POSIDONIA OCEANICA (L.) BASED COMPOST AS SUBSTRATE FOR POTTED BASIL PRODUCTION

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Abstract

BACKGROUND

Peat, the main substrate component used for the production of potted plants, is a non-renewable resource and its extraction from peatlands can degrade these particular ecosystems. European policy strongly encourages the use of peat alternatives giving "eco-label" only to substrates not containing peat. Posidonia is a Mediterranean seagrass, that produces very conspicuous wedge-shaped deposits difficult to dispose. Basil plants are generally cultivated in pot using green compost and/or peat as growing media. In this study, a commercial green compost and a posidonia residues based compost were tested in order to assess their potential use as substitutes to peat. Agronomic (biomass, leaf area, height, content of macro and micronutrients of plants) and food security (metal content in substrates and plant tissues) aspects were studied.

RESULTS

Basil plants grown on peat showed higher fresh weight and leaf area than those grown on compost mixtures. All macro and micro-element concentrations were positively and significantly affected by the presence of composts in the media.

CONCLUSION

The results obtained showed that both the compost based substrates could be used as a viable alternative or a complement to the use of peat only for basil production, without reduced absorption levels of metals compared to the peat. In particular, in the case of posidonia residues based compost, results obtained encourage the use of these residues, so as to avoid to be disposed into landfills and to reduce the environmental problems, through an eco-friendly reuse of this biomass.

Keywords: Peat, green compost, posidonia based-compost, growing media, basil production.

Introduction

In Southern Europe peat is the main substrate component used for the production of potted plants, because of its good chemical and physical properties. Unfortunately, peat is a very expensive material, especially in Mediterranean countries, because it is imported mainly from Northern and Central Europe, and recently has become more expensive and its properties more variable[1]. Germany, Italy, and The Netherlands are the main users of peat in Europe[2]. Peat is a non-renewable resource and its extraction from peatlands can degrade these ecosystems highly fragile with a great ecological and archaeological value[3]. In particular, ombrotrophic peatlands evolve only due to the atmospheric deposition, and these deposits have often been used as historical records of the impact of human activities[4-7] and/or as tool in paleoclimatic and paleovegetation reconstructions[8,9]. For these reasons, peatlands have been included in the schedule of natural habitats with a potential degradation[10], thus making it necessary to identify other growth substrates for plants in replacement of peat. European policy strongly encourages the use of peat alternatives[11,12], and the European Commission[13] has introduced the European Union "eco-label" for growing substrates (including soil improvers) that not contain any peat materials, encouraging the use of organic matter derived from the processing and/or re-use of wastes[14].

Recently, different organic residues, such as byproducts, municipal sewage sludge, and urban solid wastes, food industry, and wood processing wastes, agricultural crop residues and animal wastes[15-20] are recycled after appropriate stabilization treatments such as composting. Numerous studies have demonstrated that organic residues, after composting, can be used with very good results as growing media instead of peat[21-23, 1, 12]. Compost is a stabilized and sanitized product of composting, which is the biodegradation process of a mixture of organic substrates carried out by a microbial community composed of various populations, both in aerobic conditions and solid state[24]. Composting aims to promote the humification process of organic matter by increasing its biostability and maturity, so to improve its potential as an organic fertilizer[25]. Composts tend to improve the organic matter content of the soil[26], to provide nutrients and growth regulators[22], and to avoid adverse environmental effects that may occur in soil, including microbial immobilization of plant nutrients, production of phytotoxic compounds, induction of anaerobic conditions, etc.[17, 27, 28]. In contrast, the use of compost as a substrate component can cause some problems as a consequence of its high salt content[29, 30], unsuitable physical properties[31,32] and variable quality and composition [33, 34]. Further, the application of high rates of compost may determine an accumulation of trace metals in plants, with dangerous consequences for humans and animals that feed on these plants[35].

Posidonia oceanica (L.) Delile is a marine phanerogam endemic of the Mediterranean Sea that grows all along the coast forming extensive meadows[36]. Every year, mostly in the fall, posidonia leaves senesce and detach off the rhizomes so that, in many areas, very conspicuous wedge-shaped deposits of posidonia debris are beached along vast areas of the coast ranging from a few centimeters in the water to several meters inshore[37]. The large volumes of the beached plant residues along the Mediterranean coasts in Italy represent a serious concern for the local authorities for a number of environmental, social, and economical implications[38, 39]. Common Italian laws consider these plant biomasses as a special kind of solid waste material to be disposed into landfills, thus resulting in an enormous loss of organic materials, nutrients, and useful biomolecules[40], with additional problems associated with their transport in landfills[41]. Previous studies have demonstrated that posidonia residues-based compost showed positive chemical features and the absence of phytotoxicity phenomena [40, 42,43], and has been used in horticulture for greenhouse tomato [41, 44-46] and lettuce[45,46] cultivation, and for nursery production[47].

Ocimum basilicum L., known as sweet basil, has been used as indicator crop in relation to its high economic value and its importance for greenhouse production. A previous research showed that it may be used as a good indicator of the adverse effects of various environmental signals to plants, including high concentrations of trace metals in composts[48].

The objectives of the present study were: i) to ascertain the potential use of green compost substrates as growing media for fresh market sweet basil production, without any problem of metal accumulations, and ii) to evaluate, from the agronomical and environmental point of view, the posidonia based compost as component for growing media in comparison to a commercial green compost and peat.

Experimental

Commercial green compost (GC) was produced by Progeva s.r.l. composting plant (Laterza, Italy), using urban pruning and yard trimmings residues (100%), while posidonia-based compost (GCP) was obtained by mixing 20% beached posidonia residues (on a fresh weight basis) and 80% green urban wastes (pruning and yard trimmings residues). The mixtures were prepared respecting the microbial requirements of compost in terms of carbon/nitrogen (35 to 45) and moisture content (55 to 65%). Composting process took place in a pile (1.5 m of height and 3 m of diameter); the temperature of the windrow was kept > 55 °C for at least three days, by turning and irrigating the piles periodically to obtain the pasteurization of the biomass. The active phase of composting was considered completed after four weeks, when the temperature of the pile decreased naturally to a value less than 40 °C. The curing phase was characterized by less frequent turning and continued until the 90th day to achieve further stabilization and obtain the final product[49].

The two composts obtained were then sieved at 1 cm.

The peat used as a component of the potting mixtures was a commercial growing substrate (Brill Type 3 Special, mix of different peats added with 1 kg m^{-3} PIG-MIX 14N–16P–18K fertilizer).

The trial was conducted in a plastic (polymethacrylate) greenhouse located in Mola di Bari ("La Noria" experimental farm of the CNR–ISPA 24 m a.s.l.; 17'04°E, 41'03°N), under controlled temperature, and using sweet basil (*Ocimum basilicum* L., cv. Italian large leaf) as indicator plant.

Nine growing media were prepared by mixing GC and GCP, each in different proportions [30, 50, 70 and 100% (v:v)], with the commercial peat. A control treatment, consisting only of pure peat, was also included. In Table 1 are summarized all the treatments considered in this study. The experimental treatments were assigned in a fully-randomized design with three replications for each treatment and five pot per replication. The seedlings were produced in polystyrene plug trays (160 cells per tray with diameter of 2.5 cm and volume of 21 mL) filled with peat. The seeds were five per cell and covered with vermiculite. Two days after emergence, the number of plants was reduced to one seedling per cell. After growing in conventional plug trays for 12 days, four seedlings for pot were transferred into diameter plastic container (0.5 L) filled with each of the nine growing media.

Plants were grown for 21 days on bench and fertirrigated daily with one drip per pot (2 L h^{-1}) with nutrient solution containing (mM) 144 N (116 NO_3^-+27 NH_4^+), 46 P_2O_5, 200 K_2O, 179 CaO, 64 MgO, 86 SO_4, 1.12 Fe, 0.24 Cu, 0.032 Mn, 0.131 Zn, 0.27 B, and 0.05 Mo, and maintaining pots moisture near the field capacity for each treatment.

The nine growing media were sampled and analyzed at the beginning of the experiment, measuring the electrical conductivity (EC) and the pH value on water-soluble extract or suspension (1:5, v:v) according to European Standard 13038[50] and European Standard 13037[51], respectively. Dry bulk density (BD) was determined according to the European Standard 13041[52]. The growing media also were characterized for total Kjeldahl nitrogen and total phosphorous (Olsen method) according to the Italian Official Methods of Fertilizers Analyses[53]. The major (K, Ca, Mg, Na), metal and trace elements (Fe, Cu, Mn, Ni, Zn, B, Cd, Co, Cr, Pb) in the growing media at the beginning of the experiment were extracted by a microwave assisted digestion (Multiwave Perkin Elmer 3000, Walthman, USA) using a suprapure HNO_3:H_2O_2:HCl mixture (6:1:1), and successively quantified by inductively coupled plasma optical emission spectrometer (ICP-OES iCAP 6000, Thermo Scientific, Walthman, USA).

At the end of the experiment, when the plants reached the commercial size for fresh market, four pots were harvested at random for each treatment and replication, in order to determinate total plant fresh weight (FW), plant height (H), leaf number, and leaf area (LA). Soil Plant Analysis Development (SPAD) index was also measured with a chlorophyll meter (Konica Minolta Spad 502, Tokyo, Japan) on five leaves per plant. Successively, aerial part of plants was dried in a thermo-ventilated oven at 65 °C until reaching a constant mass, in order to measure the dry weight (DW) and dry matter (DM), and then ground through a mill (IKA, Staufen, Germany) with a 1mm sieve for chemical analysis. In particular, shoot tissues were characterized for total nitrogen, total phosphorous, major, metal and trace elements as previously described.

Treatment means were compared using orthogonal contrasts with one degree of freedom[54]. Six comparisons were made: (i) peat *vs* the eight based-compost substrates; (ii) GC-based *vs* GCP-based growing media; (iii) the linear trend in the four GC-based growing media; (iv) the quadratic trend in the four GC-based growing media; (v) the linear trend in the four GCP-based growing media; and (vi) the quadratic trend in the four GCP-based growing media. Data were subjected to the general linear model procedure[55].

Results and discussion

The pH and EC values of growing media containing either compost were higher than peat, raising linearly with increasing compost percentage in the growing medium (Table 2). In particular, higher values of pH were observed with the addition of GC, whereas higher values of EC were observed with the addition of GCP, probably due to the marine origin of the posidonia residues. The pH increased with the proportion of composts in the growing medium, in accordance with previous experiments on posidonia based compost[41-43] or compost in general[12], in relation to the presence of alkaline elements (Ca, Mg, and Na) despite peat (Table 2). In all cases, BD values of all substrates were below the maximum value (0.4 g cm^{-3}) established for an ideal substrate[56, 57]. It increased linearly with increasing of the percentage of GC in the growth medium, whereas an opposite trend appeared in the case of GCP. Bulk density provides a good indication of the porosity of the growing medium, which determines the rate at which air (oxygen) can move through the substrate[58].

All macro and micro-element concentrations were positively and significantly affected by the presence of composts in the media (Table 2), so suggesting that compost is a good source of mineral nutrients for plants[1]. GC and GCP heavy metal (Cd, Co, Cr and Pb) content was significantly higher than peat too. In particular, GCP showed an higher content of Ca, Mg, Na, B and Cd than GC, whereas an opposite trend was shown for all the other elements. In particular, the great difference in B content between the two composts used, could be reasonably ascribed to the high concentration of this element in posidonia debris[49], and to the presence of borosilicate coming from the sand residues.

GCP-based substrates had a lower concentration of Co, Cr, and Pb than GC ones, probably in relation to their relative content in posidonia residues. The differences observed in the composition of the growing media were probably related to the different nature and origin of compost matrices (Table 2) in particular for the presence of posidonia residues.

Biometric characteristics and SPAD values of basil grown on the different growing media are reported in Table 3. In general, basil plants grown on peat showed higher FW, DW and LA than those grown on compost mixtures, whereas an opposite trend was shown for SPAD values. With increasing of both composts percentage in the mixtures, significant reduction in the FW (linear) and DM (quadratic) of plants were observed. Height, number and area of leaves, and SPAD linearly decreased with higher percentage of compost in the mixtures. All the parameters analyzed in basil plants were higher in the mixtures with GCP than to those with GC. The use of compost as an alternative or a complement to peat for basil production showed the best results at the rates of 30%. This result is in accord with several previous studies. In particular, Manios[59] measured an increasing growth of various plants using a mixture of peat and compost from solid waste at 30% (v:v), whereas showed phytotoxic effects on root and shoots growth at higher doses of compost. Grigatti et al.[11] found the best results in terms of dry weight of some bedding plants, when compost was added in the growing media at rates from 25 to 50%. Loffredo and Senesi[60] and Loffredo et al.[61] demonstrated that a partial (20%, v:v) replacement of peat with compost enhanced the health and vegetative status of the ornamental plants (impatiens and China aster and philodendron, respectively). Mininni et al.[46] showed that, in growing media for lettuce seedlings production, posidonia-based compost could be used as a complement to peat at a rate of 25 or 50%, whereas for melon and tomato seedlings production the optimal dose of posidonia-based compost was 20% [46, 62].

Table 4 shows the effects of growing media studied on the elemental composition of basil shoot tissues. Plant grown on peat showed higher content of P, Ca, Mn, Fe and Ni, than those obtained on compost based growing media; micronutrients availability was probably reduced from higher pH levels in compost based growing media as observed from Pérez-Murcia et al.[22]. Plants obtained on compost based growing media had lower uptake of Cd and Cr than peat; this is probably ascribed to the greater presence of humic acid in composts that decreases plant uptake due to formation of complexes with metal [63, 64]. Between the two compost based growing media (GCP and GC), plants grown on GCP had an higher content of N, Ca, Mg, and Na, while those cultivated on GC had a greater content of K and microelements (Mn, Cu, Fe, Ni, and Zn) (Table 4) in relation to their content of the respective substrates (Table 2).

As results from other experiments, plants grown on posidonia compost based substrates had a greater content of B, without any symptom of toxicity[44, 62].

Conclusions

In general, the two compost based substrates showed suitable physical and chemical properties, and high macro and micro nutrient contents, so hoping for their use as a partial substitutes of peat in potting cultivation, especially at the rate of 30%. The two compost based substrates could be used without problem of metal accumulation in basil cultivation showing, instead, a reduction of absorption levels compared to the peat. Posidonia-based compost could be used as a partial substitute to peat in basil cultivation with a reduction of the input of mineral nutrients for its natural endowment. In addition, basil plants grown on posidonia-based compost showed better productive parameters (FW, LA and SPAD) and lower metals content than those grown on green compost. Through composting of posidonia residues, the problem of their disposal could be partially resolved; in addition, also the use of peat, that is a non-renewable resource, as substrate for growth of plants in pots could be reduced. In conclusion, these results encourage the use of composted posidonia residues as partial substitute of peat in potting cultivation, so reducing the problems derived from their accumulation near the coast and their disposal in landfills.

Acknowledgements

This work has been supported by grant to Dr. Carlo Mininni from Apulia Region "Futuro in Ricerca" P.O. PUGLIA per il FSE 2007 – 2013 Asse IV. The authors want to thank the composting company Progeva s.r.l. (Laterza, Italy) for technical support.

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Table 1. Composition of the growing media tested

Substrate*	**Composition (% volume)**
Peat	Peat 100%
GC30	GC (30%) + Peat (70%)
GC50	GC (50%) + Peat (50%)
GC70	GC (70%) + Peat (30%)
GC100	GC (100%)
GCP30	GCP (30%) + Peat (70%)
GCP50	GCP (50%) + Peat (50%)
GCP70	GCP (70%) + Peat (30%)
GCP100	GCP (100%)

* P: peat; GC: commercial green compost; GCP: posidonia based compost.

Table 2. Physical and chemical characteristics of the substrates used in the experiment

Substrates	**BD**	**pH**	**EC**	**N**	**P**	**Ca**	**K**	**Mg**	**Na**	**Fe**	**Cu**	**Mn**	**Ni**	**Zn**	**B**	**Cd**	**Co**	**Cr**	**Pb**
	(kg m^{-3})		**(dS m^{-1})**	**(g kg^{-1})**							**(mg kg^{-1})**								
Peat	0.220	5.75	0.55	1.03	1.41	22	1.27	1.59	0.28	1.13	6.7	72	5.0	9	14	0.07	0.49	1.37	2.6
GC30	0.281	6.67	0.71	1.17	2.95	27	5.9	2.8	2.01	4	32	156	28	68	22	1.39	2.82	18	25
GC50	0.322	7.33	0.88	1.35	3.43	39	9.5	4.7	2.96	7.3	50	244	52	114	35	1.94	5.50	45	34
GC70	0.332	7.57	1.19	1.38	4.45	44	10.8	5.5	3.4	8.3	53	279	55	113	44	2.15	5.69	78	47
GC100	0.365	8.44	1.44	1.52	6.02	46	14.1	5.9	3.9	9.6	66	324	38	134	49	2.64	6.43	76	45
GCP30	0.242	6.39	1.15	1.13	2.74	46	3.9	4.4	2.8	2.9	33	151	8	49	269	1.32	1.42	11	11
GCP50	0.221	6.68	1.55	1.24	3.45	53	5.4	5.5	3.5	3.9	45	184	11	74	322	1.89	2.33	18	17
GCP70	0.218	7.12	1.86	1.36	3.77	63	6.8	6.6	4.8	4.8	51	200	21	96	477	2.62	2.95	28	19
GCP100	0.194	8.18	2.05	1.44	4.53	75	8.1	9.1	5.5	5.6	64	230	29	125	709	3.36	3.72	36	22
Contrast[†]																			
Peat *vs* others	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
GC *vs* GCP	***	***	***	***	ns	***	***	***	***	***	ns	***	***	***	***	**	***	***	***
GC lin	***	***	***	***	***	***	***	***	***	***	***	**	ns	***	ns	***	***	***	***
GC qua	Ns	ns	ns	***	ns	***	***	***	***	***	*	**	**	***	ns	ns	***	***	**
GCP lin	***	***	***	***	*	***	***	***	***	***	***	***	*	***	***	***	***	***	**
GCP qua	Ns	***	ns	***	ns	ns	**	***	***	*	ns	Ns	ns	ns	**	ns	ns	ns	ns

BD=bulk density; EC=electrical conductivity; N = nitrogen; P= phosphorous; K = potassium; Ca = calcium; Mg = magnesium; Na = sodium; Cu = copper; Mn = manganese; Ni= nickel; Zn = zinc; B = boron Fe = iron; Cd= cadmium; Co= cobalt; Cr= chromium; Pb= lead.

[†] Significant at the 5% (*), 1% (**) or 0.1% (***) level of probability or not significant (ns).

Table 3. Shoot parameters of the basil grown on the nine growing media with increasing green compost (GC) and posidonia-based compost (GCP) percentage.

Substrate	**FW (g plant^{-1})**	**DW (g plant^{-1})**	**DM (g 100 f FW^{-1})**	**H (cm)**	**Leaf (n)**	**LA (cm^2 plant^{-1})**	**SPAD**
Peat	6.52	0.50	7.73	19.8	8.4	14.1	25.0
GC30	5.10	0.40	7.80	18.8	8.4	11.7	29.2
GC50	4.36	0.33	7.57	18.6	8.0	10.1	25.9
GC70	3.57	0.29	8.00	16.0	8.0	11.6	27.7
GC100	2.57	0.18	7.00	12.2	6.5	9.4	28.1
GCP30	6.08	0.50	8.31	20.6	8.3	13.8	29.4
GCP50	5.45	0.44	8.12	19.4	8.5	12.4	30.2
GCP70	5.64	0.47	8.31	20.8	8.3	13.4	29.2
GCP100	4.91	0.36	7.36	18.2	8.4	11.7	28.8
Contrast †							
Peat *vs* others	***	***	ns	ns	ns	***	***
GC *vs* GCP	***	***	***	***	**	***	**
GC lin	***	***	**	***	***	**	ns
GC qua	ns	ns	**	ns	ns	ns	*
GCP lin	*	***	***	ns	ns	ns	ns
GCP qua	ns	ns	*	ns	ns	ns	ns

FW=fresh weight; DW=dry weight; DM=dry matter; H=plant height; Leaf= leaf number; LA=leaf area; SPAD=Soil Plant Analysis Development

† Significant at the 5% (*), 1% (**) or 0.1% (***) level of probability or not significant (ns)

Table 4. Shoot tissues mineral concentration (on dry matter basis) of the basil plants grown on nine growing media with increasing green compost (GC) and posidonia-based compost (GCP) percentage.

Substrates	**N**	**P**	**Ca**	**K**	**Mg**	**Na**	**Cu**	**Mn**	**Ni**	**Zn**	**B**	**Fe**	**Cd**	**Co**	**Cr**	**Pb**
	(g kg^{-1})						**(mg kg^{-1})**									
Peat	4.08	13.85	21.4	48.5	5.3	0.96	5.8	128	5.1	54	27	103	0.16	0.08	1.41	0.64
GC30	3.92	9.25	17.3	53.3	5.7	1.33	10.3	72	0.3	72	22	78	0.05	0.08	0.45	0.70
GC50	3.96	7.63	14.9	57.3	5.3	1.81	13.0	60	0.0	77	24	75	0.02	0.14	0.33	0.82
GC70	4.07	6.68	12.6	53.4	5	2.56	12.3	67	9.0	75	24	67	0.00	0.14	0.35	0.48
GC100	3.70	5.55	11.9	59.5	5.1	4.9	15.0	98	5.9	89	27	82	0.01	0.17	0.35	0.76
GCP30	3.97	8.24	16.4	51.8	5.6	1.63	6.6	30	0.0	48	26	73	0.00	0.03	0.60	0.46
GCP50	4.12	7.95	16	52	5.7	1.86	8.0	25	1.0	53	30	76	0.02	0.03	0.36	0.44
GCP70	4.16	6.79	14.1	50.4	5.4	2.77	8.9	22	3.2	56	30	63	0.00	0.05	0.30	0.53
GCP100	4.20	7.29	16.3	51.7	6.7	2.82	12.7	22	3.4	74	39	69	0.01	0.03	0.31	0.53
Contrast [†]																
Peat *vs* others	ns	***	***	***	ns	***	***	***	ns	**	ns	***	***	ns	***	ns
GC *vs* GCP	***	ns	***	***	***	ns	***	***	ns	***	***	ns	ns	**	ns	ns
GC lin	**	***	***	***	**	***	***	***	**	*	*	ns	ns	ns	ns	ns
GC qua	*	ns	**	ns	ns	*	ns	***	*	ns	ns	*	ns	ns	ns	ns
GCP lin	*	ns	ns	ns	***	**	***	ns	ns	***	***	ns	ns	ns	ns	ns
GCP qua	ns	ns	**	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

N = nitrogen; P= phosphorous; K = potassium; Ca = calcium; Mg = magnesium; Na = sodium; Cu = copper; Mn = manganese; Ni= nickel; Zn = zinc; B = boron Fe = iron; Cd= cadmium; Co= cobalt; Cr= chromium; Pb= lead.

[†] Significant at the 5% (*), 1% (**) or 0.1% (***) level of probability or not significant (ns).