Journal of Environmental Management 166 (2016) 330–340

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

The composition and depth of green roof substrates affect the growth of *Silene vulgaris* and *Lagurus ovatus* species and the C and N sequestration under two irrigation conditions

S. Ondoño [a, *], J.J. Martínez-Sánchez [b], J.L. Moreno [a]

[a] Grupo de Enzimología y Biorremediación de Suelos y Residuos Orgánicos, Centro de Edafología y Biología Aplicada del Segura (CEBAS-CSIC), Campus Universitario de Espinardo, Aptdo. de correos 164, Espinardo, 30100 Murcia, Spain
[b] Departamento de Producción Vegetal, Universidad Politécnica de Cartagena (UPCT), Paseo Alfonso XIII, 48, CP 30203 Cartagena, Murcia, Spain

ARTICLE INFO

Article history:
Received 26 June 2014
Received in revised form
31 July 2015
Accepted 28 August 2015
Available online 30 October 2015

Keywords:
Compost
Green roofs
Mediterranean semi-arid climate
Native plant species
Carbon fixation
Microbial activities

ABSTRACT

Extensive green roofs are used to increase the surface area covered by vegetation in big cities, thereby reducing the urban heat-island effect, promoting CO_2 sequestration, and increasing biodiversity and urban-wildlife habitats. In Mediterranean semi-arid regions, the deficiency of water necessitates the use in these roofs of overall native plants which are more adapted to drought than other species. However, such endemic plants have been used scarcely in green roofs. For this purpose, we tested two different substrates with two depths (5 and 10 cm), in order to study their suitability with regard to adequate plant development under Mediterranean conditions. A compost-soil-bricks (CSB) (1:1:3; v:v:v) mixture and another made up of compost and bricks (CB) (1:4; v:v) were arranged in two depths (5 and 10 cm), in cultivation tables. *Silene vulgaris* (Moench) Garcke and *Lagurus ovatus* L. seeds were sown in each substrate. These experimental units were subjected, on the one hand, to irrigation at 40% of the registered evapotranspiration values (ET_0) and, on the other, to drought conditions, during a nine-month trial. Physichochemical and microbiological substrate characteristics were studied, along with the physiological and nutritional status of the plants. We obtained significantly greater plant coverage in CSB at 10 cm, especially for *L. ovatus* (80–90%), as well as a better physiological status, especially in *S. vulgaris* (SPAD values of 50–60), under irrigation, whereas neither species could grow in the absence of water. The carbon and nitrogen fixation by the substrate and the aboveground biomass were also higher in CSB at 10 cm, especially under *L. ovatus* – in which 1.32 kg C m^{-2} and 209 g N m^{-2} were fixed throughout the experiment. Besides, the enzymatic and biochemical parameters assayed showed that microbial activity and nutrient cycling, which fulfill a key role for plant development, were higher in CSB. Therefore, irrigation of 40% can maintain an adequate plant cover of both endemic species, particularly in a deeper and soil-containing substrate.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Green roofs have environmental and esthetic advantages (Dunnett and Kingsbury, 2010), such as improved storm-water management (Fioretti et al., 2010; Nagase and Dunnett, 2011), amelioration of the urban heat-island effect (Mackey et al., 2012), mitigation of air pollution and CO_2 sequestration (Li et al., 2010; Rowe, 2011), thermal insulation and energy savings (Jim and Tsang, 2011; Jaffal et al., 2012), increased biodiversity and urban wildlife habitats (Oberndorfer et al., 2007), and increased esthetic value of city buildings.

Extensive green roofs are light-weight systems with minimal substrate depth, varying between 5 and 15 cm, and with minimal maintenance requirements (FLL, 2008). In general, green roof substrates should be light-weight, chemically inert – free of heavy metals and pollutants -, physically stable and should retain adequate amounts of water and minerals for sufficient plant growth (Kotsiris et al., 2012). The majority of green roof substrates tend to be dominated by mineral-based components, being 80–100% mineral and 0–20% organic matter, which can contribute to the water- and nutrient-holding capacities (Beattie and Berghage, 2004; Ondoño et al., 2014). Mainly, the organic matter of green

* Corresponding author.
E-mail address: sotovar@cebas.csic.es (S. Ondoño).

http://dx.doi.org/10.1016/j.jenvman.2015.08.045
0301-4797/© 2015 Elsevier Ltd. All rights reserved.

roofs is composed of peat, coir or composts. The use of compost as an organic amendment for horticultural purposes contributes to the recycling of C and nutrients from wastes generated in different anthropic activities (e.g.: residential, agricultural, forestry, or industrial), as reported by Moreno et al. (2013) and Bastida et al. (2008, 2012). The substrate weight and depth are also limiting factors when designing an extensive green roof (Nektarios et al., 2011). Contrarily, there are consistent results showing improvement of plant growth and survival as the depth of the substrate increases (Boivin et al., 2001; Dunnett et al., 2007; Durhman et al., 2007; Getter and Rowe, 2006; Thuring et al., 2010; Papafotiou et al., 2013).

The design of new substrates capable of sustaining adequate plant development under Mediterranean climatic conditions is a challenge due to the unfavorable hot and dry, semi-arid conditions. Hence, the construction of extensive green roofs in Mediterranean cities is still limited. The most commonly used plants are those of the Crassulaceae, since they are perfectly fitted to drought conditions. Therefore, the development of suitable light-weight substrates – which can promote adequate plant growth and maintenance over time – would be an important achievement in the Mediterranean area, together with the selection of plant species. The use of endemic herbaceous and shrub plants could provide an added value to green roof design, taking into account that Mediterranean native species are also well adapted to these conditions. In some studies which had the same goal (Benvenuti and Bacci, 2010; Nektarios et al., 2011; Kotsiris et al., 2012; Papafotiou et al., 2013), the effect of substrate composition and depth on plant growth was significant. According to some authors (Nagase and Dunnett, 2011; Lundholm et al., 2010; Oberndorfer et al., 2007), grasses and forbs were more effective than *Sedum* spp. in reducing water runoff from green roofs and in the thermal insulation of buildings, which contributes to energy savings in air conditioning. In this direction, recent studies are focused on the utilization of Mediterranean grasses and forbs in green roof systems installed in Mediterranean countries (Benvenuti, 2014; Van Mechelen et al., 2014). Evidence is provided that extensive green roofs mimic habitats found in nature, a concept which is described as the 'habitat template hypothesis' (Lundholm, 2006). These natural template habitats comprise mostly rocky environments; free draining dunes, open areas on very shallow substrates and limestone pavements. The Mediterranean region with its exceptional diversity of plant species (Médail and Quézel, 1997) contains a lot of these habitats, so it should be possible to find drought-adapted, native plant species that could thrive on extensive green roofs. Hence, some herbaceous perennial plants, grasses and geophytes clearly are capable to withstand drought (e.g. *Allium cernuum*, *Festuca glauca* (Getter and Rowe, 2008); *Armeria maritima*, *Prunella vulgaris*, *Silene uniflora*, *Koeleria macrantha*, *Trisetum flavescens* (Nagase and Dunnett, 2010); *Poa compressa* (Wolf and Lundholm, 2008)).

In addition, irrigation is needed in extensive green roofs under a Mediterranean climate, but the amount and frequency are related to the plant species and substrate type and depth. A deep substrate would be desirable for water retention in a dry roof management scenario, but, on the other hand, this would pose the risk of excessive weight after heavy downpours (Benvenuti and Bacci, 2010). Therefore, we have tested different materials in two different depths in order to find an appropriate substrate for plant development under Mediterranean conditions. In this sense, we evaluated the growth of two native species (*Silene vulgaris* (Moench) Garcke and *Lagurus ovatus* L.) in each substrate type, and the carbon and nitrogen sequestration potential of each plot, taking into consideration the substrate type and depth as well as the aboveground plant biomass, as proposed by Getter et al. (2009).

We postulated that, in an extensive green roof experiment: i) both plant species would have better development in deeper substrates than in shallower ones, ii) irrigation at 40% of the potential evapotranspiration (ET_0) could allow the growth of the aforementioned two Mediterranean plant species assayed under semi-arid climatic conditions, since neither species can develop without irrigation in these conditions, and iii) substrate composition and depth would be influential factors in C and N sequestration, the composition being more important in this respect.

2. Material and methods

2.1. Substrates, plant species, and irrigation conditions

We tested two different substrates in two depths: 5 and 10 cm. These substrates are made up of compost mixed with crushed bricks (CB5 and CB10, respectively), in a 1:4 volumetric ratio, and compost mixed with soil and crushed bricks (CSB5 and CSB10), in a 1:1:3 (v:v:v) ratio. The compost was made from sheep and goat manure mixed with green wastes (plant prunings and debris), and the soil is classified as a Haplic calcisol (FAO-ISRIC and ISSS, 1998): it is a clay-loam soil (44.9% sand, 24.9% silt, and 30.3% clay). The soil was sampled in Santomera (Murcia, Spain), from a fallow land, and then sieved to 2 mm. The crushed bricks came from construction industry residues (4–12-mm diameter) from a local factory.

The two plant species tested were *S. vulgaris* and *L. ovatus*. Both species are typical of the Mediterranean semi-arid climate. *S. vulgaris* is an herbaceous perennial plant that reaches 10–100 cm in height, whose aerial parts wither in late summer or when the cold weather arrives, sprouting with the arrival of warmer spring temperatures, and it is found usually in rain-fed crops, fallow, slopes, and screes. It belongs to the Caryophyllaceae family, and it is of interest for edible uses, medicinal purposes, and phytoremediation of soils contaminated with heavy metals (Ernst and Nelissen, 2000; Arreola et al., 2004, 2006). *L. ovatus* is an annual grass (Poaceae), whose stems are 8–80 cm in height. The inflorescence is a dense panicle, and the plants are usually found in coastal sand and dunes (Valdés et al., 1987; Conesa Álvarez, 1998). Seeds of both plant species were sown in each substrate in October-2012, using a planting framework of 5 × 5 cm between each seed.

Each substrate type was prepared in triplicate for each species and for each substrate depth (5 and 10 cm). The mixtures were prepared in a concrete mixer and then poured into each experimental unit. For this, we designed six stainless steel "cultivation tables", each with dimensions of 3 × 1.5 m (Fig. S2: Supplementary data). Each cultivation table was composed of eight planting units, measuring 0.75 × 0.75 × 0.20 m (length, width, and height), so there were 48 different units in total. Three of the cultivation tables were assigned to non-irrigated conditions and the other three were subjected to irrigation at 40% of the ET_0. Manual irrigations were applied – artificial rain – throughout the month of October (2012) in order to promote the germination in both the irrigated and the non-irrigated units. The experiment lasted 10 months (from October-2012 to July-2013) and the amount of water supplied was fixed at 40% of the ET_0 in irrigated plots while in non-irrigated ones the irrigation was only applied during the first month. The amount of irrigation water (40% ET_0) was set following the instructions of Costello and Jones (2014) in an attempt to minimize water consumption in these green roof systems. By knowing the cultivation coefficient (K_C) of each plant species, the amount of irrigation water was calculated weekly, considering the registered ET_0 values of the previous seven days and multiplying it by the mean cultivation coefficient of both plant species, following the next equation (Allen at al., 1998):

Download English Version:

https://daneshyari.com/en/article/7481389

Download Persian Version:

https://daneshyari.com/article/7481389

Daneshyari.com