Dynamic Soil, Dynamic Plant ©2008 Global Science Books

Urban Composts as an Alternative for Peat in Forestry Nursery Growing Media

Rafael López[1*] • Francisco Cabrera[1] • Engracia Madejón[1] • Felipe Sancho[2] • José María Álvarez[2]

[1] Instituto de Recursos Naturales y Agrobiología de Sevilla, IRNAS-CSIC. Avda. Reina Mercedes 10, 41012, Sevilla. Spain
[2] EGMASA, Junta de Andalucía, Isla de la Cartuja, 41092, Sevilla. Spain

Corresponding author: * **rlnunez@irnase.csic.es**

ABSTRACT

Including urban composts in nursery growing media could reduce peat use and promote new markets for these products. The objective of this work was to study the effects of compost incorporation in forestry nursery growing media. Growing media were prepared mixing composts (0-75% in volume) from biosolids, municipal solid waste and pruning waste with peat. As control treatment, a peat-based substrate was employed. Hydrophysical and chemical properties of growing media were determined. Moreover the effects of these growing media on rosemary and cypress plant growth (height, stem diameter, nutrient contents) in propagation and production trials were monitored. Hydrophysical properties of compost based growing media were adequate up to 50% compost. The Carbon/Nitrogen ratio of composts (10.7-12.4) was indicative of compost maturity. Compost EC values frequently surpasses those of standard peat substrates, therefore substrate salinity limited the maximum percentage of compost in substrates. In the case of cutting propagation, rosemary growth was increased to 50% compost (EC 1.1-1.3 dS m^{-1}). Cypress seed germination was not affected until 75% compost (EC 1.4-1.9 dS m^{-1}) and its growth was increased in all compost growing media. Plant growth increased was related to the fertilizing effect of compost. Although composts content of Ni, Zn, and Pb were greater than those of standard peat substrates, only concentration of Zn was greater in compost-media cultivated plants. As a general rule, forestry nursery growing media could incorporate up to 50% composts from biosolids, municipal solid waste and pruning wastes mixed with peat.

Keywords: biosolids, *Cupressus sempervirens*, municipal solid waste, pruning waste, *Rosmarinus officinalis*
Abbreviations: AP, air porosity; **BD**, bulk density; **EC**, electrical conductivity; **OM**, organic matter; **PD**, particle density; **TP**, total porosity; **WHC**, water holding capacity

INTRODUCTION

Most nurseries in the world have based their growing media on peat. However, peat is obtained from wetlands, which are being rapidly depleted, causing environmental concerns that have lead to many individual countries to limit the extent of peat mining, and prices are increasing as a result. Since the last two decades, research on peat alternatives has been intense, and will continue being of great interest in the future (Ingelmo *et al*. 1998; Wilson *et al.* 2006). In this context, different authors have suggested that some organic materials such as well-composted municipal solid waste and biosolids composts could be feasible materials for partial peat substitution (Abad *et al*. 2001; Bugbee 2002). The increasing interest in waste recycling is another cause to advocate their recycling and use as soil or potting amendments; it could be one of the most attractive methods of solving the problem of waste disposal.

The combination of peat and compost in growing media is synergistic; peat often enhances aeration and water retention and compost or other additives improves the fertilizing capacity of a substrate. In addition, organic wastes and composts tend to have porosity and aeration properties comparable to those of bark or peat and, as such are ideal substitutes in propagating media (Chong 2005).

Except perhaps for bark, the use of organic wastes in nursery substrates is not well defined or scientifically documented (Chong 2005). Organic wastes and waste-derived composts frequently have a high salt content, which may be the most important criterion that limits the potential use of such wastes and composts in plant propagation (Chong 2005). Other constraints for use include possible presence of contaminants (trace elements, organic chemicals, glass), potential phytotoxicity derived from immaturity and/or high salt level, alkaline pH, and differences in species responses.

Government and commercial peat policies support and encourage the use of sustainable peat alternatives; these alternatives need to satisfy the relevant technical requirements and be readily available in sufficient quantities at reasonable cost. In efforts to use organic waste materials, composts have been utilized to successfully grow a wide range of crops including bedding annuals, perennials, sods, vegetables, woody shrubs and trees, and foliage plants. However, few studies have addressed the use of composts for containerized native shrub production (Wilson *et al.* 2006; Ostos *et al.* 2008) and to study the effects of composts on the different steps of nursery works (plant propagation, seedling growth).

The aim of this study was to evaluate the effects of partial peat substitution by other alternatives, such as municipal solid waste compost and sewage sludge compost, on propagation, growth and nutrition of the Mediterranean shrub *Rosmarinus officinalis*, and of the common urban tree *Cupressus sempervirens*.

MATERIALS AND METHODS

Growth media preparation

The urban composts used as components of growing media were prepared as follows:

Compost BS was produced by mixing biosolids from Jerez city (Southern Spain) wastewater treatment plant and pruning waste from gardens. The ratio biosolids: pruning waste for com-

Received: 31 July, 2008. Accepted: 1 October, 2008.

Original Research Paper

posting was 1:3 in volume. Before composting, pruning waste was grinded to fragments between 2 and 15 cm.

Compost MS was produced from a mixture of unsorted municipal solid waste (particle size < 8 cm) and garden pruning wastes (2-15 cm) from the same city. The ratio municipal solid waste: pruning waste was 1: 1.5 in volume.

Compost BSMS was produced from unsorted municipal solid waste, biosolids and pruning wastes in a ratio 1: 1: 2.

Composting was carried out using triangular windrow aerated-piles (5.5 m width and 2.5 m height). Turning was applied to the windrows every 10-15 days during the active composting period (two months). After this period, composts were stockpiled for a period of 1 month to achieve stabilization (Alvarez *et al*. 2001), and then screened to 5 mm.

The commercial growing media used routinely at nursery was used as control (substrate C). This substrate incorporates both black peat (30% in volume) and white peat (70% in volume), mineral fertilizer 16N-18P-19K at the rate of 1.5 kg $m^{-3}$and lime to correct its pH.

Growth media were prepared from the urban composts BS, MS and BSMS by mixing each compost with 75, 50 and 25% of substrate C (ratios in volume). The corresponding media were denoted as BS25, BS50, BS75, MS25, MS50, MS75, BSMS25, BSMS50 and BSMS75.

Growth media and composts analyses

Growing media and composts were subjected initially to a complete physico-chemical characterization.

Two 2 kg replications of each sample were used for major hydrophysical characteristics. The hydrophysical properties were determined in fresh samples following the methods described by Inbar *et al*. (1993). Bulk density (BD), particle density (PD), total porosity (TP), water holding capacity (WHC) and air porosity (AP) were determined. Electrical conductivity (EC) and pH were also determined in aqueous extracts (substrate: water 1: 5 in volume) of fresh samples following the European methods for substrate characterization (AENOR 2001a, 2001b).

Percent of moisture was determined by oven-drying at 105°C for 48 h and weighing before and after. The dried sample was used for the determination of particle size distribution by a sieve shaker. Sieves of 10, 4, 2, and 0.5 mm were used. Particle size distribution is presented as the percent calculated by dividing the dry weight of each fraction by the total dry weight of the sample.

Dried samples were used for the determination of chemical properties. Total organic matter was determined by the weight loss after dry combustion at 540°C and organic Nitrogen by steam distillation after Kjeldahl digestion. Nutrients (S, P, K, Mg, Ca, Fe, Cu, Mn, Zn), sodium, and heavy metals (Cd, Cr, Ni, Pb) were analysed using Inductively Coupled Plasma-Optical Emission Spectrophotometry after microwave digestion with 3: 1 (v/v) concentrated $HCl:HNO_3$ (*aqua regia*). Triplicate analyses were carried out for chemical properties. Compost samples of the MARSEP program for quality control (Houba *et al*. 1996) were also analysed. The obtained results for these samples agreed ±5% with the certified results.

Plant material and experimental design

Two plant species, rosemary (*Rosmarinus officinalis*) and Italian cypress (*Cupressus sempervirens* Piramidalis) were used in four trials. Rosemary is a woody, perennial herb with fragrant evergreen needle-like leaves, native to the Mediterranean region. Cypress is a common tree in household and public gardens. A wide young plants availability of this species at low-cost would be thus desirable for the nurseries.

In trial 1, each substrate was used to fill 3 black polyethylene trays (40 cells per tray). The resulting 30 trays were distributed at random in three blocks, each containing all the treatments (9 growing media from urban composts and the control C). One cutting of rosemary, approximately 5 cm tall, was transplanted into each cell on 6 February 2002.

In trial 2, the same design of trial 1 was maintained. In this case, three cypress seeds were sown in each cell, maintaining the design of trial 1. Trial was initiated on 6 February 2002.

In trial 3, rosemary saplings (approximately 10 cm height) were transplanted to 1.5 L pots filled with the nine growing media from urban composts and the C control substrate. Pots were randomly distributed in three blocks each containing 5 pots per treatment. Trial was initiated on 11 March 2002.

In trial 4, cypress saplings (approximately 18 cm height) were transplanted to 1.5 L pots following the same design as trial 3. Trial was initiated on 8 March 2002.

The experiments were carried out in the nursery of the county council of Seville, sited at Valdezorras, Seville, SW Spain, following the standard cultivation techniques in the nursery. The trays were moistened periodically using micro-sprinkler irrigation. The irrigation water main characteristics were: EC 1.89 dS m^{-1}, Sodium absorption ratio 2.61, nitrate-N 59.4 mg L^{-1}. Except for the mineral fertilizer incorporated in substrate C, no additional fertilizer was incorporated neither plants were fertigated.

Plant growth and nutrition

In trial 1, rosemary mortality was recorded on 3 April 2002. Height and stem base diameter were measured on 19 September 2002 in 15 plants of the central part of each tray (45 plants per treatment). A calliper was used to measure diameter to the nearest ±0.01 mm.

In trial 2, plant height was measured on 1 August 2002 in 40 (all) cypress plants per tray. Mortality was estimated from the number of recorded data. Plant nutrients and heavy metal contents were determined in one sample from each treatment. In each treatment one composite sample collected from the aerial part of the plants of 15 cells (5 cells per tray) was taken for analysis.

In trial 3, rosemary height and stem base diameter were measured at the starting of the experiment on 18 March 2002 and on 2 October 2002. Height and diameter increments were calculated from the difference between the two sampling dates. A composite sample of terminal cuttings from the 15 plants corresponding to each treatment was analysed.

In trial 4, cypress height and stem base diameter were measured at the starting of the experiment on 15 March 2002 and on 4 December 2002 and the corresponding increments were calculated.

Plant samples were dried until constant weight at 100°C and milled to pass a 0.2 mm sieve. Total Nitrogen was determined by spectrophotometry in a flow autoanalyzer after Kjeldahl digestion. Nutrients (S, P, K, Mg, Ca, Fe, Cu, Mn, Zn), sodium, and heavy metals (Cd, Cr, Ni, Pb) were analysed using Inductively Coupled Plasma-Optical Emission Spectrophotometry after microwave digestion with concentrated nitric acid. Plant samples of the IPE program for quality control (Houba *et al*. 1996) were also analysed. The obtained results for these samples agreed ±5% with the certified results.

Statistical analysis

Analyses of variance (ANOVA), considering substrate as an independent factor, were performed for the variables measured and multiple comparison of means was determined by the *post-hoc* Tukey test. A significance level of $P < 0.05$ was used throughout the study. Data normality was tested prior to analysis (Kolmogorov-Smirnov test), and when necessary, variables were transformed logarithmically. If after transformation, the data did not have a normal distribution, we used the non-parametric Kruskal-Wallis test. All statistical analyses were carried out with the program SPSS 11.5 for Windows.

RESULTS AND DISCUSSION

Physical properties of growth media and components

The distribution of particle sizes of the growing media is given in **Table 1**. Percent of coarser particles (10-4 mm and 4-2 mm) was greater in control substrate C, whereas percent of finer particles (2-0.5 mm and <0.5 mm) was greater in the composts. Therefore, the percent of finer particles (2-0.5 mm and <0.5 mm) was greater in compost based substrates, and the sum of both fractions (2-0.5 mm and <0.5 mm) increased with compost percentage in the mixtures, reaching

Table 1 Particle size distribution (%) of composts and compost based substrates.

	10-4 mm[a]	4-2 mm	2-0.5 mm	<0.5 mm
C	8.9	29.4	36.5	25.2
BS25	2.9	23.3	48.0	25.8
BS50	1.4	19.3	51.0	28.3
BS75	1.0	17.2	49.2	32.6
BS	0.1	19.9	40.0	40.0
BSMS25	2.7	18.7	42.3	36.3
BSMS50	1.5	15.2	47.5	35.8
BSMS75	0.6	13.2	46.6	39.6
BSMS	0.8	12.8	49.0	37.4
MS25	2.6	18.0	37.1	42.3
MS50	1.8	13.5	38.8	45.9
MS75	1.1	9.1	39.2	50.6
MS	0.9	9.8	42.0	47.3

[a] No particles greater than 10 mm were found

Table 2 Physical properties of composts and compost based substrates.

	BD[a]	PD[b]	TP[c]	WHC[d]	AP[e]
C	0.142	1.77	92.1	64.0	28.1
BS25	0.257	2.02	87.3	57.2	30.1
BS50	0.404	2.14	81.1	56.8	24.3
BS75	0.516	2.17	76.3	51.5	24.8
BS	0.667	2.12	68.5	51.5	17.0
BSMS25	0.285	2.05	86.1	55.8	30.3
BSMS50	0.367	2.13	82.8	54.1	28.7
BSMS75	0.522	2.17	76.0	49.8	26.2
BSMS	0.576	2.15	73.2	47.6	25.6
MS25	0.201	1.93	89.6	53.7	35.9
MS50	0.337	2.06	83.7	52.2	31.5
MS75	0.434	2.12	79.5	46.8	32.7
MS	0.578	2.13	72.9	52.3	20.5
Optimum[f]	<0.4	1.45-2.65	>85	55-70	20-30

[a] Bulk density, g cm^{-3}
[b] Particle density, g cm^{-3}
[c] Total porosity, % in volume
[d] Water holding capacity, % in volume
[e] Air porosity, % in volume
[f] Acceptable/Optimum range cited by Carmona and Abad (2007)

Table 3 Pearson's coefficients of correlation (r) for physical properties and particle size fractions in composts and compost based substrates (*n*=13).

	BD[a]	PD[b]	TP[c]	WHC[d]	AP[e]
10-4 mm (%)	-0.772**	-0.924**	0.834**	0.760**	0.320
4-2 mm (%)	-0.575*	-0.716**	0.870**	0.562*	0.014
2-0.5mm (%)	0.345	0.625*	-0.160	-0.313	-0.294
<0.5mm (%)	0.391	0.356	-0.732**	-0.399	0.090
10-2 mm (%)	-0.665*	-0.817**	-0.906**	0.652*	0.107
<2 mm (%)	0.663*	0.818**	-0.904**	0.650*	-0.105

* Significance at P<0.05
** Significance at P<0.01
[a] Bulk density
[b] Particle density
[c] Total porosity
[d] Water holding capacity
[e] Air porosity

81.8, 86.2 and 89.8% for substrates BS75, BSMS75 and MS75 respectively. Bachman and Metzger (2007) also found that particles greater than 2 mm decreased and particles 0.5-1 mm increased as percentage of pig- and beef cattle-manure vermicomposts in potting mixtures increased.

Compost bulk densities were appreciably higher than that of peat substrate (**Table 2**) and above optimum limit (<0.4 g cm^{-3}) reported by Carmona and Abad (2007). Bulk density increased in compost-based substrates as compost percent, exceeding the optimum limit in substrates at 75% compost. Bachman and Metzger (2007) also found an increase of bulk density with increasing vermicomposts amendment in substrates. The bulk densities for compost-based substrates in this study were similar to the values 0.376 to 0.542 g cm^{-3} found by Moldes *et al.* (2006) for substrates including 25 to 75% of municipal solid waste compost. Moldes *et al.* (2006) indicated a lower bulk density (0.366 and 0.438 g cm^{-3}) for the MS compost that in the present study (0.578 g cm^{-3}). Grigatti *et al.* (2007) reported values ranging from 0.24 to 0.65 g cm^{-3} for mixtures of peat and 0 to 100% composted sewage sludge, very similar to the values for BS mixtures in this study. Huang *et al.* (2001) reported BD 0.20-0.31 g cm^{-3} for substrates including 25% pine bark and 50% of similar composts. In this study bulk densities of the substrates exceeded the optimum range when base composts of MS and BSMS percentage increased to 75% and BS increased to 50%.

Total porosity was highly and negatively correlated to bulk density (r^2=0.998). Consequently, in the compost-based substrates, TP decreased with compost percent in mixtures, falling out of optimum range (>85%) when compost percentage in mixtures was above 50%. Bachman and Metzger (2007) also found a decrease of TP with increasing vermincomposts amendment in substrates. Moldes *et al.* (2006) indicated a TP in peat of 93%, very close to the value for C substrate (92.1%); however the values they found for municipal compost (82-83%) were higher than in the present study (72.9%). The higher values for TP in the composts studied by Moldes *et al.* (2006) probably are related to the higher organic matter contents (40-49%) of these materials compared to those of the present study (31.8%). On the contrary, Huang *et al.* (2001) found values in the range 57.6-67.9% for mixtures with 50% of similar composts, below those found in this study (81.1-83.7%), but in this case, the substrates also included 25% pine bark.

Water holding capacity and air porosity of composts and compost-based substrates were also lower than that of C substrate. Moldes *et al.* (2006) found a WHC of 48% for municipal solid waste compost, similar to the values obtained for the composts in the present study (47.6-52.3%). Huang *et al.* (2001) found WHC in the range 48.4-57.7% for mixtures with 50% of similar composts, close to the values determined in this study (52.2-56.8%). For WHC the general tendency is to decrease as compost percent increased in mixtures. Grigatti *et al.* (2007) found the same tendency for mixtures of peat and 0 to 100% composted sewage sludge, reaching 53.3% for WHC of compost (WHC of compost BS, 51.5%). In the case of substrates BS75, BSMS50, BSMS75, MS25, MS50 and MS75 the obtained WHC values were below the ideal range (55-70%). In the case of BS and BSMS substrates, AP values were within the optimum range (20-30%) but AP for MS substrates surpassed the upper limit.

Physical properties and particle size distribution were correlated (**Table 3**). Cumulative percentages of 10-2 mm and <2 mm particle fractions were also included in **Table 3**. Values of BD and PD were linearly and inversely related

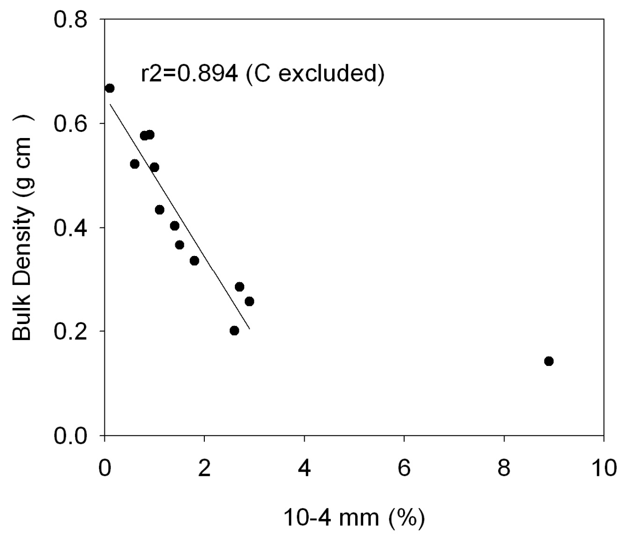

Fig. 1 Relationship between Bulk Density and Particle Size in growing media.

(r=-0.772 and r=-0.924) to coarser particles (10-4 mm). Correlation coefficients for BD were higher when data corresponding to C substrate were not included in the regression (r=-0.946). A small percentage increase of 10-4 mm particles caused a great reduction on BD (**Fig. 1**). Particle density was correlated positively to fraction <2 mm. This fraction probably includes more heavy mineral components from composts while coarse fraction (4-10 mm) was very low in compost and was mainly constituted of lightweight peat particles.

Values of WHC and TP were positively correlated to coarse (10-2 mm, 10-4 mm, and 4-2 mm) particles percentage and negatively to the small particles (<2 mm but not to 2-0.5 mm, and <0.5 mm in the case of WHC). Noguera *et al.* (2003) also found TP increased with particle size in a study of particle size influence on physical properties of coconut coir dust.

Based on their physical properties, growing media BS25 and BSMS25 were adequate as standard substrates. Growing media BS50, BSMS50 and MS25 presented one or two of the considered properties outside the optimum range. Hence, their use could be limited to some species or the water regime at the nursery should be modified. For the mixtures BS75, BSMS75, MS50 and MS75 several hydrophysical properties made them unsuitable as growing media.

Chemical properties of growth media and components

The results of the chemical analysis of the composts and peat based substrate C, are given in **Table 4**. Values of these properties in compost based substrates were between values of the C substrate and values of the corresponding compost. Composts BS and BSMS showed a pH similar to that of C substrate. Compost MS presented the higher pH (7.6), approximately one unit above composts BS and BSMS and above the limit (5.2-6.3) considered by Carmona and Abad (2007) as optimum for substrates.

Values of EC in all compost were considerably higher than that of C substrate. Compost EC values frequently surpasses those of standard peat substrates: Pérez-Murcia *et al.* (2006) and Wilson *et al.* (2006) gave values of EC 2.04 dS m^{-1} (1:6 extract) and 11.2 dS m^{-1} (1:2 extract) respectively for composted sewage sludge. Hernández-Apaolaza *et al.* (2005) reported values of EC >6 dS m^{-1} (in saturate paste extract) in substrates with 15% of composted sludge. Barral *et al.* (2007) reported values of EC 1.2 and 1.4 dS m^{-1} (1:5 extract) for composts of green waste-municipal solid waste and green waste–sewage sludge respectively. Moldes *et al.* (2006) and Barral *et al.* (2007) reported values of EC 2.4 dS m^{-1} (1:5 extract) for municipal solid waste compost. Abad *et al.* (2001) indicated that 52 of 100 compost tested in Spain presented EC values above the optimum range. Sodium content in composts BS, BSMS and MS was 3 to 8 times higher than in C substrate, but was lower than values found for similar composts (Moldes *et al.* 2006; Grigatti *et al.* 2007).

Organic matter (OM) content of the three composts were similar, approximately 30%. This value was below most values cited in the literature for these kinds of compost (40-58%, Hernández-Apaolaza *et al.* 2005; Moldes *et al.* 2006; Barral *et al.* 2007), but was similar to the value reported by Bernal *et al.* (1998) for city refuse mature compost. The Carbon/Nitrogen ratio (C/N) of composts BS, BSMS and MS (11.3, 10.7, 12.4) were close to 12. These values were indicative of compost maturity (Bernal *et al.* 1998; Iglesias-Jiménez and Pérez-García 1992). Wilson *et al.* (2002) indicated a C/N ratio lower than 15 to allow N mineralization whereas C/N ratios greater than 20 resulted in immobilization. Therefore the composts used in this study could be considered stable, mature and beneficial for subsequent N release and plant availability.

Phosporus content in composts BS, BSMS and MS was higher than in C substrate. Composts BS and BSMS have two-fold more P than composts MS, due to the presence of biosolids which are rich in this nutrient. Biosolids composts usually have higher but variable P contents. Several authors (Wilson *et al.* 2002; Wilson *et al.* 2006; Barral *et al.* 2007; Grigatti *et al.* 2007) reported values from 4.13 to 43.2 g kg^{-1}. Composts in this study also had higher contents of the nutrients K, Ca and Mg than C substrate. Therefore composts might be a significant source of nutrients (Ebertseder and Gutser 2001).

Table 4 Chemical characteristics of composts and peat-based substrate.

*	Units	BS	BSMS	MS	C
pH		6.60 a	6.79 a	7.59 b	6.40 a
EC	dS m^{-1}	2.41 ab	3.64 b	2.13 ab	0.18 a
OM	%	32.2 a	27.2 a	31.8 a	86.9 b
C/N		11.3 a	10.7 a	12.4 a	49.2 b
N	g kg^{-1}	14.2 b	12.8 b	12.8 a	8.83 a
P	g kg^{-1}	10.8 c	10.5 c	5.08 b	1.24 a
K	g kg^{-1}	6.89 b	6.59 b	5.82 b	3.00 a
Ca	g kg^{-1}	102.1 b	107.9 b	81.9 b	23.6 a
Mg	g kg^{-1}	7.04 b	7.36 b	6.92 b	1.07 a
Na	g kg^{-1}	1.18 ab	1.61 ab	2.60 b	0.32 a
Cu	mg kg^{-1}	113 b	192 b	173 b	23 a
Mn	mg kg^{-1}	273 b	282 b	272 b	35.3 a
Zn	mg kg^{-1}	258 b	401 c	328 b	25.3 a
Cr	mg kg^{-1}	56.7 ab	58.3 ab	67.7 b	8.7 a
Ni	mg kg^{-1}	27.0 b	43.0 b	40.7 b	2.67 a
Cd	mg kg^{-1}	0.56 ab	1.09 b	0.51 ab	0.12 a
Pb	mg kg^{-1}	78.7 a	138 b	293 b	35.0 a

*EC, electrical conductivity; OM, organic matter; C/N, carbon/nitrogen ratio
Values in rows followed by the same letters were not statistically different (Tukey test, P<0.05)

Micronutrients and heavy metals content in the three composts was between 2.2 and 16.1 times higher than the values found in C. The most relevant increases were observed for Zn (13- and 15.8-fold) and Ni (15.2- and 16.1-fold) in the composts MS and BSMS. Comparable results were obtained by Moldes *et al.* (2006) for municipal solid waste composts. For green waste-sewage sludge compost, Grigatti *et al.* (2007) reported values approximately two times higher than for BS compost, being also Ni among the more abundant heavy metals. Spanish regulations for compost (Spanish State 2005) fix limits for heavy metals, mainly for their agricultural use. This regulation classifies compost BS and BSMS as Class B compost, without restriction in (agricultural) use. Lead content in MS compost was over the limit proposed (200 mg kg^{-1}) for class C compost (agricultural use with restriction). Although during a correct composting process conditions (high pH, oxygen) favour metal oxidation reducing availability (Carmona and Abad 2007), it is necessary to control heavy metal contents in this kind of unsorted municipal solid waste.

Plant survival

The percentages of plant survival in the different growing media in the four trials are shown in **Table 5**. Electrical conductivity of the growing media is also given in the table in ascending order.

Plant survival was higher in trials 3 and 4 (transplanting) than in trials 1 and 2 (cutting and seedling). The higher rate (75%) of composts in transplanting trials did not produce any decrease in plant survival.

Cypress seedlings survival was approximately 95%, with no specific trends related to treatments. Salinity affects negatively on germination (Murillo *et al.* 1993), however, the effects of these types of composts incorporated to growing media are contradictory. In some cases compost did not induce any reductions in the germination (Pérez-Murcia *et al.* 2006) but in other cases, any reduction in germination or deleterious growth responses were associated to excess soluble salts or other toxins (Wilson *et al.* 2002; Moldes *et al.* 2006). Italian Cypress is classified as moderately salt tolerant species (North Carolina Cooperative Extension

Table 5 Plant survival (%) in the different trials and growing media.

	EC * dS m-1	Rosemary cutting	Cypress seedling	Rosemary transplant	Cypress transplant
C	0.183 a	100.0	95.0	100.0	100.0
BS25	0.685 b	99.2	95.0	100.0	93.3
MS25	0.685 b	99.2	93.3	100.0	100.0
BSMS25	1.028 bc	97.5	87.5	100.0	100.0
MS50	1.115 bc	99.2	98.3	100.0	100.0
BS50	1.158 bc	94.2	92.5	100.0	100.0
BSMS50	1.295 c	71.7	97.5	100.0	100.0
MS75	1.400 cd	95.0	97.5	100.0	100.0
BS75	1.850 de	50.8	94.2	100.0	100.0
BSMS75	1.920 e	54.2	92.5	100.0	100.0

* EC, electrical conductivity. Values in columns followed by the same letters were not statistically different (Tukey's test, P<0.05).

2008), and probably this resistance limits the negative effects of salinity on germination.

In the case of rosemary cuttings, plant survival decreased to 72% in BSMS50 treatment, and to 51-54% in treatments BS75 and BSMS75. These mixtures presented the highest EC values. Salinity could be in this case responsible of the plant mortality in the case of higher compost ratio in growing media. Rosemary is considered a highly salt tolerant species (North Carolina Cooperative Extension 2008) therefore the effect of salinity have been greater in the case of cutting propagation than in seed germination.

Plant growth

Plant heights in the different growing media corresponding to trial 1 (cutting propagation of rosemary) and trial 2 (seed propagation of cypress) are shown in **Fig. 2**. Rosemary plant height (**Fig. 2A**) in compost mixtures containing 25 and 50% were significantly greater than in C treatment. Significant differences among compost type or compost ratio (25-50%) were not detected. In mixtures BS75 and BSMS75 the height of died plants was considered 0 for the calculation, and for this reason the average height value was below that of C treatment. If data corresponding to dead plants are not considered, the average height would be 25.4 and 27.2 cm respectively, values greater than that of C treatment (20.9 cm) but still below the average heights in the 25 or 50% compost media. Plant stem diameter (data not shown) followed similar trends. Height decreased in the media containing 75% compost in relation to the other compost based-media were partially due to effect of salinity (died plants) but also it could be related to the poor physical properties of media as compost ratio increased (**Table 2**). Wilson *et al.* (2002) reported similar results in the case of containerized perennials (from cutting propagation) grown in media containing a biosolids-yard trimmings compost, and attributed the smaller plant development in media with high proportions of compost (50% or greater) to substrate compression.

Fig. 2B showed the height of cypress plants. Plant heights in all compost-based media were twice more than that in C substrate. For the three types of compost the average height was greater for 50% compost in growing media. Among compost types, heights for mixtures BS and BSMS were similar (for the same compost percentage) and greater than in the case of MS compost substrates. The alkalinity of compost MS (**Table 4**) could be related with this behaviour. These results are in agreement with several cases cited in the literature in which plant were propagated from seeds: Benito *et al.* (2005) indicated good development of ryegrass in substrates containing 50-100% pruning waste compost; Moldes *et al.* (2006) reported 25-50% of municipal solid waste composts as adequate for *Lepidium and Hordeum*; Barral *et al.* (2007) indicated 25% of municipal solid waste composts as adequate for barley but 50% causing problems due to salt excess; Ostos *et al.* (2008) found the best development of *Pistacia lentiscus* in substrates containing 40% biosolids-pruning waste compost or 40% municipal solid waste-pruning waste compost.

Increase in plant height corresponding to trials 3 and 4 are shown in **Fig. 3**. Opposite to the observations in rosemary cutting propagation trial, rosemary transplants grew better in all compost-based growing media (including 75%

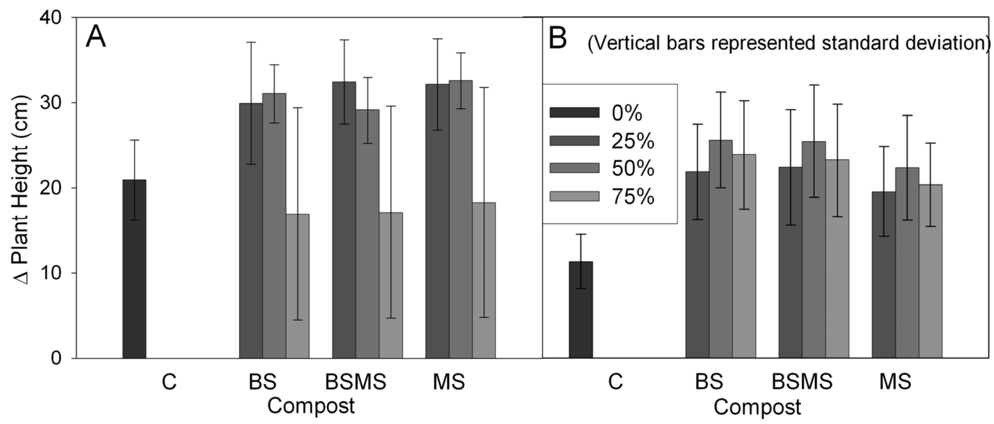

Fig. 2 Heights (cm) of the plants growing in compost growing media. (**A**) Rosemary in trial 1 (cutting propagation); (**B**) cypress in trial 2 (seedling).

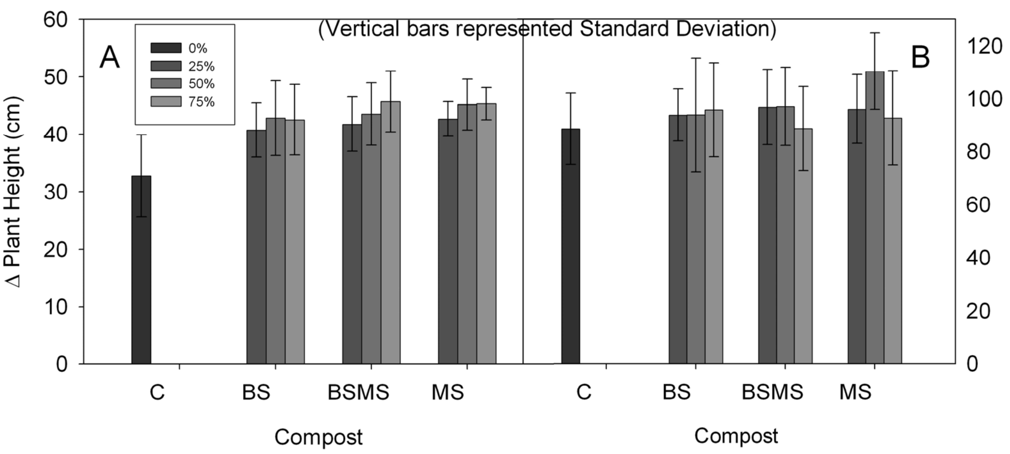

Fig. 3 Plant height increases in compost growing media. (**A**) Rosemary in trial 3; (**B**) cypress in trial 4.

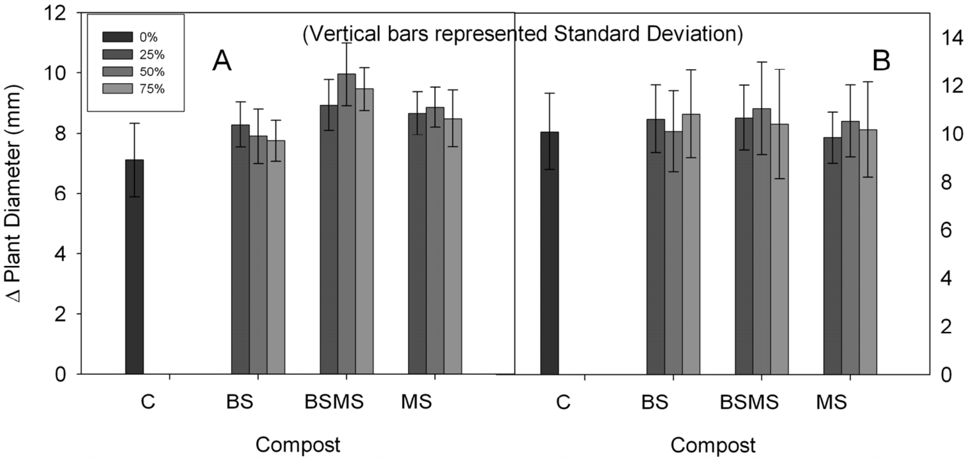

Fig. 4 Increase in stem diameter in compost growing media. (**A**) Rosemary in trial 3; (**B**) cypress in trial 4.

composts substrates) than in the C treatment (**Fig. 3A**). Detrimental effects related to the high percentage (75%) of compost in the media (salinity) did not appear in this trial therefore they were associated to the initial stages of growth. The salt tolerant character of rosemary (North Carolina Cooperative Extension 2008) probably permits such high peat for compost replacement. There were not statistical differences among the three compost types. In general, percentages of 25% compost in the substrates produced shorter plants than 50 or 75% compost, though differences among compost percentage were not significant. The highest plants were obtained in BSMS75, MS75 and MS50 substrates. Rosemary stem diameter (**Fig. 4A**) was also greater in compost-based substrates than in C substrate. Lowest values were obtained with BS mixtures and the highest ones with BSMS mixtures. The highest values in diameter also corresponded to mixtures with the high compost ratio (50-75%): BSMS50, BSMS75 and MS50. As a result, rosemary growth has been more favourable in substrates with high compost (50-75%) replacement. Ingelmo *et al.* (1998) also attained 75% peat replacement by several composts and wastes but in this case rosemary plants were similar or smaller than control plants, probably because the pots were fertigated avoiding the fertilizing effect of compost.

Growth in height and diameter of cypress plants are shown in **Fig. 3B** and **Fig. 4B**, respectively. Cypress plants growing in compost-based media reached higher heights than in C but, in general, differences were not significant, except for substrate MS50. The stem diameter was similar in all substrates. The potential beneficial effects of the compost-based media observed in rosemary (trial 3) could be deprived by composts salinity (**Tables 4, 5**), the moderate salt tolerance of Italian Cypress (North Carolina Cooperative Extension 2008) and by the poorer physical quality of compost-based media (**Table 2**). These results are in accordance with those observed by others researchers: Ingelmo *et al.* (1998) observed that the higher *Cupresus sempervirens* corresponded to the control; Hernández-Apaolaza *et al.* (2005) obtained the best results for this plant species with pine bark and 30% composted sewage sludge and coconut fibre and 30% composted sewage sludge, and they indicated that "high soluble salt concentrations immediately after planting are an important but manageable consequence of biosolids compost incorporation"; Wilson *et al.* (2006) stated that incorporation of compost (sewage sludge and yard trimming) in the medium did not affect the growth of native shrubs.

Plant nutrition

Selected nutrient and heavy metal concentration in rosemary corresponding to the different growing media assayed in trial 3 are shown in **Table 6**. Nitrogen contents were similar for all growing media. The obtained values (approximately 1%), were below survey range indicated by Mills and Benton Jones (1996), but there were higher than

Table 6 Element concentration in rosemary (trial 3) in each growing media.

	N %	P %	K %	Na %	Cu mg kg^{-1}	Zn mg kg^{-1}	Cr mg kg^{-1}
C	0.97	0.099	1.05	0.575	5.91	13.5	0.75
BS25	1.04	0.178	1.09	0.786	1.23	24.6	1.76
BS50	0.96	0.169	1.19	0.619	1.98	28.7	0.29
BS75	1.09	0.183	1.31	0.566	2.65	30.2	0.54
BSMS25	0.96	0.100	0.95	0.495	2.72	18.9	1.44
BSMS50	0.94	0.108	1.13	0.500	2.45	23.2	0.49
BSMS75	0.93	0.118	1.30	0.508	1.76	25.8	0.26
MS25	1.00	0.123	1.00	0.573	2.02	26.4	1.86
MS50	1.08	0.137	1.31	0.530	4.03	38.2	0.25
MS75	0.96	0.136	1.29	0.515	4.64	32.2	0.60
Survey range*	2.09-2.52	0.26-0.35	2.36-2.55	0.02-0.19	3-23	39-106	--

* Survey range cited by Mills and Benton Jones (1996).

the value found by Sardans *et al.* (2005) for 1 year-old leaves subjected to N fertilization (0.96%). These results indicated that nitrogen immobilisation in compost-based substrates was not occurred, as it was previously pointed out C: N ratio values in composts (**Table 4**). Compost in media also produced greater P content in plants, especially in the case of BS substrates, due to the P content in the composts (**Table 4**). Reported values for field growing and P fertilized rosemary were far below (0.05%) the values found in this trial. Potassium contents tended to be greater as compost percentage increased in the substrates. These results indicated the fertilizing capacity of compost incorporation to the growing media.

Rosemary Na content followed the tendency BSMS-media < MS-media < C-media < BS-media and it has no relation to compost Na content.

Metals such as Cu (**Table 6**), Fe and Mn (data not shown) decreased in rosemary plants cultivated in compost-based media in relation to peat-based substrate, in spite of the high relative contents of metals in composts (**Table 4**). Higher pH of compost-media probably reduced the availability of these metals. Heavy metals such as Cr (**Table 6**), Ni and Cd (data not shown) were also maintained in low levels. Only plant Zn was clearly greater in compost-media cultivated plants but the values were far below upper limit of survey range or toxicity limit (in general at levels above 200 mg kg^{-1}; Mills and Benton Jones 1996).

CONCLUSIONS

Composts from urban origin (biosolids, municipal solid waste and pruning waste) were suitable components of forestry nursery growing media. The hydrophysical properties of growing media were related to its particle size distribution. Substrates prepared by mixing peat and composts showed adequate physical properties if compost in mixtures was below 50%. Salinity and type of use also limited the maximum percentage of compost. In the case of cutting propagation, maximum allowable percentage of compost in substrates is limited to 50%. Seed germination was not affected until 75%. In comparison to peat based substrate, seedling growth was increased by compost incorporation until 75% in the case of salt tolerant species though, in general, better plant development was obtained at 50% compost. Plant growth improvement was related to the fertilizing effect of compost. The use of urban compost could be a sustainable alternative for partial peat substitution (up to 50%) that contributes at the same time to the recycling of urban wastes.

ACKNOWLEDGEMENTS

This study was supported by Spanish Ministry of Innovation and Research (Project AGR-FOR 2002-02633) and by the Andalusian Ministry of Environment (Project LIFE00 ENV/E/543). The authors gratefully acknowledge the contribution of the nursery of "Diputación de Sevilla".

REFERENCES

Abad M, Noguera P, Burés S (2001) National inventory of organic wastes for use as growing media for ornamental potted plant production: case study in Spain. *Bioresource Technology* **77**, 197-200

AENOR (2001a) Norma UNE-EN 13037. Soil improvers and growing media. Determination of pH. Asociación Española de Normalización y Certificación, Madrid, Spain, 11 pp

AENOR (2001b) Norma UNE-EN 13038. Soil improvers and growing media. Determination of electrical conductivity. Asociación Española de Normalización y Certificación, Madrid, Spain, 13 pp

Alvarez J, Del Campo A, Sancho F (2001) Research and technologic development of composting processes and its application in the agriculture and forestry sectors. In: *ORBIT 2001, Organic Recovery and Biological Treatment*, 9-12 May, 2001, Seville, Spain, pp 107-113 (Proceedings)

Bachman GR, Metzger JD (2007) Physical and chemical characteristics of a commercial potting substrate amended with vermicompost produced from two different manure sources. *HortTechnology* **17**, 336-340

Barral MT, Moldes A, Cendón Y, Díaz-Fierros F (2007) Assessment of municipal solid waste compost quality using standardized methods before preparation of plant growth media. *Waste Management and Research* **25**, 99-108

Benito M, Massager A, De Antonio R, Moliner A (2005) Use of pruning waste compost as a component in soilless growing media. *Bioresource Technology* **96**, 597-603

Bernal MP, Paredes C, Sánchez-Monedero MA, Cegarra J (1998) Maturity and stability parameters of composts prepared with a wide range of organic wastes. *Bioresource Technology* **63**, 91-99

Bugbee JG (2002) Growth of ornamental plants in container media amended with biosolids compost. *Compost Science and Utilization* **10**, 92-98

Carmona E, Abad M (2007) Aplicación del compost en viveros y semilleros. In: Moreno Casco J, Moral Herrero R (Eds) *Compostaje* (1st Edn), Mundi-Prensa, Madrid, Spain, pp 397-424

Chong C (2005) Experiences with wastes and composts in nursery substrates. *HortTechnology* **15**, 739-747

Ebertseder T, Gutser R (2001) Nutrition Potential of Biowaste Composts. In: *Applying Compost Benefits and Needs*, 22-23 November, 2001, Federal Ministry of Agriculture, Forestry, Environment and Water Management of Austria and European Communities, Brussels, Belgium, pp 111-128 (Seminar Proceedings)

Grigatti M, Giorgioni ME, Ciavatta C (2007) Compost-based growing media: Influence on growth and nutrient use of bedding plants. *Bioresource Technology* **98**, 3526-3534

Hernández-Apaolaza L, Gascó AM, Gascó JM, Guerrero F (2005) Reuse of waste materials as growing media for ornamental plants. *Bioresource Technology* **96**, 125-131

Houba VJG, Uittenbogaard J, Pellen P (1996) Wageningen Evaluating Programmes for Analytical Laboratories (WEPAL), organisation and purpose. *Communications in Soil Science and Plant Analysis* **27**, 421-431

Huang Y, Chen J, Robinson CA, Caldwell RD (2001) Changes in physical properties of peat, bark, and compost-formulated media after foliage plan production. In: James BL (Ed) *Proceedings of Southern Nursery Association Research Conference*, 2001, SNA, Atlanta, GA USA, pp 69-71

Iglesias-Jiménez E, Pérez-García V (1992) Determination of maturity indices for city refuse composts. *Agriculture, Ecosystems and Environment* **38**, 331-343

Inbar Y, Hadar Y, Chen Y (1993) Waste management. Recycling of cattle manure: The composting process and characterization of maturity. *Journal of Environmental Quality* **22**, 857-863

Ingelmo F, Canet R, Ibañez MA, Pomares F, García J (1998) Use of MSW compost, dried sewage sludge and other wastes as partial substitutes for peat and soil. *Bioresource Technology* **63**, 123-129

Mills HA, Benton Jones J (1996) *Plant Analysis Handbook II* (2nd Edn), MicroMacro Publishing, Athens, Georgia, USA, 407 pp

Moldes A, Cendón Y, López E, Barral MT (2006) Biological quality of potting media based on msw composts: A comparative study. *Compost Science and Utilization* **14**, 296-302

Murilo JM, Cabrera F, López R (1993) Effect of beet vinasse on germination and seedling performance of ryegrass (*Lolium multiflorum* Lam. cv. Barwoltra). *Journal of the Science of Food and Agriculture* **61**, 155-160

Noguera P, Abad M, Puchades R, Maquieira A, Noguera V (2003) Influence of particle size on physical properties of coconut coir dust as container medium. *Communications in Soil Science and Plant Analysis* **34**, 593-605

North Carolina Cooperative Extension (2008) Salt tolerant plants recommended for pender county landscapes. North Carolina State University. Available online: http://pender.ces.ncsu.edu/library/71/salt%20Tolerant%20Plants.pdf

Ostos JC, López-Garrido R, Murillo JM, López R (2008) Substitution of peat for municipal solid waste- and sewage sludge-based composts in nursery growing media: Effects on growth and nutrition of the native shrub *Pistacia lentiscus* L. *Bioresource Technology* **99**, 1793-1800

Pérez-Murcia MD, Moral R, Moreno-Caselles J, Pérez-Espinosa A, Paredes C (2006) Use of composted sewage sludge in growth media for broccoli. *Bioresource Technology* **97**, 123-130

Sardans J, Rodá F, Peñuelas J (2005) Effects of water and a nutrient pulse supply on Rosmarinus officinalis growth, nutrient content and flowering in the field. *Environmental and Experimental Botany* **53**, 1-11

Spanish State (2005) Royal Decree-Law 824/2005 *Spanish State Bulletin* **171**, 19 July. BOE, Madrid, Spain, pp 25653-25654

Wilson SB, Mecca LK, Danielson HE, Graetz DA, Stoffella PJ (2006) Container and field evaluation of three native shrubs grown in compost-based media. *Compost Science and Utilization* **14**, 178-183

Wilson SB, Stoffella PJ, Graetz DA (2002) Development of compost-based media for containerized perennials. *Scientia Horticulturae* **93**, 311-320