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Behavior and evolution of sustainable organic substrates in a vertical garden

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ABSTRACT

The development of green areas in the cities, on occasion is hindered as there is not enough area available. In response to that, the concepts of vertical gardens, green façades, covers or vegetable garden on terraces have emerged, which they constitute innovative forms or urban naturation. These novel cultivation systems require substrates that allow the anchoring of the plant, contribute with water, air and nutrients that help an appropriate plant development, besides being light and environmentally sustainable. The purpose of this study was to assess the behaviour and the evolution of sustainable organic substrates used as growing mediums in a vertical garden. Five substrates made with mixtures of the following components and volume ratio were used: 70% composted pine bark +30% coconut fibre, 70% coconut fibre +30% composted pine bark, 70% composted plant residues +30% composted pine bark, 70% composted plant residues +30% coconut fibre, and a control with 90% coconut fibre (powder) +10% expanded polystyrene. Two ground cover plant species were used as indicator plants: *Frankenia laevis* and *Pachysandra terminalis*. The results show that the substrates with different combinations of pine bark with coconut fibre presented low densities and high porosity, as well as optimum pH levels, electric conductivity and a stable content in organic matter during the test. The use of substrates with mixture of pine bark and coconut fibre becomes in a sustainable and appropriate practice in vertical gardening with ground cover vegetation.

1. Introduction

The accelerated urbanization process and the exponential growth in the big cities of the world have contributed to the reduction of areas for vegetation, having an effect on environmental problems. More than the 50% of worldís population live in cities. And it is estimated that, by 2030 this figure will exceed 60% (Banco-Mundial, 2013). This progressive urbanization process also leads to waste generation problems. Thus, the cities exert a strong pressure over the environment, direct or indirect being responsible of 80% of the total of energy consumption, more than 70% of the total of generated residues and more than 60% of greenhouse gas (Grimm et al., 2008), deteriorating the natural environment gradually.

The use of vegetation in urban planning has become in an essential aspect, because it offers benefits such as: reduction of urban heat island effect (Alexandri and Jones, 2008; MacIvor and Lundholm, 2011), retention of humidity (Thuring et al., 2010), contribution to biodiversity (Gedge and Kadas, 2005), ultimately, urban landscaping improvement (Maas et al., 2006; White and Gatersleben, 2011). In response to urban naturation, designs of sustainable cities that incorporate vegetation in the urban environment, are proposed with the aim of attenuating the imbalance between urbanisation and conservation of environment (Urbano-López, 2013; Wong et al., 2010). The vertical gardens in façades or interiors of edifications constitute the most innovative representations of urban naturation and powerful tools for the bioclimatic and sustainable design when the available space is very limited

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(Alexandri and Jones, 2008). Vertical naturation, either of façades or green walls, consists on covering the buildings with permanent plants capable of covering on their own or helped by substructures (Gross, 2012). Agronomically, this modality of gardening requires the use of a growing medium which besides allowing the satisfactory development of the root system, is light, capable of supporting the vegetation and to reach an optimum water/oxygen relation (Baixauli and Aguilar, 2002) and, at structural level, to reduce the weight of all the system and its effect over the load capacity of the building (FLL, 2002). At present, the peat, stone wool and perlite are the most used growing mediums for the production and/or implementation of plants, mainly for gardening and horticulture (López-Cuadrado et al., 2006). Environmental and economic reasons motivate the research on the use of alternative materials that contribute to the minimum use or almost- no- application of these growing mediums. In Spain, researches have been developed on the use of compost and/or substrates as growing mediums aimed to reduce the use of peat as traditional material in the organic substrates, as its reserves are limited, non-renewable and its extraction causes a strong environmental impact (Masaguer-Rodríguez et al., 2015). The stone wool has a low mechanic stability, limited duration and generates problems for its elimination; the perlite, when it physically degrades, forms small particles that can produce flood-flush at the bottom of the bag (López-Cuadrado et al., 2006).

The necessity of cultivating plants out of their natural environment creates the obligation to use technology to produce quickly, with quality and in a cost-effective manner. Therefore, it exists a great demand of new growing mediums that provide physical support, water, oxygen and the necessary nutrients for vegetative development (Masaguer-Rodríguez et al., 2015). On the other hand, the agricultural, forestry or urban activities create organic residues that require a proper management and that, in line with the principle of reducing, recycle and reuse are valued as potential materials for the elaboration of growing mediums that are sustainable, efficient, stable and from local raw materials. Therefore, the aim of this research was to study the physical and chemical properties of sustainable organic substrates obtained from waste materials and their evolution over time once they are established in their vertical garden with ground cover plants.

2. Material and methods

2.1. Location of the experiment

The testing was established in the Finca Experimental El Encín (experimental field) of the Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA), situated in the locality of Alcalá de Henares, Comunidad de Madrid (Spain), geographically located at coordinates 40° 31′ 33″ N and 3° 17′ 22″ W and at an altitude of 610 m a.s.l.

2.2. Description of treatments, installation of the testing and experimental design

For the test, it was used a system of vertical gardening with commercial modular panels of the company Intemper Española *S.L.* (*Naturpanel*®) (Fig. 1).

The system consists on an industrial polyethylene structure equipped with a reservoir (cistern) at the bottom part for the optimisation of the water supply for the plants. It has a dimension of 60 × 30 × 10 cm (width × height × depth), which makes possible to introduce two bags of substrates that form eight quadrants of 15 × 15 cm (four upward, four downward) for the layout of vegetation. The panels are connected by pipes on the sides in the lower part, both for water supply and interconnection between panels (Fig. 2).

Fig. 1. Vertical garden in the wall overlooking the water feed pipe on the left side of the plant cell wall.

Fig. 2. Support Naturpanel® used in the installation of the vertical garden.

Five substrates were evaluated, created from: composted pine bark, composted plant residues resulting from tree pruning and urban gardens and coconut fibre from Sri Lanka. Four mixtures were prepared in volumetric proportions (70%–30%) and a control mixture made from coconut fibre (90% coconut powder) and expanded polystyrene (10%). Thus, the mixtures used were: 1) 70% composted pine bark +30% coconut fibre (CPB + CF), 2) 70% coconut fibre +30% composted pine bark (CF + CPB), 3) 70% composted plant residues +30% composted pine bark (CPR + CPB), 4) 70% composted plant residues +30% coconut fibre (CPR + CF) and 5) 90% coconut fibre +10% expanded polystyrene (CF + EP, control). The physico-chemical and chemical characteristics (pH, electrical conductivity, and organic matter and C/N ratio) of the initial materials used in the elaboration of the growing media are showed in Table 1. All substrates were fertilized with 4 g L^{-1} of 8–9 months slow release

Table 1
Physico-chemical and chemical characteristics of the primary materials used for the manufacture of substrates evaluated in a vertical garden with ground cover vegetation (average values[a]).

Substrate[b]	pH	EC (dS m^{-1})	OM (%)	C/N
CPB[f]	6.00	0.52	74.7	69.3
CF[f]	6.60	0.14	90.6	101.5
CPR[g]	7.20	0.72	36.5	15.0
Reference level.[c]	5.2–6.3	0.15–0.50[d]	>80%	20–40[e]

Values of pH and EC were determined in a ratio sample: water 1:5 (v/v).
[a] Averages with different letter in a column are statistically different (Tukey, $p \leq 0.05$).
[b] CPB= composted pine bark, CF=coconut fibre, CPR= composted plant residues, EC= electrical conductivity, OM= organic matter, and C/N= carbon/nitrogen relationship.
[c] Abad et al. (1993).
[d] Carmona and Abad (2008).
[e] Abad et al. (2000).
[f] Vidueira (2010).
[g] Masaguer-Rodríguez et al. (2015).