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Research Article

Nursery Growing Media: Agronomic and Environmental Quality Assessment of Sewage Sludge-Based Compost

Barbara De Lucia,[1] Giuseppe Cristiano,[1] Lorenzo Vecchietti,[1]
Elvira Rea,[2] and Giovanni Russo[1]

[1] *Department of Agro-Environmental and Territorial Sciences (DISAAT), University of Bari Aldo Moro, Via G. Amendola 165/A, 70125 Bari, Italy*
[2] *CRA, Agricultural Research Council, Research Centre for the Soil-Plant System, Via Della Navicella 2-4, 00184 Rome, Italy*

Correspondence should be addressed to Barbara De Lucia; barbara.delucia@uniba.it

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There is a stringent need to reduce the environmental impact of peat in the plant nursery production chain. In this experiment, the use of different rates of sewage sludge compost in the preparation of growing media for potted Bougainvillea was evaluated to assess its efficiency for the replacement of peat and to quantify the environmental impact of such alternative substrates by the life cycle assessment (LCA) method. Five substrates containing increasing proportion of composted sewage sludge to peat (0%, 25%, 40%, 55%, and 70% v/v) were used, and their physicochemical properties were measured. Bougainvillea plant growth, biomass production, and macro- and micronutrient absorption were also determined. The main results were that compost addition improved the plant nutrient and increased the substrate pH, electrical conductivity (EC), and dry bulk density values. Globally, the results showed that compost could be used at up to 55% by volume with no negative effects on plant growth. The LCA showed that use of compost reduced the environmental loads of the growth media, except the Global Warming Potential value (GWP100). Environmental implications of the use of compost in the plant nursery chain are discussed.

1. Introduction

Ornamental plant nursery production is one of the most specialized examples of intensive agriculture, with the large use of nonrenewable resources to maximize plant growth and reduce production time in an effort to capitalize on-sale profits. Because of this, the “green industry” is often considered a nonpoint (or diffused) polluting industry, due to the low efficiency in the management practices. The most common growing media used in Mediterranean ornamental nursery is peat, alone or mixed with inorganic coarse materials [1], because of its good chemical and physical properties. The development of substrates alternative to peat is necessary for three main reasons: (i) peat resources are limited and costly; (ii) the social pressure to reuse the waste resulting from human or industrial activities is growing rapidly, (iii) the economic need for reusing locally produced waste is more and more urgent [2, 3]. In Italian ornamental nurseries the cost of the substrate affects by up to 12–15% the overall production cost of the potted plants [4]. It is appropriate to consider replacing peat with other organic resources with favorable economically and environmentally features [5].

Composted organic wastes, properly mixed, can make excellent substrates for vegetable transplants [6, 7], especially sewage sludge due to its widespread production. Composting transforms sewage sludge into a drier, more uniform, and biologically stable product potentially suitable for plant rooting and rich in plant nutrients [8]. However, the proportion of compost in the final substrate is also very important, in order to minimize potential hazards due to the presence of heavy metals and pathogens. Combinations of peat with sewage sludge compost and other materials can minimize the negative properties of single materials (high salinity, heterogeneity, and contaminants) [9]. Reduced use of nonrenewable resources and use of new materials for production of growing media would allow a reduction in the environmental impact of industrial processes. Positive results can be quantified by the life cycle assessments (LCA) analysis method of environmental impact of the composting processes and to the growth media production [10, 11]. The European Commission considers the LCA method as an instrument with a scientific bases able to provide the overall environmental costs of any productive process throughout its whole life cycle.

Previous studies on compost use in agriculture have focused on specific agronomic aspects such as plant nutrition, water holding capacity, and species specificity. Differently, the choice of a growing media composition is constrained technical considerations (e.g., growing medium characteristics, crop requirements, safety, reliability, availability of constituents, and price). In substituting a peat substrate for a peat-biosolid compost mix, it is essential for the grower to consider crop quality. However few studies have addressed the global quality (agronomical and environmental) of horticultural growing media [12]. A previous study reported that to reduce the environmental impacts of a peat growing medium it is necessary to replace peat for alternative materials (e.g., perlite, wood fiber, and green compost) [13]. Currently, there is a lack of environmental quality data relating to sewage sludge compost application and rates in ornamental nursery as growing medium [14].

In this research, the use of different rates of sewage sludge compost in the preparation of growing media for potted Bougainvillea was evaluated in order to assess its efficacy as a peat replacement and to quantify the environmental impact of the substrate, by the LCA method, to optimize the ornamental nursery production chain. The simultaneous evaluation of the agronomic quality and environmental impact of the different rates in volume of biosolid compost in the production chain of the growing media consists in the innovative aspect of this research: actually data for the Mediterranean shrubs production does not exist.

In this research, the use of different rates of sewage sludge compost for the preparation of growing media for potted *Bougainvillea* was evaluated in order to assess its suitability to replace peat in the ornamental nursery production chain and to quantify the environmental impact of the substrate by the LCA method.

2. Materials and Methods

2.1. Characteristics of the Compost. The compost used as a component of growing media for this experiment (SSC) was obtained by mixing of urban sewage sludge (30% by volume) from Manduria municipality (TA, Southern Italy) and pruning rejects: urban "green" and olive grower (70% by volume), both locally available, in a composting plant. The mixture (about 3 m^3) was composted in a pilot plant, using the Rutgers static pile composting system, with forced aeration and controlled temperature. The mixture reached temperature values greater than 60°C and the thermophilic phase lasted 60 days. After 95 days, the biooxidative phase of composting was over and then the pile was allowed to mature for an additional month.

Table 1: Physical and physicochemical characteristics of sewage sludge.

Parameter	Value in dry sewage sludge (SS)	Limit value in dry SS (according to Italian Legislation Lgs D. 99/1992)
Colour	7.5Y 2/1	
Moisture content (%)	11.8	—
Total OM (%)[a]	42.3	—
Oxidizable OC (%)[a]	21.9	≥20.0
pH (H_2O)	7.64	—
EC (dS m^{-1})	4.10	—
C : N ratio	6.12	—
$CaCO_3$	19.8	
CHA/CFA	n.d.	—
Total Kjeldahl Nitrogen TKN (%)[a]	3.21	≥1.50
P_2O_5 (%)[a]	1.91	≥0.40
K_2O (%)[a]	0.21	—
CEC (cmol$^{(+)}$ kg^{-1})	n.d.	—
Pb (%)[a]	49.0	750
Cd (%)[a]	5.21	20.0
Ni (%)[a]	24.0	300
Zn (%)[a]	1057	2500
Cu (%)[a]	216	1000
Hg (%)[a]	5.10	10.0
Cr^{+6} (%)[a]	1.20	—

[a] Values on a dry matter basis; data are mean values, $n = 3$.

The main physical, physicochemical, and chemical parameters were analyzed in sewage sludge (Table 1) and SSC (Table 2) and raw materials added subsequently to prepare the growing media (Table 3).

Concerning the dry sewage sludge (Table 1), the pH value was slightly alkaline and the EC value was medium-high, whereas the $CaCO_3$ content was largely due to the wastewater treatments of the sewage sludge with CaO and $FeCl_3$. The P content was in the common range of values for an organic fertilizer, whereas the K content was relatively small, possibly due to its solubility and transport in sewage sludge wastewater. According to Italian Law (Legislative Decree 99/1992), the heavy metal contents measured in the dry sewage sludge sample were under the limits.

The obtained compost showed a good degree of maturity (Table 2), according to different criteria suggested in the literature [15], such as the ratio of total organic carbon to total nitrogen (TOC/TN).

The compost showed an absence of phytotoxicity, according to the germination index (GI) > 50% (data not shown).

The main physicochemical parameters of the used materials are reported in Table 3. The commercial *Sphagnum* peat (P) from Germany was used in combination with pumice and

Table 2: Physical and physicochemical characteristics of sewage sludge compost.

Parameters	Value in sewage sludge compost (SSC)	Limit values in SSC (according to Italian Legislation Lgs D. 75/2010)
Colour	10YR 3/2	
Moisture content (%)	44.4	≤50.0
Total OM (%)[a]	58.6	—
Oxidizable OC (%)[a]	29.0	≥20.0
C : N ratio	10.2	≤25.0
CHA/CFA	1.96	—
Total Kjeldahl Nitrogen TKN (%)[a]	2.83	—
P_2O_5 (%)[a]	0.91	—
K_2O (%)[a]	0.71	—
CEC ($\mathrm{cmol}^{(+)}\ \mathrm{kg}^{-1}$)	77.0	—
Pb (%)[a]	6.40	140
Cd (%)[a]	0.10	1.50
Ni (%)[a]	3.20	100
Zn (%)[a]	394	500
Cu (%)[a]	14.1	230
Hg (%)[a]	0.10	1.50
Cr^{+6} (%)[a]	0.10	0.50

[a] Values on a dry matter basis; data are mean values, $n = 3$.

pozzolana (volcanic materials) and almond shell that improve aeration and water holding capacity of the growth substrates.

2.2. Experimental Procedure and Greenhouse Experiment. A greenhouse pot experiment was carried out to evaluate the main physical and chemical properties of five growing media obtained by mixing sewage sludge-based compost and peat in different ratios and to evaluate the potential use of these substrates as growing media for commercial *Bougainvillea* production.

The five compared substrates were obtained by mixing increasing rates of sewage sludge compost (25%, 40%, 55%, and 70% v/v) with a fixed rate of inert the other materials (30% v/v) to fulfillment to 100% of the substrate volume, including the *Sphagnum* peat. A peat based and compost-free substrate (SSC0), typically used in the Apulia nurseries, was also prepared as control by mixing peat (70%) pumice (15%), almond shells (10%), and pozzolana (5%).

Heavy metal content was also determine (Table 6).

The experiment was conducted in a commercial nursery located in Monopoli SE Italy, 40° 57′ 00″N, 17° 18′ 00″E 23 m a.s.l.), in a greenhouse at keeping the temperature between 15 ± 2°C at night and 28 ± 2°C during the day temperature 60% relative humidity. On December 4 2012 rooted cuttings of *Bougainvillea glabra* "Sanderiana" were potted singly in brown plastic containers (5 L volume). Each pot was filled with one of the test substrates. The young plants (one month old) had the following size: 12 cm height, 7 cm diameter, and 18 g fresh weight.

The growing density, on bench, was 8 plants m^{-2} for a total of 135 plants (27 plants per growing medium). The irrigation system was a microdrip. The plants were irrigated with only water during the first week, and then they were daily fed with a water soluble fertilizer N : P : K (5 : 1 : 7.5) plus microelements in dose of 0.5 g/L water. From the beginning of trial to 90 (days after transplant) DAT the nutrient solution was diluted according to the compost percentage of the substrate (Table 7). The plants grown in SSC45 and SSC70 have shown N deficiency symptoms (91 DAT); then the solutions were unified in all treatments, with the dose 0.5 g/L water (N : P : K= 5 : 1 : 7.5).

From the beginning of the trial up to 90 DAT the nutrient solution quantity per pot was of 250 mL/d; then, up to the May 6 (trial end), they received 4 interventions per day with a volume of 250 mL/pot per intervention.

2.3. Measurements and Analytical Methods. The greenhouse experiment ended at 150 DAT when, on average, the plants reached the commercial size. The plant growth was determined after 90, 120, and 150 DAT. On each sampling date nine plants per treatment (three per replicate pot) were randomly harvested and used for the following biometric measurements: number of leaves, leaf area (cm^2) (LI-COR 3100 area meter), and fresh and dry weight. The growing media were dried in an air-forced oven at 60°C to constant weight and milled to below 0.25 mm by a Tecator Cyclotec, 1093 PBI. The parts of the plants above ground were separated from the roots and gently washed many times with tap water and then finally with deionized water. A mixed sample of all the replications of each treatment was collected. Next, the samples were dried at 60°C to constant weight and crushed to 0.25 mm. The total Kjeldahl nitrogen (TKN) was measured using 1 g samples of both growing media and plant tissues using the Kjeldahl method after 96% H_2SO_4 hot digestion. Total phosphorus was determined (P) by the colorimetric molybdovanadate phosphoric acid method. The remaining nutrients and the heavy metal content were determined in digested samples by inductively coupled plasma atomic emission spectrometry (ICP-AES). One gram of dried samples was mineralized using 20 mL of 65% HNO_3 solution. After digestion, samples were transferred into 50 mL volumetric flasks and then filtered through a Whatman 42 filter. The analyses were carried out in triplicate.

The main chemical and physicochemical properties of the five growing media were determined according to the following standardized UNI EN methods: 12579 (for sampling), 13037 (for the pH value), 13038 (for electrical conductivity, EC), 13041 (for dry bulk density and shrinkage), 13654-1 (for nitrogen), and 13652 (for quantification of H_2O-soluble nutrients and heavy metals) [16, 17].

The germination index (GI) was calculated using seeds of *Lepidium sativum* L. [18].

2.4. Statistical Analysis. The greenhouse experiment was carried out following a randomized block designed with three

Table 3: Physical and physicochemical characteristics of the raw materials used: compost (SSC), almond shell (A), pumice (Pu), pozzolana (S), and sphagnum peat (P).

Raw materials	pH	EC ($dS\,m^{-1}$)	Dry bulk density ($g\,cm^{-3}$)	Easily available water (%V)	Shrinkage (%V)
SSC	7.90	5.54	0.45	9.93	13.17
A	5.71	0.26	0.38	1.19	00.00
Pu	6.72	0.08	0.81	2.88	00.00
S	6.43	0.10	1.62	10.43	00.00
P	5.62	0.33	0.13	6.53	15.33

Data are mean values, $n = 3$.

Table 4: Physical and physicochemical characteristics of the growing media used (at transplant).

Growing medium	pH	EC ($dS\,m^{-1}$)	Bulk dry density ($g\,cm^{-3}$)	Easily available water (%V)	Shrinkage (%V)
Acceptable range (^{1})	5.2–6.5	<0.5	≤0.4	20–30	<30
SSC0	5.80^{c}	0.45^{e}	0.28^{c}	13.71^{a}	15.87^{a}
SSC25	6.36^{b}	1.52^{d}	0.35^{b}	12.01^{a}	14.97^{a}
SSC40	6.50^{b}	2.15^{c}	0.39^{b}	6.01^{b}	14.10^{b}
SSC55	6.85^{a}	2.85^{b}	0.45^{ba}	5.86^{b}	13.40^{c}
SSC70	6.90^{a}	3.80^{a}	0.55^{a}	5.06^{b}	13.01^{c}
Significance	*	**	*	**	*

(^{1}): ideal substrate. Data are mean values, $n = 3$.
In each column different letters indicate significant differences for $P \leq 0.05$ (test S.N.K.).
*indicates difference at $P \leq 0.05$; **indicates difference at $P \leq 0.01$.

Table 5: Chemical characteristics of the growing media used (at transplant).

Growing medium	mg kg^{-1} Total						
	N	P	K	Ca	Mg	Fe	Mn
SSC0	330^{d}	1561^{d}	1027^{c}	5927^{c}	660^{e}	239^{c}	69^{b}
SSC25	550^{c}	2962^{c}	2058^{b}	17346^{b}	1682^{d}	933^{b}	114^{a}
SSC40	790^{b}	3050^{c}	2765^{a}	18652^{b}	2783^{c}	1056^{ab}	128^{a}
SSC55	890^{b}	3858^{b}	2692^{a}	20857^{ab}	3732^{b}	1188^{a}	136^{a}
SSC70	1010^{a}	4413^{a}	2805^{a}	22328^{a}	4040^{a}	1320^{a}	151^{a}
Significance	**	**	**	**	**	**	**

Data are mean values, $n = 3$. **indicates difference at $P \leq 0.01$.
In each column different letters indicate significant differences for $P \leq 0.05$ (test S.N.K.).

Table 6: Average values of the heavy metals content of the growing media used (at transplant).

Growing medium	mg kg^{-1}					
	Pb	Cd	Ni	Zn	Cu	Cr^{+6}
Italian Law value	140	1.50	100	500	230	<0.5
SSC0	12.04^{c}	0.06^{b}	1.58^{c}	12^{c}	13^{b}	<0.5
SSC25	33.23^{b}	0.19^{a}	1.78^{c}	82^{b}	13^{b}	<0.5
SSC40	34.00^{b}	0.22^{a}	2.56^{b}	102^{ab}	15^{ab}	<0.5
SSC55	35.66^{b}	0.28^{a}	3.33^{ab}	122^{a}	19^{a}	<0.5
SSC70	47.49^{a}	0.31^{a}	4.13^{a}	143^{a}	18^{a}	<0.5
Significance	**	*	**	**	**	n.s.

Data are mean values, $n = 3$.
In each column different letters indicate significant differences for $P \leq 0.05$ (test S.N.K.).
*indicates difference at $P \leq 0.05$; **indicates difference at $P \leq 0.01$; n.s. indicates nonsignificant difference.

Table 7: Dilution ratio of nutrient solution supplied to the growing media from 1 to 90DAT.

Growing medium	Dilution ratio (% V : V)	
	Nutrient solution	Water
SSC0	100	0
SSC25	64.29	35.71
SSC40	42.84	57.16
SSC55	21.43	78.57
SSC70	0	100

Table 8: Raw materials used for the production of the tested growing media and their transport distance from the production areas to the firm.

Materials	Transport distance (km)
Urban sewage sludge	130
Green wastes	40
Peat	2500
Pumice	600
Almond shell	150
Pozzolana	100
Sewage sludge compost	0

replications. To compare the differences between specific treatments, the S.N.K. test was used. All statistical tests were conducted using the CoStat software package (2002).

2.5. Environmental Analysis. A comparison of the growing media production used in the experimental test was carried out (from June to November 2012) by means of a life cycle assessment (LCA) analysis, to gain more knowledge about the environmental impact and the resource use along the substrate production chain. The LCA is a method to analyse and assess the potential environmental impact caused by the used materials (ISO 14040-44) [19]. The product system comprising the composting plant and technique, the compostable organic sewage sludge, the produced compost, peat, pumice, almond shell, and pozzolana, and the five formulated growing media were included in the LCA. In accordance to the ISO 14040 standards, the inventory of the inputs (matter and energy) and the environmental outputs (water, air, and soil emissions) was accomplished using data obtained by direct interviews with the entrepreneurs, business inspections, and previously published data [20]. The transport distance of each raw material from the production area to the composting farm was also included as an input value (Table 8).

The data were elaborated using GABI 04 software with the CML2010 interpretation method [21] to determine the impacts indexes, expression of the environmental load of the growing media productive process. In the LCA evaluation of the composting process and all the assumptions about the boundaries of the production system, the adopted functional unit, and the objectives of the study were evaluated in accordance with [12, 22]. For the growing media comparison, the process functional unit has been set at 1 kg. The limits of the productive system include the wastes transport to the firm and the growing media components production and packaging.

3. Results and Discussion

3.1. Physical and Chemical Characteristics of the Growing Media. Main physicochemical properties of the different raw materials and growing media used are shown in Tables 3 and 4 and the values established for an optimal substrate [23]. At start of the experiment the percentage in the mixtures of compost from urban sludge significantly affected values of the physical and physicochemical properties in relation to those observed in the control treatment (SSC0) (Table 4). Compost addition produced increased the values of pH and electrical conductivity (EC). The pH values of SSC0, SSC25, and SSC40 were within or close to the acceptable range (5.2–6.5) and significantly increased with the highest proportion of CSS (55% and 70%) in the substrate.

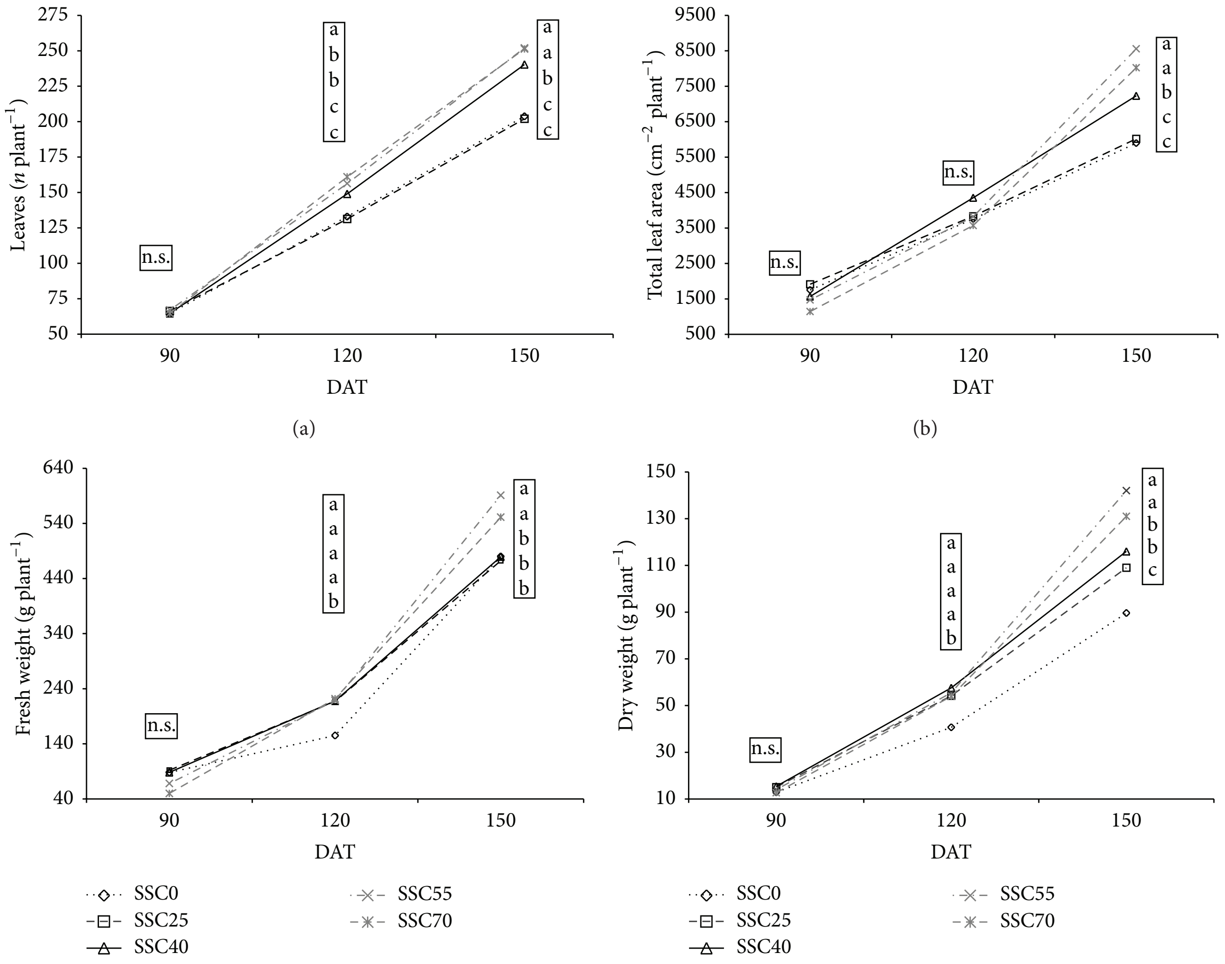
The electrical conductivity (EC) values of the growth media were strongly affected by the addition of CSS; the values exceeded the limit for an optimal growth substrate in the mixtures having more than 25% compost: the SSC0 being the only substrate that fulfilled optimal reference level (Table 4).

The physical parameters at transplanting were influenced by the percentage of compost in the growing media. The increases in bulk density were within acceptable values only in SSC0, SSC25, and SSC40 treatments. Compost addition to the mixtures decreased the values of shrinkage and easily available water, and only the substrate with SSC25 showed similar values to those found in the control treatment as regards the shrinkage. Main macro- and micronutrient contents were also significantly affected by compost rate in the media (Table 5). The TKN quantity was more than triple in peat free substrate (SSC70) compared to the control. The heavy metal content was also increased by the higher proportions of compost additions, but all the measured values where under the Italian legal thresholds for its safe use in agriculture (Table 6).

3.2. Plant Growth and Tissue Composition. Significant increases were observed in the growth of *Bougainvillea* plants with increasing compost rates in the mixtures (Figures 1(a)–1(d)).

On average, at 120 and 150 DAT, leaves number increased in SSC40, SSC55, and SSC70 growing media (Figure 1(a)). The leaf area only differed between treatments only at 150DAT with the lowest value found in plants grown on SSC0 and SSC25 substrates (Figure 1(b)). The weight also increased at 120 DAT in compost enriched substrates (Figure 1(c)), with the highest values recorded for SSC55 and SSC70 (peat free) substrates. The increasing rates of compost at 120 DAT also increased the dry weight values, compared to the control, with no difference between the rates (Figure 1(d)); at 150 DAT the dry weight showed the highest values in SSC55 and SSC70.

The increase in plant biomass production with the use of compost as a growing media component could be attributed



(a) (b) (c) (d)

Figure 1: Leaves number (a), leaf area (b), fresh (c), and dry (d) weight in Bougainvillea potted plants at 90, 120, and 150 DAT as influenced by growing media. Each point is the mean of three replications. Within the same DAT values with the same letter are nonsignificantly different $P \leq 0.05$.

to the high input of nutrients provided by composts, and in our experiment increases in P, Ca, Mg, Fe, Mn, Cu, and Zn (Tables 5 and 6) likely played a key role. Improvement of plant biomass production by CSS was higher on a dry basis than on a fresh basis, confirming the increased plant uptake of nutrients. In general, compost addition significantly influenced the nutritional status of the *Bougainvillea* aerial part (Tables 9 and 10). Macronutrient contents were significantly enhanced with the increasing rate of compost in the substrate. This result is probably due to a higher macronutrient availability in compost based growing media (Table 5).

A decrease of Mn concentration in plant tissue was observed with increasing compost presence in growing media (Table 10).

Tognetti et al. (2007) reported that the pH increases when mature composts are applied, [24]. The increase in EC values with rising proportions of composts in amended soils was reported by De Lucia et al. [25] where composted sewage sludge was incorporated into urban soils for three landscaping plants (*Phillyrea angustifolia*, *Myrtus communis,* and *Pistacia lentiscus*). The results showed that the chemical properties of the amended soils were also directly affected by the SSC rate, but the effect of the compost on organic matter, nitrogen, and potassium contents decreased over time. Perez-Murcia et al. (2006), in experiments using substrates obtained by mixing sewage sludge compost with peat to grow horticultural plants (broccoli), found that the EC values of the growth media were strongly affected by the addition of CSS; the values exceeded the limit for an ideal substrate in the mixtures having more than 30% compost [9]. Bulk density increased with the adding of compost, as reported in previous studies that used compost as substrate component [26].

Hidalgo and Harkess [27] evaluated vermicompost as a substrate amendment mixed at different ratios with peat moss for chrysanthemum production and reported that the bulk density, the percentage of pore space, and water holding capacity increased as the vermicompost content increased. Presence of coarse particles in the compost increased the substrate aeration and water retention in compost enriched plant growth substrates [27, 28]. Macro- and micronutrients

Table 9: Concentrations of macronutrients in tissues of Bougainvillea plants as influenced by growing media (150DAT, on dry matter basis).

Growing medium	mg kg^{-1}					
	N	P	K	Ca	Mg	Na
SSC0	25.1^{c}	6.53^{d}	38.3^{c}	19.7^{c}	9.63^{c}	4.01^{b}
SSC25	27.3^{c}	7.02^{c}	40.4^{c}	19.1^{c}	12.4^{b}	4.55^{b}
SSC40	30.2^{b}	7.51^{b}	45.2^{b}	20.9^{b}	14.3^{b}	5.30^{a}
SSC55	31.5^{b}	7.74^{b}	48.3^{b}	21.1^{b}	15.7^{b}	5.70^{a}
SSC70	35.4^{a}	8.40^{a}	56.2^{a}	23.4^{a}	18.5^{a}	5.92^{a}
Significance	*	*	**	*	*	*

Data are mean values, $n = 3$.
In each column different letters indicate significant differences for $P \leq 0.05$ (test S.N.K.).
*indicates difference at $P \leq 0.05$; **indicates difference at $P \leq 0.01$.

Table 10: Concentrations of micronutrients in tissues of Bougainvillea plants as influenced by growing media (150DAT, on dry matter basis).

Growing medium	mg kg^{-1}				
	Fe	B	Mn	Cu	Zn
SSC0	138^{c}	32.1	121.0^{a}	27.9^{b}	75.4^{c}
SSC25	141^{c}	30.3	90.6^{b}	30.5^{b}	124.7^{b}
SSC40	146^{b}	33.3	88.3^{b}	32.2^{b}	133.1^{b}
SSC55	$156a^{b}$	30.95	82.2^{c}	36.9^{a}	151.7^{a}
SSC70	169^{a}	31.4	85.4^{bc}	40.2^{a}	160.8^{a}
Significance	*	n.s.	**	*	**

Data are mean values, $n = 3$.
In each column different letters indicate significant differences for $P \leq 0.05$ (test S.N.K.).
*indicates difference at $P \leq 0.05$; **indicates difference at $P \leq 0.01$; n.s. indicates nonsignificant difference.

increased in compost-based mixtures compared to the control, confirming that sewage sludge compost can be a source of macro- and micronutrients [29]. The increase in macronutrient levels with compost incorporation was also observed by in an experiment of potted *Pelargonium* production [30]. Research has shown that the use of sewage sludge generally increases the heavy metal contents in compost: comparable results were reported by Wuest et al. (1995) in experiments involving aged mushroom compost [31].

Concerning the plant growth, positive correlations between the leaf area and the shoot dry weight have been reported by Tremblay and Senecal [32]. The increase in plant biomass production with the use of compost as a growing media component has been previously reported [9, 33]. The macronutrient availability improved with compost addition to the media: our results are in agree with Stellacci et al. in the growth of containered *Quercus ilex* [34]. Similar to our findings, Ostos et al. found that the P uptake was notably enhanced in *Pistacia lentiscus* cultivation [29]. Pinamonti et al. [35] found significant increases in the N, P, and K contents in cucumber, tomato, and strawberry plants grown in peat-sewage sludge compost media. Falahi-Adrakani et al. (1987) reported that cabbage and broccoli accumulated greater amounts of N and K from the composted sewage sludge amended medium [36]. The Mn decreases have been reported by other authors [5] and it is probably a consequence of the reduced Mn availability induced by the high pH values of these growing media (Table 5).

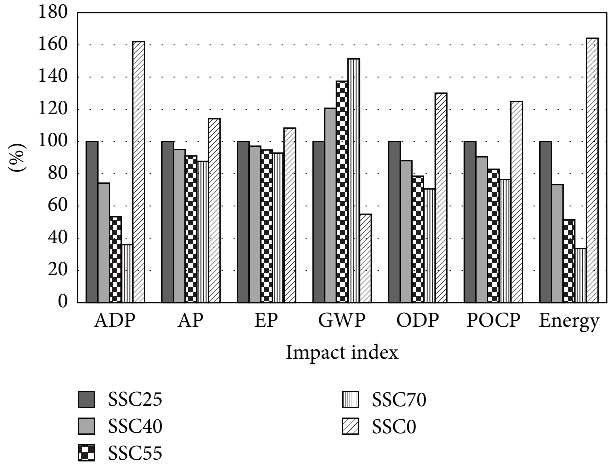
3.3. Life Cycle Analysis (LCA) Analysis. The results of the environmental analysis are reported in Figure 2.

The environmental burden of SSC25 was considered as a reference value equal to 100% of environmental burden. The growing media environmental loads decreases by reducing the peat content for all the compared indexes apart from GWP_{100} (Global Warming Potential), even if the compost content increases atmospheric emissions due to the composting process emissions and waste transport (Figure 2).

These results were influenced by the long distance of the peat production areas (North Europe) from the composting and packaging plant. The GWP_{100} index showed an opposite trend, indicating a potential growing media environmental burden increase as the added compost dose increases. This could be attributed to to the increase of atmosphere emissions associated to the composting process. Our results were in line with previously published data on the environmental impact of growing media [13]. The LCA also showed that the SSC70 medium produced the best environmental performance for all the indices, except for GWP. This environmental benefit could be attributed to the absence of peat in such substrate.

In addition, a higher use of compost produces C sink phenomena [37–39] because the composting process retains part of the original sewage sludge C in the mature compost, rather than its release by oxidation or fermentation when the same wastes are landfilled.

Considering the environmental burdens avoided by the accumulation of organic waste in landfills and the reduction



Depletion of the abiotic resources	ADP	kg Sb eq.
Climate change	GWP_{100}	kg of CO_2 eq.
Ozone layer depletion	ODP	kg R-11 eq.
Acidification	AP	kg of SO_2 eq.
Eutrophication	EP	kg of PO_4^{3-} eq.
Formation of photochemical oxidants	POCP	kg of ethylene eq.
Primary nonrenewable energy consumption	Energy	MJ

Figure 2: LCA of growing media compared: analysis results.

of fertilizers, some authors [22, 40, 41] have obtained an environmental credit for the production of compost. In this case, the use of compost can reduce the overall environmental load of the substrates or field crops. Finally, by maximizing the peat replacement by compost produced near the growing media production farms, the impact due to its transport is further reduced [42].

4. Conclusion

The presented results showed that replacement of peat by sewage sludge compost can increase as compared to the typical plant nursery substrates, mainly by increasing macro- and micronutrients supply to plants. In our experiment, replacement of peat up to 55% yielded in Bougainvillea plants of comparable quality as to the typical peat based substrate. The LCA showed that the addition of compost greatly reduced the environmental impact of the plant nursery chain.

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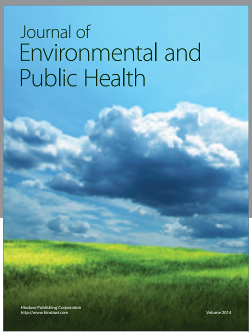
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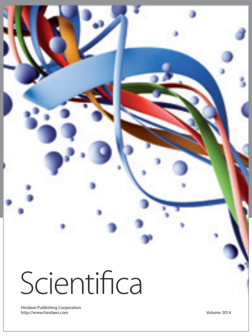
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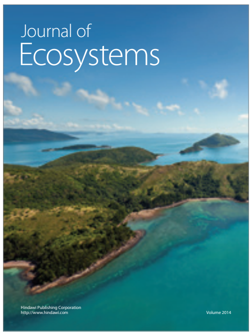
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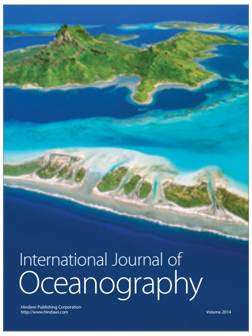
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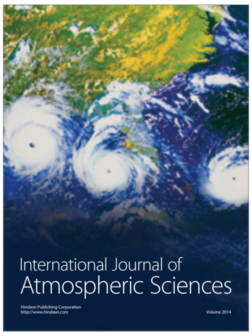
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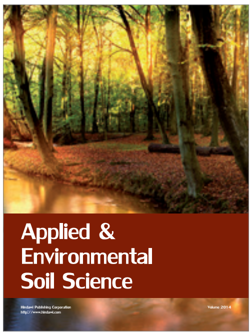
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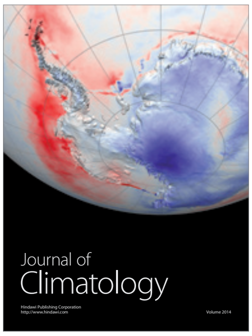
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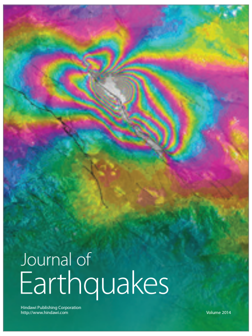
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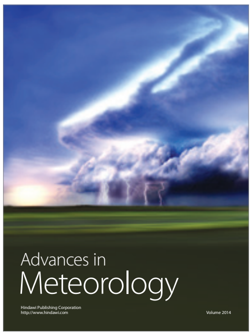
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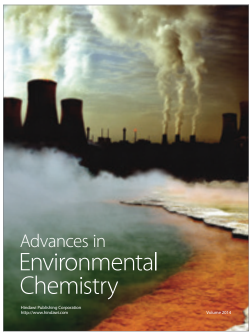
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