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Short communication

Water-holding capacity and plant growth in compost-based substrates modified with polyacrylamide, guar gum or bentonite

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ABSTRACT

Humectant agents are used to improve seed germination and survival in hard environments through their effect on water-holding capacity. In this work, we have evaluated the combined effect of substrate composition and humectant agents on the water-holding capacity and growth of *Lolium multiflorum* in different mixtures based on municipal solid waste composts. A commercial polyacrylamide, bentonite or guar gum have been added to mixtures of two municipal solid waste composts with either manure vermicompost or pine bark compost. Water-holding capacity of the substrates and plant production after five weeks in the greenhouse were evaluated. Only bentonite increased water retention of the substrates, likely because the compost-based substrates already presented high water retention. None of the humectant agents had significant effects on the growth of *Lolium multiflorum*. The use of bentonite can be recommended for increasing water-holding capacity of organic substrates in this case, but given the overall small effects of the humectant agents, an adequate choice of the organic materials could suffice for the formulation of adequate plant substrates in this case.

1. Introduction

The use of soilless substrates has been a constant in commercial horticulture during the last decades and recently, a new field of application for these substrates has been found in urban agriculture, in particular in green roofs or vegetal gardens (Farrell et al., 2013; Young et al., 2014; Grard et al., 2015; Matlock and Rowe, 2017). Due to the environmental issues associated to the extraction of peat, which was traditionally the main component in most substrates, the search for alternative components has been a subject of abundant research during the last decades (Abad et al., 2001). Special attention has been paid in this sense to the use of composts, urban wastes and other organic materials of residual origin (Barral et al., 2007; Paradelo et al., 2009, 2012b, 2016). In the new scenario of increasing (or at least sustained) demand for soilless substrates due to the requirements of urban agriculture, research on the use of residual materials and the main properties of the substrates produced is still necessary.

For almost all applications of soilless substrates, water retention is a decisive factor due to its influence in seed germination and plant growth. This is specially true in some applications where severe conditions that limit water availability exist. For example, in green roofs, the substrate layer is often restricted to a depth of 10 cm or less. Other problems are for example due to irrigation limitations, high rate of desiccation due to exposure and free draining, so water stress is one of the most common limitations for plant growth on green roofs (Farrell et al., 2013; Young et al., 2014). Plant production under these conditions is challenging in what concerns water supply to seeds or plant during implantation, as happens in other contexts where water retention is limited, such as in post-fire environments or minesoils.

The extreme relevance of water supply in these cases makes the study of water-holding capacity and its potential increase in substrate formulations an essential issue. In this sense, the use of humectant agents for increasing water retention in soilless substrates is an interesting subject of research, even for materials with relatively high water-holding capacity. Water-retention additives have the potential to increase substrate water availability leading to greater plant growth and survival without the need for large amounts of extra growing media (Martin and Szort, 2001; Farrell et al., 2013). These include substances of diverse nature and origin, either organic or inorganic, natural or artificial. Natural materials employed include clays, which have been traditionally used for the amendment of sandy soils in many arid and semiarid areas of the world (Ajayi and Horn, 2016), and natural polymers such as guar gum (Patil et al., 2011). Among the artificial additives, hydrogels are among the most widely employed for agricultural, horticultural or forestry applications (Hüttermann et al., 2009; Agaba et al., 2010; Shi et al., 2010; Kabiri et al., 2011; Paradelo et al.,

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2012a; Crous, 2017); they are cross-linked crystalline forms of insoluble polyacrylamide gel that absorb and store water up to 500 times their own weight when saturated (Johnson, 1984). However, information regarding combinations of humectants and compost for use as substrates is still scarce.

In this work, we have studied the possibility of recycling municipal solid waste (MSW) composts as components of substrates, focusing on water retention. However, previous studies have shown that substrates based solely on MSW compost may be inadequate for plant production due to high salinity and phytotoxicity (Moldes et al., 2013; Barral et al., 2007), so we have blended MSW composts with composted pine bark or manure vermicompost, that are easily available in the region and do not present plant toxicity. We have assessed the water-holding capacity of these mixtures with or without three substances with high water retention as additives (polyacrylamide, bentonite and guar gum). Given that for substrate applications it must be assured that no plant harm exist, potential phytotoxicity of the substrates produced has been assessed by a growth trial using *Lolium multiflorum*.

2. Materials and methods

2.1. Composts

Four composts were used for the experiment. MSWC1 is a compost obtained from aerobic treatment of source-separated biodegradable fraction of municipal solid waste (MSW); MSWC2 is a compost obtained by anaerobic fermentation of the biodegradable fraction of MSW, separated before collection, followed by an aerobic composting step, to stabilize the incompletely digested residue. Both MSW composts were provided by industrial composting facilities located in A Coruña (Spain). MV is a mixed manure vermicompost supplied by a local producer in Galicia (Spain). CPB is composted pine bark produced by aerobic composting in windrows, supplied by Costiña (O Pino, A Coruña, Spain). Their main properties are summarized in Table 1.

2.2. Humectant agents

Three humectant agents were employed in the study: a commercial polyacrylamide (Alcosorb® Pearl) supplied by Ciba Especialidades Químicas S.L. (Barcelona, Spain); bentonite, a commercial mixture of smectitic clays supplied by Minas de Gador S.L. (Almería, Spain); and guar gum, supplied by Sigma-Aldrich (Madrid, Spain);.

2.3. Substrates

A total of 28 different mixtures with three replicates per mixture were prepared following the scheme summarized in Fig. 1. Each MSW compost was blended either with manure vermicompost or with composted pine bark, producing four mixtures 1:1 (on a volume basis). With each of these four blends, three series were prepared with different doses of each of the three humectant agents: dose 0 (no humectant agent added); dose 1 (1 g L^{-1} of guar gum or Alcosorb or 100 g L^{-1} of bentonite); and dose 2 (10 g L^{-1} of guar gum or 3 g L^{-1} of Alcosorb or 300 g L^{-1} of bentonite). These doses were selected to match those used in similar studies in the literature.

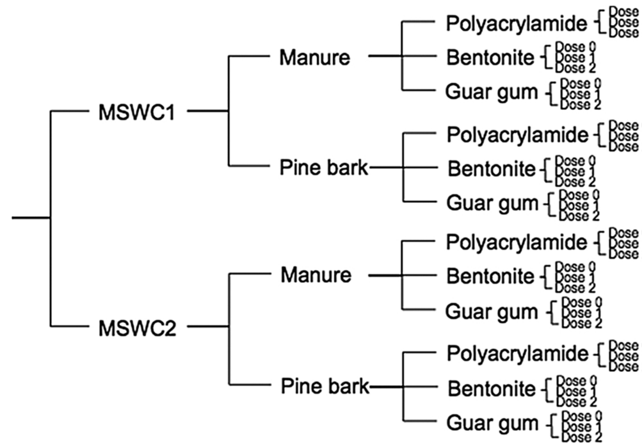

Fig. 1. Experimental design for substrate formulation.

Table 1
Properties of the composts used in substrate formulation. MSWC: municipal solid waste compost; MV: manure vermicompost; CPB: composted pine bark; EC: electrical conductivity; TOM: total organic matter; WHC: water-holding capacity.

Compost	pH_w	EC (dS m^{-1})	TOM (g kg^{-1})	C/N	WHC (cm^3 cm^{-3})
MSWC1	8.7	5.1	380	12	0.60
MSWC2	8.4	2.3	487	17	0.48
MV	7.9	0.7	376	21	0.37
CPB	5.3	0.4	914	194	0.47

2.4. Analyses of the substrates and greenhouse experiment

Water retention at pF 2 (0.1 bar) was determined using a Richards membrane extractor following the method described by Guitián and Carballas (1976). For the growth experiment, pots, 12 cm diameter and 7 cm high, were filled with 400 cm^3 of each mixture in three replicates, and 50 seeds of Italian ryegrass (*Lolium multiflorum*) were sown in each pot and transferred to the greenhouse. A multinutrient solution (Welgro Standard Plus commercial; Química Masso S.A., Barcelona, Spain) containing 17% N, 15% K_2O, 30% P_2O_5, 0.13% Fe, 0.052% Mn, 0.06% Zn, 0.02% B and 0.005% Mo, was added twice to the pots in order to obtain final concentrations of 220 mg N L^{-1}, 160 mg K L^{-1} and 170 mg P L^{-1}. In order to avoid heat and water stress, pots were watered daily during the experiment. At the end of the growth period (five weeks) the plants were harvested by cutting them off between the root and stalk, and the fresh and dry (65 °C) weight of the shoots were recorded.

2.5. Statistics

Four factors were included in the statistics for the study of the effect of substrate composition and humectant agents on water-holding capacity and plant production: type of MSW compost (factor 1, two levels), use of either manure or pine bark (factor 2, two levels), humectant agent (factor 3, four levels) and dose of humectant agent (factor 4, three levels). Linear regression model analysis and ANOVA for each individual factor plus multi-way analysis of variance for the interactions between factors were performed using the R statistical package for MacOSX (R Core Team, 2015).

3. Results and discussion

All the substrates presented high water holding capacity values irrespective of the materials employed in their formulation (Fig. 2), as expected given their predominantly organic composition, with values ranging from 83 to 151 g 100 g^{-1}. There were no significant differences between the two MSW composts, but blending them with pine bark increased water holding capacity to a greater extent than manure vermicompost (Table 2). A significant effect of the humectant agent employed as well as the dose employed was also found: bentonite was the most effective to increase water holding capacity, followed by the polyacrylamide, whereas the highest rate (dose 2) was more effective than the lowest one. In addition to the significant effect found for these individual factors, significant interactions were also found between them: it is noteworthy that, while the choice of MSW compost (factor 1)