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Research Paper

Evaluation of two green composts for peat substitution in geranium (*Pelargonium zonale* L.) cultivation: Effect on plant growth, quality, nutrition, and photosynthesis

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ABSTRACT

Peat is the most representative component in the preparation of growing media used in horticulture. However, environmental issues and increased production costs, related to peat extraction and commercialization, are stimulating the use of new materials and technologies as alternatives to peat-based growing media. Among other locally-produced materials, green compost is one of the most promising alternatives for peat substitution although its variability in terms of physico-chemical characteristics represents the main constraint. In the present work, two composts, differing in terms of the initial composting raw materials, were evaluated for peat substitution and their influence on plant growth and quality, nutrient and water uptake, and gaseous exchange activity. A bedding plant (geranium), cultivated in an intensive growing system, was chosen as the test plant and 100% peat as the control. During the greenhouse experiment, plants were grown in five different growing media, i.e. only peat, 30% and 50% peat volume replaced by the two composts. Growing medium characteristics, plant growth and biometric parameters, water and nutrient uptake, and gaseous exchange activity were evaluated as crop performance indicators. The green compost derived from mixed raw material negatively influenced plant nutrition and photosynthesis, thus significantly reducing plant biomass accumulation and quality. The green compost derived from selected material was found to be a valuable growing medium for peat substitution. This thus supports the widespread opinion that high-quality compost can be produced through the selection of composting material.

1. Introduction

Peat represents an ideal growing medium in horticulture due to its physico-chemical characteristics, which are optimal for many plant species and the management of different cultivation systems (Raviv, 2013; Sonneveld and Voogt, 2009). Nevertheless, peat moss is a non-renewable resource in the short-medium term, and its extraction and use impact negatively on wetland ecosystems as well as producing greenhouse gas emissions (Bullock et al., 2012; Cleary et al., 2005).

Various different composted materials have been proposed as candidates for peat substitution, including municipal solid waste (Moldes et al., 2007; Ostos et al., 2008), sewage sludge (De Lucia et al., 2013; Ostos et al., 2008), animal manure (Shober et al., 2010; Tittarelli et al., 2009), agro-industrial waste (Bustamante et al., 2008; Kritsotakis and Kabourakis, 2011). Among the possible composted materials for peat substitution, those based on green refuse are probably the most promising (Raviv, 2013). Green composts have been tested in several experiments for the cultivation of vegetables (Brito et al., 2015; Tittarelli et al., 2009), shrubs (Mugnai et al., 2007), and ornamental species (Olszewski et al., 2009) including geranium (López-Cuadrado et al., 2008).

The standardization of compost characteristics is seen as one of the major concerns in its operative use (Raviv, 2013; Sonneveld and Voogt, 2009). The selection of locally-produced raw materials for composting is one way of obtaining high-quality and standardized green composts while this is not possible for many other compost types such as, for example, those derived from organic urban refuse (Raviv, 2013). The use of green compost is an efficient strategy for re-using green refuse, which would otherwise be disposed of as waste material with increased production costs (Mininni et al., 2012; De Lucia et al., 2013). Growing media based on green compost are considered eco-friendly while the European Commission's "Ecolabel" is denied to growing media

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containing other compost types (e.g. based on sewage sludge) or peat. Therefore, among all composted materials, the production and use of green compost, for peat substitution, can be a strategy worth exploring.

The effects of peat substitution by compost on cultivated plants have often been evaluated by observations limited to plant growth (e.g. Estévez-Schwarz et al., 2009; Olszewski et al., 2009). Many works also report the effects on nutrient and/or non-nutrient concentrations in plant tissues, and/or on other tissue characteristics (Brito et al., 2015; De Lucia et al., 2013; Larcher and Scariot, 2009; López-Cuadrado et al., 2008; Tittarelli et al., 2009). Gaseous exchange and/or plant water relations have very rarely been assessed for plants cultivated in compost-based growing media (e.g. Mugnai et al., 2007; Bakry et al., 2013). Finally, there is a lack of studies assessing the effects of peat substituted by green compost on plant nutrition and photosynthesis which in turn mostly determine plant growth and quality.

The main aim of this work was to evaluate the performance of two green composts derived from selected and non-selected green refuse, as candidates for the replacement of peat in potted geranium cultivation, in terms of crop plant growth, nutritional status, and ecophysiological response.

2. Materials and methods

2.1. Potting growing media

Two different composts were tested in the experiment. Both composts, provided by private companies, were obtained locally (Tuscany, Italy) from green refuse. The main difference between the two types was in the materials used for the composting process. For the first compost, only selected greenhouse (mostly vegetables) and nursery (mostly ornamental shrubs) green waste (i.e. plant trimmings, prunings and crop residues) were used to obtain the "selected-green compost" (SC). The "mixed-green compost" (MC) was instead produced by using non-selected (mixed) green refuse from different cultivation systems, public and private green areas, and heterogeneous environments including urban, peri-urban and coastal areas.

Composting process was carried out following standardized procedures. In both cases, trapezoidal piles of green organic material were composted for a period of roughly six months until compost maturation. During the composting period, the temperature was monitored and the piles were managed to keep a target humidity of 55–65% in order to ensure optimal conditions for microbial metabolism. The composts obtained were analysed before starting the experiment in accordance with UNI 10780 (1998). Table 1 reports the main chemical characteristics of both composts. None of the analysed parameters exceeded Italian regulations (D.Lgs. n° 75, 29 April 2010).

The two composts were then combined with peat (H value = 4–5) to obtain the tested growing media. Five different growing media (hereafter mixtures) were tested in the experiment: i.e. i) 100% peat (PC) was chosen as the standard (control) growing medium, following the growers' common practices for bedding plants cultivated locally; ii) 30% peat volume replaced by selected-green compost (SC30); iii) 50% peat volume replaced by selected-green compost (SC50); iv) 30% peat volume replaced by mixed-green compost (MC30); v) 50% peat volume replaced by mixed-green compost (MC30).

2.2. Plant material and growing conditions

The experiment was carried out at CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Research and Economics, Pescia, Tuscany, Italy (lat. 43°54′ N, long. 10°42′ E), in an unheated plastic greenhouse, under typical Mediterranean climate conditions. The greenhouse was covered with a polyethylene film. A 40% shading net was placed above the canopy to prevent harmful temperatures on sunny days.

Geranium (*Pelargonium zonale* L.) cuttings with four unfolded leaves were transplanted into 1.5-L pots (Ø 14 cm) on 14 March 2014. All plants were fed with the same amount of nutrients supplied through controlled release fertilizer (5 kg m^{-3} of Osmocote Pro® 3–4 months containing 190 g kg^{-1} N, 39 g kg^{-1} P, 83 g kg^{-1} K) blended with the growing medium before transplant. Fertilizer was added taking into account plant nutrient requirements, possible nutrient leaching due to water drainage, and the chemical composition of the irrigation water. Adjustments in water pH were performed using sulphuric acid to keep the pH value close to 6.0.

Table 1
Chemical and microbial characterization of both composts (compost SC and MC) used for the preparation of substrate mixtures.

Parameter	Units	SC	MC	Reference values[a]
Humidity	g 100 g^{-1}	25.6	17.3	< 50
Total N	g 100 g^{-1}	1.8	2.6	
Total C	g 100 g^{-1}	22.2	28.3	> 20
C/N ratio		12.6	10.9	< 50
Humic and fulvic acids	g 100 g^{-1}	14.2	7.6	> 2.5
pH (1:10)		7.6	7.5	6.0–8.5
EC (1:10)	μS cm^{-1}	264	322	
Na	g kg^{-1}	1.05	2.49	
Cl	g kg^{-1}	1,21	3.47	
Cd	mg kg^{-1}	< 0.25	< 0.25	< 1.5
Cr	mg kg^{-1}	< 0.25	< 0.25	< 0.5
Hg	mg kg^{-1}	< 0.10	0.11	< 1.5
Ni	mg kg^{-1}	36.9	44.6	< 100
Pb	mg kg^{-1}	48.1	15.9	< 140
Cu	mg kg^{-1}	128.3	62.0	< 230
Zn	mg kg^{-1}	177.2	144.9	< 500
Salmonella	MPN 25 g^{-1}	absent	absent	absent
Escherichia coli	CFU g^{-1}	< 10	< 10	< m = 1000 or M = 5000

[a] Limit values imposed by the Italian law D.Lgs. n° 75, 29 April 2010.

Plants were moved to the greenhouse and placed on benches for pot cultivation. Eight plants per replicate were spaced to obtain a crop density of 16 pt m^{-2} and arranged in a randomized block design with six replicates (48 plants per mixture) for a total of 240 pots. Plants were irrigated using one pressure-compensated dripper per pot ensuring a flow rate of 2 L h^{-1}. Raw water from the experimental farm (electrical conductivity 0.42-0.60 dS m^{-1} and pH 6.2–6.6) was used for irrigation. The irrigation was triggered using a standard timer initially adjusted (roughly every 3-8 days, depending on the growth period) on the basis of climate conditions and by monitoring the water leaching fraction (i.e. the ratio between the quantity of water drained out from the pots after irrigation and the quantity of water supplied during irrigation) during the cultivation.

Radiation, relative humidity, and air temperature were monitored throughout the experimental period by a portable data logger (Decagon Em50; Decagon Devices Inc., Pullman, WA 99163 – USA). Minimum, mean and maximum daily averaged photosynthetic active radiation values were 32.5, 142.3, and 323.3 μmol m^{-2} s^{-1}, respectively. Mean daily cumulative global radiation was 6.1 MJ m^{-2} d^{-1}. The average minimum, mean and maximum daily air temperatures were 11.8, 17.7 and 26.6 °C, respectively. Mean daily relative air humidity averaged 66.5%.

2.3. Growing medium and plant analyses

The physico-chemical characteristics of the peat control growing medium and each mixture obtained by peat and composts were determined before the addition of the chemical fertilizer. Total N and C contents were assessed on a dry matter basis (EN 13654-1, 2001 and UNI 10780, 1998, respectively) while other chemical parameters were analysed in the 1:5 (V:V) solid:water extract: i.e. pH (EN 13037, 1999), EC (EN 13038, 1999), N-NO_3, P-PO_4, K, Ca, Mg, Fe, Na, and Cl (EN