https://doi: 10.17221/1/2017-HORTSCI

Heterogeneous response of two bedding plants to peat substitution by two green composts

Daniele Massa*, Domenico Prisa, Sara Lazzereschi, Sonia Cacini, Gianluca Burchi

CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Research and Economics, Pescia, Italy

**Corresponding author: daniele.massa@crea.gov.it*

Abstract

Massa D., Prisa D., Lazzereschi S., Cacini S., Burchi G. (2018): Heterogeneous response of two bedding plants to peat substitution by two green composts. Hort. Sci. (Prague), 45: 164–172.

The promotion, at local level, of resource recycling chains, with low environmental impact and costs, appears of great interest for the production of green composts to replace peat in ornamental crops. In this work, two green composts, differing for the criterion of raw material selection for composting, were tested for the cultivation of two bedding plants in comparison with 100% peat based substrate. Leaf chlorophyll (SPAD index), biometric and growth parameters, and tissue mineral composition were measured to assess growing media-plant system performances. Both growing media and plants gave heterogeneous responses depending on substrate characteristics and plant requirements and/or tolerance to abiotic stress. Plant biomass was reduced by 63% (on average) in the most sensitive species due to the high Cl concentration detected in one of the two green composts; a similar trend was observed for SPAD index. The results support the shared idea that the selection of raw material is a strategy of primary importance in the composting process to obtain high quality green compost.

Keywords: *Impatiens hawkeri*; *Petunia × hybrida*; growing media; SPAD chlorophyll; chloride toxicity

Peat is an ideal substrate for its physicochemical characteristics that are optimal for the cultivation of many plant species (Sonneveld, Voogt 2009; Raviv 2013). Nevertheless, peat extraction from bog wetlands is arising more and more concerns related to many environmental issues (Cleary et al. 2005; Raviv 2013). Therefore, a new generation of peat-free growing media is emerging; among all, green compost is one of the most promising alternatives (Raviv 2013), especially if the added value of its production chain is taken into consideration.

The production of growing media by green refuse composting represents one of the most worthwhile strategies for peat substitution since it implies the promotion, at local level, of resource recycling chains, which show low environmental impact (Raviv 2013; Lazzerini et al. 2016). Life cycle analyses show that peat, together with plastic, represents one of the major factors increasing gas emissions in potted plant production (Warner et al. 2010; Lazzerini et al. 2014). Conversely, it has been estimated that gas emissions related to compost are significantly lower when compared with peat and coir in container productions (Lazzerini et al. 2016). Furthermore, the use of growing media based on green compost can lead to a significant reduction of production costs (e.g. due to the disposal of green refuse) and give an added value for

Supported by the Tuscany Region (Italy) as part of the "Subinnova" project.

https://doi: 10.17221/1/2017-HORTSCI

nursery produces (Mininni et al. 2012; De Lucia et al. 2013); for example, to receive the "Ecolabel" from the European Commission growing media can not contain peat while the reuse of organic waste for cultivation purposes is encouraged.

The creation of local chains for re-use of green waste can be considered strategic since it can ensure availability of growing media from renewable and local low-cost sources (Mininni et al. 2012). A local survey, conducted by CREA (Council for Agricultural Research and Economics) in the nursery district of Pistoia (Tuscany, Italy) province (one of the biggest area for nursery production in the EU zone), showed that roughly 75 m^3/ha per year of green waste could be available depending on cropping system; other authors report even much higher (i.e. 140 m^3/ha) volumes (Newman 2014). Taking into consideration a mean reduction volume of 45% during composting process (depending on the raw material) and the total volume of growing media required for the cultivation of different species in the same area, it has been estimated that up to 80% of peat could be replaced, on average, by green compost produced at local level using nursery green waste.

Green waste derived by pruning and production scraps can generally be burnt, in open disposal areas, or landfilled (Newman 2014). However, the first practice is subjected to several restrictions (depending on local regulations) and creates undesired atmospheric emissions of carbon dioxide (CO_2). For example, assuming a mean volumetric mass of 0.5 t/m^3 and water content ranging 80–40% in nursery plants, about 1,540 t/ha of CO_2 would be produced per year by burning 75 m^3/ha green refuse as above estimated. On the other hand, green waste landfill may increase drastically the risk of spreading plant pathogens and can compromise the agronomic fertility of soils. Alternatively, green waste must be disposed as "special" incurring additional costs (Newman 2014).

Up to now, major uncertainty among nursery growers in the use of compost as a growing medium derives from the difficulty of having standardized characteristics. Also, green composts may contain heavy metals and pathogens that have detrimental effects on product yield and quality (De Lucia et al. 2013). However, the re-use of green waste deriving from nursery or other tracked local sources can ensure a direct control of the raw materials used in composting processes, which is a key factor to obtain high-quality standardized green composts (Raviv 2013).

In the present work, two different locally produced green composts were evaluated as peat substitutes on two bedding plants. The main objectives of the work were: (i) to assess the performance of green composts derived from selected and non-selected green refuse; (ii) to evaluate whether the raw material can provide high quality green compost with stable physicochemical characteristics; (iii) to evaluate the plant response to growing media under commercial greenhouse growing conditions.

MATERIAL AND METHODS

Two green composts, which differed for the raw material collected for composting, were tested in the experiment. In one case, only greenhouse and nursery green waste was used to obtain the "selected-green compost" (SC). The second compost (mixed-green compost, MC) was obtained by green refuse from different cultivation systems, public and private green areas, and heterogeneous environments including urban, peri-urban and coastal areas. The composting process followed high quality procedures. Trapezoidal piles of raw material were composted until maturation (about six months); temperature and humidity (55–65%) were monitored to ensure optimal conditions for microbial metabolism. Laboratory analyses, performed at the end of the composting process according to UNI 10780 (1998), provided the following results for SC and MC compost, respectively: humidity 2.56 and 1.73 g/kg, N 0.18 and 0.26 g/kg, C 0.22 and 0.28 g/kg, C/N 12.6 and 10.9, humic and fulvic acids 1.42 and 0.76 g/kg, pH (1:10) 7.6 and 7.5, electrical conductivity 264 and 322 μs/cm, Na 1.05 and 2.49 g/kg, Cl 1.21 and 3.47 g/kg, Cd < 0.25 mg/kg, Cr < 0.25 mg/kg, Hg < 0.10 and 0.11 mg/kg, Ni 36.9 and 44.6 mg/kg, Pb 48.1 and 15.9 mg/kg, Cu 128.3 and 62.0 mg/kg, Zn 177.2 and 144.9 mg/kg, *Salmonella* absent, *Escherichia coli* < 10 CFU/g. The analysed parameters did not exceed Italian regulations (D. Lgs. No. 75, 29 April 2010).

Five different treatments tested in the experiment were: (i) 100% peat (PC) chosen as standard (control) substrate in bedding plant production; (ii) 30% peat volume replaced by selected-green compost (SC30); (iii) 50% peat volume replaced by selected-green compost (SC50); (iv) 30% peat volume re-

https://doi: 10.17221/1/2017-HORTSCI

placed by mixed-green compost (MC30); (v)) 50% peat volume replaced by mixed-green compost (MC50). Physicochemical characteristics (Table 1) of substrate mixtures were assessed as follows. Total N and C content were measured on a dry matter basis (EN 13654-1:2001 and EN13137:2002, respectively); other chemical parameters were analysed in the 1:5 (V/V) substrate:water extract: i.e. pH (EN 13037:1999), EC (EN 13038:1999), $N\text{-}NO_3$, $P\text{-}PO_4$, K, Ca, Mg, Fe, Na, and Cl (EN 13652:2001).

The experiments were conducted in a commercial glasshouse located in Torre del Lago Puccini, Tuscany, Italy (lat. 43°54'N, long. 10°16'E), under typical Mediterranean climate conditions of coastal areas. New Guinea Impatiens (*Impatiens hawkeri* W. Bull) Paradise® Series 'Papete' (hereinafter *Impatiens*) and *Petunia*×*hybrida* Surfinia® 'Hot Red' (hereinafter *Petunia*) were transplanted into 1.5-liter pots (Ø 14 cm) on 14 March 2014 and arranged in a randomized block design with three replicates for each species, eight plants per replicate (24 plants per treatment), for a total of 240 pots. Plants were irrigated intermittently with nutrient solution and managed according to growers' standard practices ensuring that all plants were treated the same apart from the growing media.

The experiment lasted 70 days until plants development reached standard level for commercial purposes. At the end of the experiment all plants were subjected to destructive analysis for the determination of flower, leaf and stem fresh and dry weight (after drying in a forced-air oven at 80°C for 72 h), and flower number. SPAD index was measured on six leaves pinched from the bottom to the apex of the canopy of each plant (for a total of 144 measurements per treatment). Tissue mineral content was evaluated on collected dry matter as follow. Reduced N was determined through Kjeldahl distillation after dry matter digestion with sulphuric acid. Dry matter was then subjected to nitric-perchloric acid digestion to determine: (i) P content through colorimetric method using a spectrophotometer; (ii) K, Ca, Mg, Fe and Na content through atomic absorption spectrophotometry. Finally, Cl content was determined by means of titration with mercury nitrate after dry matter water extraction.

One-way analysis of variance (ANOVA) was performed on all collected data to assess significant ($P \le 0.05$, 0.01 and 0.001) differences among treatments. Statistics and graphics were supported by the program Statgraphics Centurion XV (Stat Point, Inc., USA).

RESULTS

Compost physical and chemical properties

The presence of the two green composts, in the tested substrates, did not influence severely the physical characteristics of the growing media in comparison with the 100% peat control substrate (data not shown). Slight, although significant, reductions could only be found for water container capacity and total porosity (–13%, on average) while no significant difference was detected for other essential parameters such as easily available water and water buffering capacity. On the other hand, the presence of the two composts changed significantly the chemical properties of the root zone (Table 1).

In general, all nutrient ions were significantly increased by the selected-green compost while only organic N, and mineral P, K and Fe, in the water extract, were found increasing by the addition of the mixed-green compost compared with peat control substrate (Table 1). However, the most remarkable differences were observed for K in 50% compost replacement (up to 3.2 folds higher, on average) if compared with 100% peat substrate. On the other hand, both composts increased significantly the presence of saline ions (i.e. Na and Cl) in the root zone (Table 1), especially Cl for the mixed-green compost, which reached values up to 5.9 folds higher than the peat control substrate. Electrical conductivity increased in the water extract compost treatments as expected due to its correlation with cation concentrations in the root zone (Sonneveld, Voogt 2009). The same increase was observed for pH.

Plant responses

Plant response to the different treatments differed for plant species and compost type. The selected-green compost has no effect on biomass accumulation (Fig. 1) and partitioning (Table 2) for both *Petunia* and *Impatiens*, which showed data comparable to those obtained for the peat control substrate. The same trend was observed for the

https://doi: 10.17221/1/2017-HORTSCI

Table 1. Chemical characterization of the different growing media mixtures. Total nitrogen (N) and carbon (C) are expressed as concentration in the dry weight (g/100g) whereas pH, electrical conductivity (EC, µS/cm), and nutrient ($N-NO_3$, $P-PO_4$, K, Ca, Mg and Fe) and saline ions (Na and Cl) concentrations (mg/l) were measured in the 1:5 (V/V) water extract

Treatment	N	C	C/N	pH	EC	$N-NO_3$	$P-PO_4$	K	Ca	Mg	Fe	Na	Cl
PC	0.98^{b}	37.85^{a}	38.55^{a}	5.99^{b}	177.07^{c}	1.43^{c}	1.82^{c}	21.27^{c}	16.01^{bc}	1.63^{c}	0.88^{b}	16.91^{b}	9.17^{d}
SC30	1.35^{a}	28.12^{bc}	21.15^{c}	6.68^{ab}	273.47^{ab}	17.24^{b}	2.72^{b}	50.81^{b}	19.49^{b}	5.13^{b}	0.96^{a}	22.30^{a}	15.50^{cd}
SC50	1.52^{a}	25.37^{c}	16.82^{d}	6.96^{a}	453.67^{a}	34.32^{a}	4.43^{a}	69.09^{a}	26.96^{a}	8.32^{a}	0.98^{a}	25.60^{a}	20.83^{c}
MC30	1.39^{a}	35.00^{a}	25.28^{b}	7.43^{a}	241.33^{b}	2.26^{c}	2.45^{bc}	47.24^{b}	12.47^{c}	1.96^{c}	1.96^{a}	22.35^{a}	38.50^{b}
MC50	1.52^{a}	30.57^{b}	20.09^{cd}	7.47^{a}	332.67^{ab}	2.48^{c}	2.69^{b}	68.40^{a}	11.63^{c}	2.25^{c}	2.25^{a}	25.51^{a}	54.00^{a}
ANOVA[a]	**	***	***	**	***	***	***	***	***	***	**	***	***

[a]one-way ANOVA; n.s. – non significant; *,**,*** – significant at $P \leq 0.05$, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ($P = 0.05$)

Table 2. Percentage of dry weight in Leaves, Stems, Flowers and Total (shoot) biomass, and respective organ to Total dry weight ratio (Le/Total, St/Total and Fl/Total, respectively) as determined at the final destructive analysis for *Petunia* and *Impatiens*

Treatment	*Petunia*							*Impatiens*						
	Leaves	Le/Total	Stems	St/Total	Flowers	Fl/Total	Total	Leaves	Le/Total	Stems	St/Total	Flowers	Fl/Total	Total
PC	8.75^{a}	0.39^{b}	10.93^{a}	0.50^{a}	9.52	0.11^{a}	9.82^{a}	10.78	60.23^{a}	6.29	28.82	8.34	10.95	8.67
SC30	7.64^{ab}	0.41^{b}	10.84^{a}	0.47^{ab}	9.62	0.12^{a}	9.13^{ab}	10.47	58.52^{ab}	5.80	26.95	8.07	14.52	8.29
SC50	7.24^{abc}	0.40^{b}	10.42^{a}	0.48^{a}	10.41	0.12^{a}	8.85^{ab}	9.82	60.33^{a}	5.00	25.46	7.39	14.21	7.59
MC30	6.24^{bc}	0.46^{ab}	9.35^{ab}	0.47^{ab}	12.17	0.07^{ab}	7.62^{bc}	9.82	55.11^{ab}	4.82	28.61	7.21	16.28	7.24
MC50	5.58^{c}	0.55^{a}	8.04^{b}	0.40^{b}	8.70	0.05^{b}	6.50^{c}	9.92	52.38^{b}	5.40	30.32	7.46	17.30	7.56
ANOVA[a]	**	**	**	*	n.s.	*	***	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.

[a]statistical analysis as described in Table 1

https://doi: 10.17221/1/2017-HORTSCI

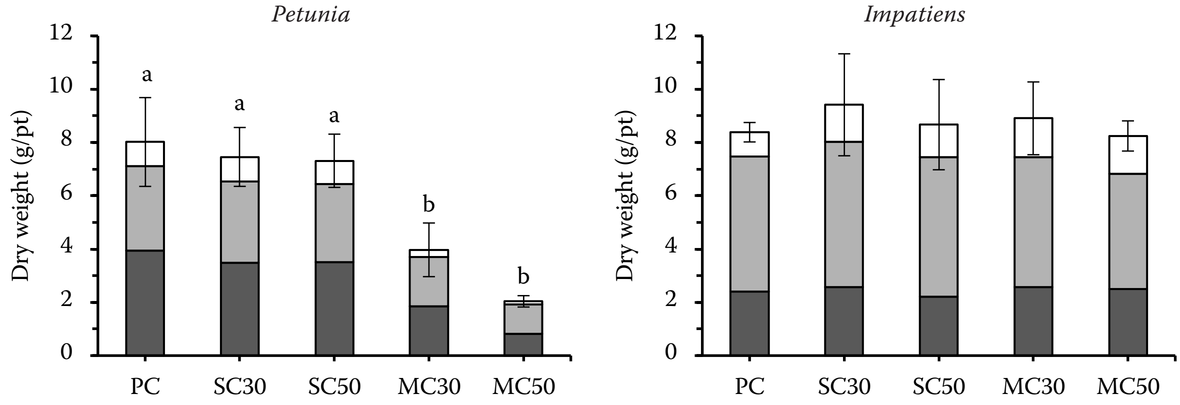

Fig. 1. Plant dry weight is reported for stems (dark grey), leaves (light grey) and flowers (white) as the average of three replicates ± SD; presence or absence of different letters means significant difference according to one-way ANOVA and Tukey's (HSD) multiple-range test (P < 0.05) or ii) not significant, respectively

number of flowers and SPAD index (Fig. 2). On the contrary, the mixed-green compost caused a remarkable reduction (63%, on average) in biomass accumulation of all organs in *Petunia* as compared with the peat control substrate (Fig. 1). Significant reductions were also observed for the percentage of dry weight in all organs of *Petunia*, with the exception of flowers, compared with the peat control substrate (Table 2). Only the 50% peat replacement by mixed-green compost resulted in a significant

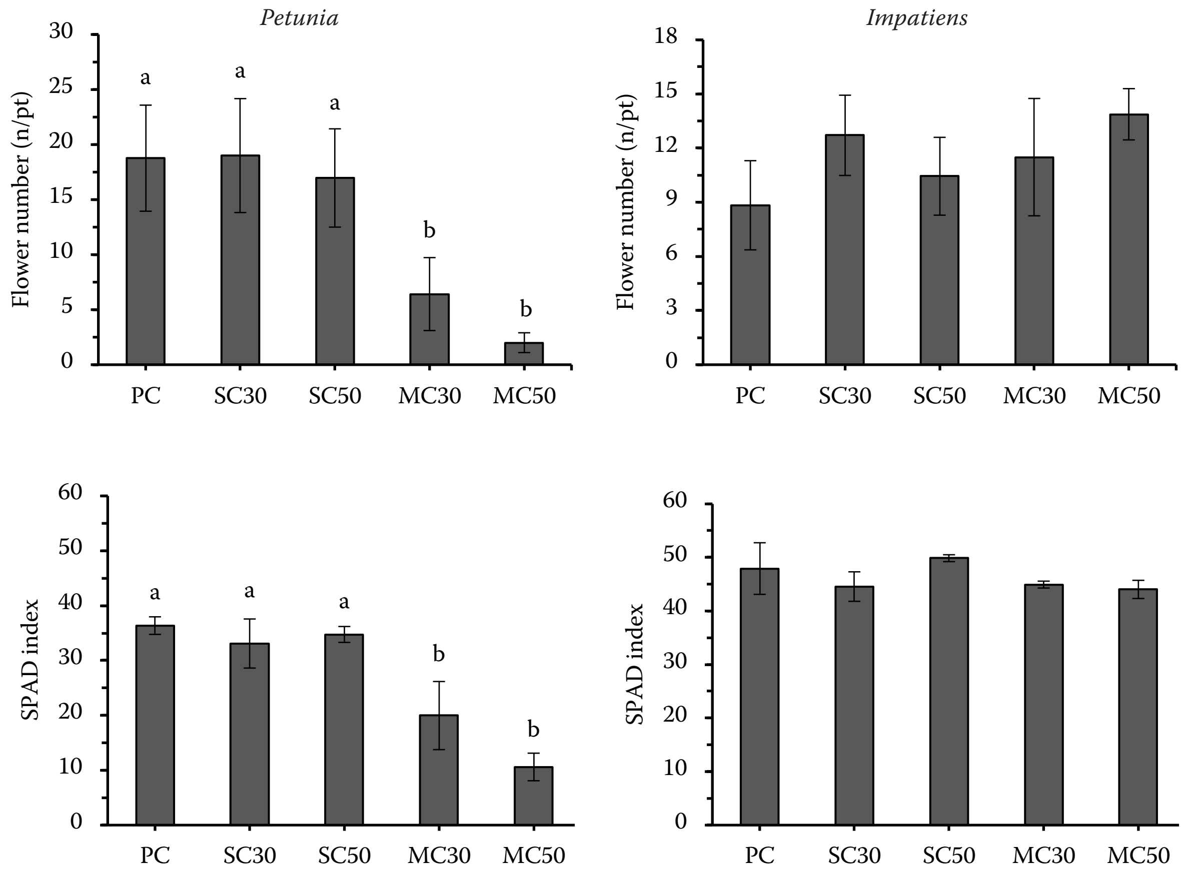

Fig. 2. Flower number and leaf chlorophyll (SPAD index) content are reported for *Petunia* and *Impatiens.* Columns represent the average of three replicates ± SD; presence or absence of different letters means significant difference according to one-way ANOVA and Tukey's (HSD) multiple-range test (P < 0.05) or not significant, respectively

https://doi: 10.17221/1/2017-HORTSCI

Table 3. Mineral concentration (g/kg) in the shoot dry matter of *Petunia* as determined at the final destructive analysis. Values represent the average of three replicates

Treatment	N	P	K	Ca	Mg	Fe	Na	Cl
PC	38.83^{a}	4.11	41.61^{b}	30.10	6.71	0.39	11.55^{a}	20.69^{d}
SC30	30.38^{b}	3.10	80.81^{a}	28.32	7.16	0.31	7.52^{c}	27.29^{cd}
SC50	33.74^{ab}	3.38	80.58^{a}	34.25	8.98	0.38	8.91^{bc}	33.25^{bc}
MC30	30.19^{b}	3.27	84.30^{a}	35.53	7.73	0.45	9.21^{abc}	41.91^{ab}
MC50	34.72^{ab}	3.40	91.48^{a}	32.15	8.44	0.48	10.18^{ab}	52.72^{a}
ANOVA^{a}	*	n.s.	***	n.s.	n.s.	n.s.	**	***

^{a}statistical analysis as described in Table 1

Table 4. Mineral concentration (g/kg) in the shoot dry matter of *Impatiens* as determined at the final destructive analysis. Values represent the average of three replicates

Treatment	N	P	K	Ca	Mg	Fe	Na	Cl
PC	25.70^{ab}	3.26	19.31^{b}	33.99^{a}	6.74	0.47	3.62^{a}	15.07^{b}
SC30	25.76^{ab}	3.03	32.61^{a}	28.63^{ab}	7.34	0.34	3.15^{ab}	16.90^{b}
SC50	28.05^{a}	3.21	33.46^{a}	26.21^{ab}	7.41	0.42	2.49^{b}	15.51^{b}
MC30	21.98^{b}	2.55	34.30^{a}	25.85^{ab}	6.45	0.38	3.48^{a}	25.27^{a}
MC50	23.24^{b}	2.14	44.73^{a}	21.51^{b}	6.75	0.58	3.04^{ab}	28.19^{a}
ANOVA^{a}	*	n.s.	*	*	n.s.	n.s.	**	***

^{a}statistical analysis as described in Table 1

$$y = \begin{cases} 7.60 & \text{if} \quad x \le 18.03 \\ -0.16x + 10.48 & \text{if} \quad 18.03 < x < 65.56 \\ 0 & \text{if} \quad x \ge 65.56 \end{cases}$$

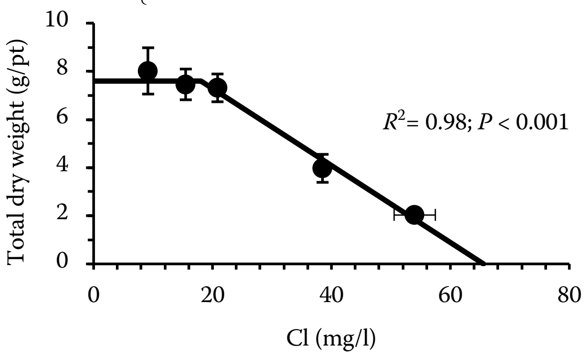

Fig. 3. Maas and Hoffman (1977) model fitted on total (shoot) dry weight of *Petunia*. Circles represent the average of measured data ± SE; the continuous line represents data fitting

variation in biomass partitioning that showed reduced ratios for stems and flowers and increased leaf biomass compared with peat control substrate (Table 2). However, effects observed in *Petunia* were not detected for *Impatiens*, which showed no significant variation in all the above described parameters among the different treatments (Figs 1 and 2 and Table 2). A negative correlation was observed between the increase of Cl in the root zone (Table 1) and *Petunia* total biomass accumulation (R = –0.92, P < 0.001, n = 15); similar patterns were also observed for the number of flowers and SPAD chlorophyll (Fig. 2).

The presence of compost in the tested substrates influenced tissue mineral concentration in both *Petunia* and *Impatiens* plants with the exception of P, Mg and Fe that did not vary significantly among treatments (Tables 3 and 4). Tissue N content showed an unclear pattern: only SC30 and MC30 resulted in reduced values, as compared with the peat control substrate, only in *Petunia* plants (Table 3). Calcium was instead the only nutrient significantly reduced by MC50 treatment but only in *Impatiens* plants. Potassium showed a general tendency to increase in plant tissues of all compost treatments and both plant species (Tables 3 and 4); it was likely due to the increased availability for this element in

https://doi: 10.17221/1/2017-HORTSCI

the root zone caused by the presence of compost (Table 1). Sodium concentration in plant tissue was generally reduced by the presence of compost in the growing medium (Table 3 and 4). On the contrary, a significant positive correlation was found between tissue Cl content and substrate Cl concentration of both *Petunia* (R = 0.93, P < 0.001, n = 15) and *Impatiens* (R = 0.90, P < 0.001, n = 15) plants (Tables 1, 3 and 4). The possible toxic effects of Cl on plant performance were evaluated by the Maas and Hoffman (1977) model although a significant relationship (R^2 = 0.98; P < 0.001) between total shoot biomass and Cl concentration in the root zone could only be observed for *Petunia* (Fig. 3).

DISCUSSION

The addition of compost to growing media typically increases pH in the root zone. Although this effect is seen as one of the major drawbacks in the use of composts for peat replacement (Sonneveld, Voogt 2009; Larcher et al. 2011), as matter of fact, it can be easily corrected with the acidification of irrigation water, especially if microirrigation system is adopted (Chong 2005).

On the other hand, the enhanced availability of nutrients, caused by the addition of composts in the root zone, has been reported by other authors and can represent a source of nutrient elements to reduce the supply of chemical fertilisers in potted plants (Martínez-Blanco et al. 2013).

In general, the addition of compost to growing media improves plant nutrition of ornamental crops (De Lucia et al. 2013; Raviv 2013). However, in the present study only K showed a defined pattern in tissue accumulation since it increased significantly in all treatments for both species in comparison with peat substrate; such an effect was also observed by other authors for bedding plants (Grigatti et al. 2007). The higher K intake may help plants to limit the passive absorption of Na (Massa et al. 2009) although also decrease in Ca concentration can occur in such a condition (Li et al. 2013). Some of these effects can be recognized in Table 3 and Table 4 where plants grown in selected-green compost showed lower tissue Na concentration while plants grown in the mixed-green compost showed lower Ca concentrations. Reduced Na uptake has been associated with the presence of compost in pot-grown plants (Fiasconaro et al. 2015).

The addition of mixedgreen compost in the root zone negatively affected plant biomass accumulation, flower number and SPAD index of *Petunia*. The latter two parameters are of great interest for the marketing of bedding plants; in fact, flower number and biomass can have a strong impact on produce appearance while SPAD chlorophyll measurements are correlated to leaf greenness and have been proposed to evaluate the quality of ornamental species (Loh et al. 2002). The poor performance of mixed-green compost in the cultivation of *Petunia* was probably due mainly to the high concentration of Cl in the root zone, which in turn determined high tissue Cl content. Ornamental plants usually show larger tissue Cl accumulation due to increased external Cl concentration with detrimental effects on plant yield and quality (Cai et al. 2014; Breś et al. 2016).

Symptoms of excess Cl are similar to salt toxicity with reduced plant development and diffused leaf chlorosis (Barker, Pilbeam 2007). Cai et al. (2014) observed reduced photosynthetic efficiency and biomass accumulation in rose plants grown under salinity and showing high accumulation of Cl in leaves while both chlorophyll content and photosynthetic efficiency were found decreasing by increasing substrate Cl concentration in geranium cultivation (Breś et al. 2016). The latter data agreed with SPAD values shown in Fig. 2.

Salinity stress can significantly reduce photosynthetic activity (Barker, Pilbeam 2007) and net nutrient intake (Massa et al. 2009) of ornamental plants. These effects were not observed for *Impatiens* (Figs 1 and 2, Table 2). Increased Cl concentration in green composts has been found to reduce plant growth and quality of bedding plants depending on species (Garcia-Gomez et al. 2002). In this study, the mixed-green compost showed poorer performance in comparison with the selected-green compost, which is consistent with the known Cl effects. Indeed, data reported in Fig. 1 are compatible with the hypothesis that Cl induced salinity stress in *Petunia*.

Plant response to stress induced by saline ions is usually described by the Maas and Hoffman (1977) model, which enables estimation of species-specific thresholds for loss of plant yield and quality. In this work, the application of this model was successful in fitting dry biomass accumulation of *Petunia* as a function of Cl concentration in the root zone as shown in Fig. 3. For this crop, a threshold of 18.03 mg/l

https://doi: 10.17221/1/2017-HORTSCI

Cl (in the water extract) and an angular coefficient of –0.16 were estimated following the statistical approach proposed by Magán et al. (2008). The same model could not be applied to *Impatiens* because the investigated Cl concentration range did not produce any significant decrease in biomass accumulation (Fig. 1). Different tolerance thresholds have been identified previously for different species depending on their sensitivity to saline ions (Sonneveld et al. 1999).

CONCLUSION

The results in this study suggested that the selected-green compost was a more valuable and safe growing medium for peat substitution in bedding plant cultivation than the mixed-green compost. Use of the latter involved a major degree of uncertainty. These results support the premise that high-quality compost can be achieved by careful selection of raw material (Raviv 2013).

Acknowledgment

Authors thank "Azienda agricola Marco Carmazzi", Via della Fontanella, Torre del Lago (Tuscany, Italy) for their support and technical contribution.

References

Barker A.V., Pilbeam D.J. (2007): Handbook of Plant Nutrition. Boca Raton, CRC/Taylor & Francis.

Breś W., Bandurska H., Kupska A., Niedziela J., Frąszczak B. (2016): Responses of pelargonium (*Pelargonium hortorum* L.H. Bailey) to long-term salinity stress induced by treatment with different NaCl doses. Acta Physiologiae Plantarum, 38: 1–11.

Cai X., Niu G., Starman T., Hall C. (2014): Response of six garden roses (*Rosa* × *hybrida* L.) to salt stress. Scientia Horticulturae, 168: 27–32.

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

Cleary J., Roulet N.T., Moore T.R. (2005): Greenhouse gas emissions from Canadian peat extraction, 1990–2000: A life-cycle analysis. Ambio, 34: 456–461.

De Lucia B., Cristiano G., Vecchietti L., Rea E., Russo G. (2013): Nursery growing media: Agronomic and environmental quality assessment of sewage sludge-based compost. Applied and Environmental Soil Science, Article ID 565139.

Fiasconaro M.L., Antolín M.C., Lovato M.E., Gervasio S., Martín C.A. (2015): Study of fat compost from dairy industry wastewater as a new substrate for pepper (*Capsicum annuum* L.) crop. Scientia Horticulturae, 193: 359–366.

Garcia-Gomez A., Bernal M.P., Roig A. (2002): Growth of ornamental plants in two composts prepared from agroindustrial wastes. Bioresource Technology, 83: 81–87.

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

Larcher F., Berruti A., Gullino P., Scariot V. (2011): Reducing peat and growth regulator input in camellia pot cultivation. Horticultural Science, 38: 35–42.

Lazzerini G., Lucchetti S., Nicese F.P. (2014): Analysis of greenhouse gas emissions from ornamental plant production: A nursery level approach. Urban Forestry and Urban Greening, 13: 517–525.

Lazzerini G., Lucchetti S., Nicese F.P. (2016): Green House Gases (GHG) emissions from the ornamental plant nursery industry: A Life Cycle Assessment (LCA) approach in a nursery district in central Italy. Journal of Cleaner Production, 112: 4022–4030.

Li Y., Qin J., Mattson N.S., Ao Y. (2013): Effect of potassium application on celery growth and cation uptake under different calcium and magnesium levels in substrate culture. Scientia Horticulturae, 158: 33–38.

Loh F.C.W., Grabosky J.C., Bassuk N.L. (2002): Using the SPAD 502 meter to assess chlorophyll and nitrogen content of benjamin fig and cottonwood leaves. Horttechnology, 12: 682–686.

Maas E.V., Hoffman G.J. (1977): Crop salt tolerance. Current assessment. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, 103: 115–134.

Magán J.J., Gallardo M., Thompson R.B., Lorenzo P. (2008): Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions. Agricultural Water Management, 95: 1041–1055.

Massa D., Mattson N.S., Lieth H.J. (2009): Effects of saline root environment (NaCl) on nitrate and potassium uptake kinetics for rose plants: a Michaelis-Menten modelling approach. Plant and Soil, 318: 101–115.

Martínez-Blanco J., Lazcano C., Christensen T.H., Muñoz P., Rieradevall J., Møller J., Antón A., Boldrin A. (2013): Compost benefits for agriculture evaluated by life cycle assessment. A review. Agronomy for Sustainable Development, 33: 721–732.

Mininni C., Santamaria P., Abdelrahman H.M., Cocozza C., Miano T., Montesano F., Parente A. (2012): Posidonia-based compost as a peat substitute for lettuce transplant production. HortScience, 47: 1438–1444.

https://doi: 10.17221/1/2017-HORTSCI

Newman J.P. (2014): Container nursery production and business management manual. University of California (System). Division of Agriculture and Natural Resources.
Raviv M. (2013): Composts in growing media: What's new and what's next? Acta Horticulturae (ISHS), 982: 39–52.
Sonneveld C., Baas R., Nijssen H.M.C., Hoog J.d. (1999): Salt tolerance of flower crops grown in soilless culture. Journal of Plant Nutrition, 22: 1033–1048.
Sonneveld C., Voogt W. (2009): Plant Nutrition of Greenhouse Crops. New York, Springer.
Warner D.J., Davies M., Hipps N., Osborne N., Tzilivakis J., Lewis K.A. (2010): Greenhouse gas emissions and energy use in UK-grown short-day strawberry (*Fragaria* × *ananassa* Duch) crops. Journal of Agricultural Science, 148: 667–681.

Received for publication January 2, 2017
Accepted after corrections September 20, 2017