela florida*, *Potentilla fructiosa*, *Deutzia gracilis*, *Ligustrum vulgare*). In our experiment, *Viburnum tinus* and *Photinia X fraseri* were preliminary chosen as test species for their different growth behaviors: *Viburnum tinus* is a Mediterranean-type sclerophyllous species (Salleo *et al.* 1997) which shows a slower growth, short internodes, reduced apical dominance and a dense and spread canopy, while *Photinia X fraseri* is characterized by a fast growth, with a very strong apical dominance with leads to the formation of a principal shoot and a few lateral shorter ones. The results showed that the two species had a different response to the CGW, probably related to their growth behaviors. *Viburnum* seemed to be less affected by CGW addition while CGW reduced *Photinia* growth in terms of biomass production and quality.

Water Stress

After 3 days of water shortage T_{50}, T_{75} and T_{100} showed a lower water content (15-25%) compared to control (35%) both in *Photinia* and *Viburnum* (Table 4). On the contrary, T_{25} maintained a similar water content compared to control, with no significant differences (32%). After 7 days, however, all the treatments showed significantly lower water content values (around 10%) compared to control (15%). To attest the harmful effect of this situation on plant water relations, midday xylem water potential (æ$_{xyl}$) was measured. As expected, æ$_{xyl}$ was directly linked to substrate water content, but with different species responses: *Viburnum* showed a less sudden dehydration than *Photinia*, especially after 3 days of stress, when æ$_{xyl}$ in peat-based media and T_{25} had significant higher values compared to the other treatments and slightly decreased compared to day 0 (around -7 MPa in *Viburnum*, around -8 MPa in *Photinia*). On the contrary, CGW-based media with higher compost percentages (T_{75} and T_{100}) already reached very negative values (around -15 in *Viburnum* and -20 MPa in *Photinia*). After 7 days, however, the very low substrate water content led to a total plant dehydration in all the treatments of both species, as æ$_{xyl}$ values reached -25/-30 MPa. Wilson *et al.* (2003) found that the peat-based substrate had a significant higher moisture content than the T_{50} or T_{100} compost media they used, explaining it with the higher bulk and particle densities of the compost substrate associated with lower water retention than the peat-based substrate, but no experiments have been ever previously conducted in order to directly attest the role of compost percentage in woody plants' water relations. At the whole plant level, the repercussions of water deficit are important effects on plant phenology, phasic development, growth, carbon assimilation, assimilate partitioning and plant reproduction processes (Taiz and Zeiger 2006). Among the selected species, *Viburnum* is commonly able to resist more severe and prolonged drought under environmental conditions characterized by high temperatures and high irradiance levels than *Photinia* (Salleo *et al.* 1997) establishing a high potential gradient between leaves and roots. In our case, the sudden drought experienced by the plantlets, which can easily arise in Mediterranean climates when no irrigation is available, had a deleterious effect on plant water relations especially in compost-

TABLE 4.
Effect of different CGW percentages on substrate water content (SW, %) and midday xylem water potential (Ψxyl, MPa) in *Photinia X fraseri* and *Viburnum tinus* container-grown plants subjected to water stress for 0, 3 and 7 days.

	Photinia						*Viburnum*					
		SW			Ψ_{xyl}			SW			Ψ_{xyl}	
Treatment	0	3	7	0	3	7	0	3	7	0	3	7
T_0	48a	35a	15a	-4a	-8a	-28a	47a	35a	13a	-4a	-7a	-25a
T_{25}	50a	32a	10b	-4.5a	-8.6a	-30a	47a	32a	9b	-4.5a	-7.5a	-28b
T_{50}	51a	25b	9b	-4.2a	-18b	-30a	50a	25b	10b	-4.2a	-12b	-30b
T_{75}	47a	15c	9b	-4a	-20b	-30a	50a	22b	10b	-4a	-15b	-30b
T_{100}	48a	15c	8b	-4.5a	-22b	-30a	47a	15c	10b	-4.5a	-18c	-30b

Data are reported as means (n=5), separated by Tukey's test. Different letters in a single column show statistically significant differences for P<0.05 (n=5).

based media grown plants, except when a low CGW percentage was used (T_{25}). Due to the short stress duration, however, no negative effects on growth were detected but they can presumably rise up when water deficit is constantly repeated during the vegetative season. For this reason, the use of high compost levels in the substrate may be avoided or reduced when water supply is not available.

Conclusions

CGW addition to peat-based media may have positive agronomic and economic consequences for commercial ornamentals nursery production, but its effect is basically species-related. In fact, CGW was effective in improving *Viburnum* growth when added at low percentage to the peat-based media, whereas it showed a depressing effect on *Photinia* growth. On the contrary, careful attention must be provided in irrigation scheduling, as high compost percentages can lead to a stress onset when water supply becomes inadequate.

Acknowledgements

The research was funded by ARSIA Toscana, Project "*Iniziative di collaudo e trasferimento di tecniche idonee per l'impiego di compost di qualità in agricoltura*". The authors wish to thank Dr. Paolo Marzialetti (Ce.Spe.Vi., Italy) for its skilful technical assistance, and Azienda Quadrifoglio (Italy) for the compost supply.

References

Agnew, J.M. and J.J. Leonard. 2003. The physical properties of compost. *Compost Sci. Util.*, 11:238-264.

Alexander, R. 2001. Compost utilization in landscapes - *In*: P.J. Stoffella, and B.A. Kahn (eds.) *Compost utilization in horticultural cropping systems*. CRC Press LLC, Boca Raton, pp. 151-175.

Chong, C. and D.L. Rinker. 1991. Spent mushroom compost re-utilized in ornamental crop culture. *Mushroom World*, 2:51-52.

De Boodt, M., O. Verdonck and I. Cappaert. 1974. Method for measuring the water release curve of organic substrates. *Acta Hort.*, 37:2054-2063.

Ferrini, F. and F.P. Nicese. 2003. Effect of compost-based substrates on growth and leaf physiology of *Acer campestre* and *Cornus alba* potted plants. Proceedings II International Symposium on Plant Health in Urban Horticulture, Berlin (Germany) 27-29th August 2003.

Gils, J., C. Chong and G. Lumis. 2005. Response of container-grown ninebark to crude and nutrient-enriched recirculating compost leachates. *HortScience*, 40:1507-1512.

Hanlon, E.A., B.L. McNeal and G. Kidder. 2002. Soil and container media electrical conductivity interpretations. SS117, Florida Cooperative Extension Service, University of Florida.

Hartz, T.K., F.J. Costa and W.L. Schrader. 1996. Suitability of composted green waste for horticultural uses. *HortScience*, 31:911-915.

Hue, N.V. and B.A. Sobieszczyk. 1999. Nutritional values of some biowastes as soil amendments. *Compost Sci. Util.*, 7:34-41.

Klock-Moore, K. 1999. Growth of impatiens 'Accent Orange' in two compost products. *Compost Sci. Util.*, 7:58-62.

Miller, R.W. and Donahue R.L. 1990. *Soils. An introduction to soils and plant growth* - 6th ed., Prentice Hall, USA, pp.124-128.

Pardossi, A., P. Vernieri and F. Tognoni. 1991. Evaluation of the pressure chamber method for the assessment of water status in chilled plants. *Plant Cell Env.*, 14:675-682.

Poole, R.T., C.A. Conover and J.N. Joiner. 1981. Soils and potting mixtures. In: J.N. Joiner (ed.). *Foliage plant production*. Prentice-Hall, USA.

Rosen, C.J., P. Bierman and E.C. Rosen. 1998. Soil test interpretations and fertilizer management for lawns, turf, gardens, and landscape plants. BU-1731-F, University of Minnesota Extension Service.

Salleo, S., A. Nardini and M.A. Lo Gullo. 1997. Is sclerophylly of Mediterranean evergreens an adaptation to drought? *New Phytol.*, 135:603-612.

Sanderson, K.C. 1980. Use of sewage-refuse compost in the production of ornamental plants. *HortScience*, 15:173-178.

Taiz, L. and E. Zeiger. 2006. *Plant Physiology*, 4th Ed. - Sinauer Associates, USA

Wilson, S.B., P.J. Stoffella and D.A. Graetz. 2001. Compost-amended media for growth and development of Mexican heather. *Compost Sci. Util.*, 9:60-64.

Wilson, S.B., P.J. Stoffella and D.A. Graetz. 2002. Development of compost-based media for containerized perennials. *Sci. Hort.*, 93:311-320.

Wilson, S.B., P.J. Stoffella and D.A. Graetz. 2003. Compost amended media and irrigation system influence containerized perennial Salvia. *J. Amer. Soc. Hort. Sci.*, 128:260-268.

Wilson, S.B., L.K. Mecca, H.E. Danielson, D.A. Graetz and P.J. Stoffella. 2006. Container and field evaluation of three native shrubs grown in compost-based media. *Compost Sci. Util.*, 14:178-183.

Wootton R.D., F.R. Gouin and F.C. Stark. 1981. Composted, digested sludge as a medium for growing flowering annuals. *J. Amer. Soc. Hort. Sci.*, 106:46-49.