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Use of grape marc compost as substrate for vegetable seedlings

E. Carmona*, M.T. Moreno, M. Avilés, J. Ordovás

Departamento de Ciencias Agroforestales, Universidad de Sevilla, Spain

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ABSTRACT

An experiment was conducted to study the potential of compost made from dealcoholised grapevine marc and grape stalk (GM) as growing medium component in plug seedlings production of lettuce, tomato, pepper and melon. Four media were prepared: GM, a commercial peatmoss-based plug medium (Pt), used as control, and two GM + Pt mixtures (1:1 and 1:2, v:v). Their physico-chemical characteristics were analysed, and bioassays were carried out for the detection of their phytotoxicity and nitrogen drawdown index (NDI). Seedlings grown in a greenhouse in Seville, during spring 2007, were irrigated 5 days a week with a Hoagland solution. Each species was arranged in a randomised block design with four replications. Substrates showed no phytotoxicity or nitrogen immobilisation. Physical characteristics of GM suggested some limitations for use as growing medium in plug seedlings production (total available water content of 12.7% in GM and 25.9% in Pt), although it can be avoided by blending with other substrates and by managing irrigation. At the time of transplant lettuce seedlings showed only differences in green colour intensity measured by SPAD, which was higher in GM (20.3) that in Pt (18.7). Seedling height of pepper, melon and tomato grown in GM was on average 30% lower than that achieved in Pt. The height increased as the proportion of Pt in the substrates did so. There were also differences in dry weight and root neck diameter in tomato and melon that were lower in GM than in Pt. Both parameters improved with the proportion of Pt in the mixtures. Plants analyses showed significant differences that did vary depending on the species and the treatment, and they suggest nutrient imbalances in seedlings. These results would indicate that, under a correct irrigation and fertilisation management, GM and GM + Pt blending could be used successfully as medium component for plug production of vegetable seedlings.

1. Introduction

Annually, the production of vegetable plug transplants in Spain exceeds 3 billion plants, being the most common species lettuce, tomato and pepper. The use of high-quality substrates is particularly important in plug seedlings production, considering that, during their germination and their first stages of development, plants are especially sensitive to negative factors of the medium, and because containers have low height and small volume, which limits water and air supply.

The total consumption of substrates by plug transplants industry in Spain has been estimated over 220,000 m^3 annually (Carmona and Abad, 2008). The most usual substrates used for this purpose are *Sphagnum* peat and, to a lesser extent, coconut fibre. The high price of both materials and the heavy dependence of consumer countries, coupled with the fact that peat is a non-renewable natural resource, whose extraction causes the destruction of areas of high ecological value, have stimulated interest in finding new materials. Thus, numerous studies have been published on the potential use of diverse wastes of urban, agro-industrial or agricultural origin as substrates to replace peat in the production of vegetable plug transplants (Vavrina et al., 1996; Roe et al., 1997; Mazuela and Urrestarazu, 2005). The results concerning the suitability of these composts have varied significantly and were not always satisfactory. Their failure, depending on the materials used and on the proportions in the mixtures, were attributed to the presence of organic phytotoxins (Roe and Kostewicz, 1992), to high EC in municipal solid wastes (Vavrina, 1994; Herrera et al., 2008), to immaturity in hardwood bark compost (Bearce and Postlethwaite, 1982), to excess of NH_4^+ in spent mushroom compost (Lohr et al., 1984), to B toxicity in urban solid wastes (Rosen et al., 1993), or to poor physical properties caused by low aeration or scarce water-holding capacity (Kostov et al., 1996).

Amongst the materials that, potentially, can be used as alternatives for peat, wastes from the wine industry, which Spain produces annually in the order of 1.8×10^6 tons (Bustamante, 2007), are widely available. They include the remains of the racemes or stalks,

Abbreviations: EC, electrical conductivity; CV, coefficient of variation; GI, germination index; GM, grape marc; Kunsat, unsaturated hydraulic conductivity; NDI, N drawdown index; Pt, peat-based commercial substrate; S, sand; *A*, aeration capacity; EAW, easily available water; RW, reserve water; PS, porous space; Θcc, container capacity; Ψ, hydric potential.

* Corresponding author at: ETSIA, Universidad de Sevilla, Carretera de Utrera, km 1, 41013 Seville, Spain. Tel.: +34 95 448 6452; fax: +34 95 448 6436.
E-mail address: eusebio@us.es (E. Carmona).

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the marc, containing the skin, pulp and seeds of the grapes, and the wine lees or wine sediments after fermentation. European legislation requires that these wastes are sent to the distilleries for their processing and obtaining tartrates. The residue from this process is dealcoholised marc, which is acid and contaminating due to its high contents of phenolic substances with a phytotoxic and antimicrobial effect. In order to avoid these drawbacks, these wastes must be composted before their use in agriculture.

A good number of studies have been made on the use of grape marc compost as organic fertilisers and soil amendments (Madejón et al., 2001, 2002; Rannalli et al., 2001; Díaz et al., 2002; Bertrán et al., 2004; Patti et al., 2004; Rodríguez et al., 2006; Bustamante, 2007; Moldes et al., 2007; Bustamante et al., 2008a). Descriptions have also been made of the suppressive character of wine industry waste composts against soil phytopathogens (Borrero et al., 2004, 2006, 2009; Trillas et al., 2006; Segarra et al., 2007). However, lesser references are available concerning their characterisation and utilisation as peat substitutes in soilless growing media (Kostov et al., 1996; Reis et al., 1998; Bustamante et al., 2008b).

The objective of this work is characterizing the grape marc compost, both pure and in a mixture with a peat-based commercial substrate, and testing the behaviour of these composts as a medium for the plug seedling production of lettuce (*Lactuca sativa* L.), tomato (*Lycopersicon esculentum* Mill.), pepper (*Capsicum annuum* L.) and melon (*Cucumis melo* L.).

2. Materials and methods

The compost was prepared by composting in open-air windrows, with periodical turnovers, a mixture of dealcoholised grapevine marc and grape stalk in a 1:1 (v:v) proportion, during a 5-months period in the Spring–Summer 2006. Six compost sub-samples were taken in different areas of the piles at depths between 20 and 80 cm, according to sampling rules of European Committee for Standardization (2001 and 2002). An aliquot of the mixture of these sub-samples was used in this study.

Four substrates were prepared: (i) only compost (GM), (ii) mixture of GM with a blond peat-based commercial substrate (Pt) in volumetric proportion of 1:1 (GM + Pt, 1:1), (iii) mixture of GM and Pt in volumetric proportion of 1:2 (GM + Pt, 1:2), and (iv) pure Pt as a substrate control.

Before the experiment, the following physical properties were assessed as established in the standards on analyses for amendments and growing media (European Committee for Standardization, 2001 and 2002): bulk density, water characteristic curve and container capacity. The particle density of Pt was assessed by pycnometry (Flint and Flint, 2002), and by submersion, considering the buoyancy of the material, in GM and its mixtures (Ordovás et al., 1996). Some chemical properties were also assessed: pH and electrical conductivity (EC) in water slurries 1:2, total N using the Dumas method (Bremner, 1996), total phosphorus as per Murphy and Riley (1962); B according to Keren (1996) and the rest of total elements by atomic emission/absorption spectrometry. Assimilable elements were assessed in 1:5 (v/v) suspensions, using water to extract N and P, ammonium acetate to extract K, Ca and Mg, and DTPA-$CaCl_2$ for the metallic microelements. In the corresponding extracts, N (NO_3^-—N and NH_4^+—N) was measured by reflectometry with RQflex 10 colorimeter by Merck, phosphorus as per Murphy and Riley (1962), and the rest of the elements by atomic emission/absorption spectrometry. Tests were done in duplicate.

To detect phytotoxicity, a germination test on plates were performed using lettuce, tomato, pepper and melon seeds as plant material and sand (S) as a control substrate (Ortega et al., 1996), calculating the germination indexes (GI) for GM and Pt. Finally, the N drawdown index (NDI_{150}) (Handreck, 1992) of GM and Pt was also assessed.

The substrates were used as culture media for the plug seedling production of lettuce 'Invierno de Mallorca'; tomato 'Roma', pepper 'Cristal (Negrillo)'; and melon 'Piñoné'. Seeds of lettuce were sown in 150-cell plug trays, 104-cell plug trays were used for tomato and pepper and 40-cell plug trays were used for melon. An experimental randomised block design was used, with 4 replications, each experimental unit containing 40 melon plants, 48 tomato or pepper plants, and 50 lettuce plants. The tests were performed in a greenhouse in Seville, during spring 2007, with irrigation 5 days a week with Hoagland solution. The number of germinated seeds was controlled daily. Plant growth parameters were measured 45 days after sowing, when the transplants reached approximately the commercial transplanting size. The green colour intensity of leaves, related to the chlorophyll content, was measured using a Minolta SPAD-502 chlorophyll meter (Minolta, Osaka, Japan). The composition in nutrients of their aerial parts was assessed using the same methods described for the total elements in the substrates.

The statistical analysis of the results was carried out by ANOVA using Tukey's test for comparison of means of the root length and the germination percentages (data were normalised by transform 'arcsine of the square root') and using polynomial contrast comparisons for the vegetative parameters. All statistical analyses were performed using the Statgraphics Plus 5.1 software package.

3. Results and discussion

The most frequently cited problems with using compost in the growing medium for vegetable transplants include unstable or immature compost, high soluble salt concentrations and poor water-holding capacity. Both water-holding capacity and the ratio of water to air in the root medium after drainage are important for the production of quality transplants, and depend on the size and shape of the particles, and the height of the container.

As opposed to Pt, with a fibrous appearance, GM looks like a fine gravel, with approximately 50% of its particles measuring more than 2 mm. The thicker particles are those corresponding to seeds and rests of stalks, which were hardly altered during composting due to their lignocellulosic nature. Although there are only a few differences in effective porous space (PS) between GM and Pt (Table 1), the proportion of big pores is greater in GM, resulting in a greater aeration capacity (*A*), and lesser container capacity (Θcc), easily available water (EAW) and reserve water (RW). The physical interaction amongst fibrous and polyhedric particles in the mixtures of both substrates results in a change in pore geometry, leading to *A*, Θcc and EAW values that are not always intermediate between those of GM and Pt.

Similar physical characteristics (high *A* and low EAW and RW) were obtained by Bustamante et al. (2008b) in composts obtained by mixing GM and manure.

Excluding the content of total available water (EAW + RW), which is low, the rest of the physical properties of GM comply with the requirements recommended by Abad et al. (1999) in substrates for production of vegetable seedlings. In plug trays with small container, where drainage after watering is poor due to its low height (5–7 cm), low aeration of the substrate is a more limiting factor than a low retention of water, which could always be solved by more frequent watering. High aeration at 6 hPa suction might imply an advantage for its use as a substrate in plug seedling production.

The contents of total elements (Table 2) are of the same order of magnitude as those in vegetable wastes, except for the Ca and K values, which are somewhat low, and for the Fe value that, conversely, is very high. This may be due to the chemical