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Winery–distillery composts as partial substitutes of traditional growing media: Effect on the volatile composition of thyme essential oils

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ABSTRACT

The purpose of the experiment was to study the effects of the use of three different types of winery–distillery composts as substrate components for thyme (*Thymus vulgaris)* cultivation on the yield and composition of the essential oils present in this herb. A major component of the composts was exhausted grape marc combined with different quantities of one of the following co-composting wastes: citrus juice waste (for compost C1), tomato soup waste (for compost C2) or cattle manure (for compost C3). The substrates were prepared by mixing traditional peat–perlite mixture (PP) with increasing proportions of each respective compost (0%, 25%, and 50% by volume) and the physical and physico-chemical properties of the substrates were analyzed. The best results for the cultivation of thyme were obtained with the growing media prepared using composts derived from exhausted grape marc mixed with citrus juice waste (C1) or cattle manure (C3). Essential oils were extracted by hydrodistillation and analyzed using GC–MS and GC–FID. Forty-six volatile compounds were tentatively identified, with thymol, *p*-cymene, carvacrol, linalool and 1,8-cineole (eucalyptol) being the major compounds. The total concentration of volatiles in the control samples (29.6 g kg^{-1}) was significantly increased in treatment B (to 34.6 g kg^{-1}), consisting of compost C1 at the proportion 50% by volume, and treatment E (to 37.6 g kg^{-1}), made from compost C3 at the proportion 25% by volume, showing that the characteristics of the composts used as components of the growing media strongly affected the production of essential oils in the thyme plants.

1. Introduction

Thyme (*Thymus vulgaris* L.) of the Lamiaceae family is an herbal plant, native to the western Mediterranean region (Spain, France and Italy), where it is still found growing wild on rocky slopes. At present, thyme is cultivated all over Europe, in Caribbean countries, and in the US (Viuda-Martos et al., 2007; Balladin and Headley, 1999). It can be used whole or ground for food seasoning, as it contains a wide array of active phytochemicals (e.g., flavonoids, terpenes, polyphenols, curcumins and coumarins). Thyme not only enhances the flavor of foods, but it also improves their functional properties (Viuda-Martos et al., 2007).

The essential oils (products obtained from raw materials by water or steam distillation) are used on a wide scale in food, cosmetic and pharmaceutical industries (Rouatbi et al., 2007; Balladin and Headley, 1999) due to their antiseptic, carminative, antimicrobial, and antioxidant properties (Rouatbi et al., 2007; Nieto et al., 2010; Lee et al., 2005). The essential oils of more than 100 species of the genus *Thymus* have been investigated and about 360 volatile compounds have been isolated from this plant. Among them, monoterpenes are the most prominent group, while sesquiterpenes occur in trace amounts only. Generally, plants of the genus *Thymus* are considered the most common source of monoterpenoid phenols, i.e., thymol and carvacrol (Pavel et al., 2010). The ratio of these two phenols may have a major impact on the flavor of thyme seasoning (Nieto et al., 2010). Several chemotypes of thyme have been reported, e.g., carvacrol-type, thymol-type, linalool-type or geraniol-type (Pavel et al., 2010). On the other hand, volatile organic compounds, such as volatile terpenes, play an important role in

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tropospheric photochemistry by modifying the ozone budget and by increasing the yield of Secondary Organic Aerosols (Guenther, 2002) and their production is related with defence mechanisms used by plants to withstand numerous abiotic and biotic stress conditions and mediate ecological interactions with the biotic environment (Gershenzon and Dudareva, 2007).

On the other hand, there is a strong demand for alternative soilless substrates, which is steadily increasing due to environmental constraints. Hence, the use of compost, partially substituting substrate materials traditionally used, such as peat or perlite, seems to be a good solution from the economic standpoint, at the same time well-responding to sustainable development criteria (Ostos et al., 2008). Composts are high in nutrients and exhibit high ion exchange capacity, thus reducing the need for mineral fertilizer use through an increased fertigation efficiency (elevated retention of the nutrients in the potting media). Additionally, composts enhance the growth of plants, as they possess plant growth regulators (Atiyeh et al., 2001) and can present other positive properties such as the suppressiveness capacity against phytopathogens (Suárez-Estrella et al., 2007).

In addition, the increasing generation of wastes from the agro-food industry implies a potential environmental risk, due to the seasonal and polluting nature of these wastes that difficult their management and disposal. Winery and distillery, citrus and vegetable-processing industries in EU countries produce huge amounts of wastes, especially Spain, with approximately 48% of the world's olive oil production, 13.4% of the world's wine production and 7% of the world's citrus production.

Composts made from agricultural agro-industrial wastes are generally free of xenobiotics and low in heavy metals (Ntougias et al., 2008). Therefore, composting of the agro-food wastes, mainly from the winery–distillery industry, not only can be effective in the treatment of agricultural residues, minimising their environmental impact, but also it can constitute a environmentally-friendly alternative to traditional materials, such as perlite or peat, commonly used as growing media for plants.

Therefore, the main objectives of the present investigation were: (a) to determine the main physical and physico-chemical characteristics of the mixtures prepared with winery–distillery composts and peat–perlite to evaluate the suitability of these mixtures as growing media for the cultivation of thyme (*T. vulgaris* L.) and (b) to evaluate the effects of the composition of these mixtures on the volatile composition of essential oils present in the thyme plants.

2. Materials and methods

2.1. Compost elaboration

The growing media for thyme cultivation were elaborated using three different types of compost, each type containing exhausted grape marc, at a rate of 60% on a dry weight basis, as the major component, combined with 40% of either of the following wastes: citrus juice waste, tomato soup waste or cattle manure. In this way, three types of composts were prepared:

- Compost 1 (C1): exhausted grape marc + citrus juice waste (60:40),
- Compost 2 (C2): exhausted grape marc + tomato soup waste (60:40),
- Compost 3 (C3): exhausted grape marc + cattle manure (60:40).

The composting mixtures (about 1800 kg each) were composted in a pilot plant, in trapezoidal piles (1.5 m high with a base of 2 × 3 m), by the Rutgers static pile composting system, which maintains a temperature ceiling in the pile, involving on-demand ventilation through temperature feedback control. The bio-oxidative phase of the composting process was considered finished when the internal temperature of the compost pile was close to the external value and the heat exchange came to a standstill. The air-blowing was then stopped to allow the composts to mature over a period of two months. The moisture of the compost piles was monitored weekly by adding necessary water to obtain contents above 40%. The final composts displayed good chemical properties and an suitable degree of maturity, as it is shown in the following parameters (Bernal et al., 2009): total nitrogen contents >2% (C1 = 2.16; C2 = 2.25; C3 = 2.92); total organic carbon to total nitrogen ratio (TOC/TN) <20 (16.6 for C1, 16.8 for C2 and 14.5 for C3); cation exchange capacity (CEC) >60 meq 100 g^{-1} organic matter (C1 = 139, C2 = 153 and C3 = 163 meq 100 g^{-1}); CEC/TOC >1.9 meq g^{-1}, 2.54, 2.82 and 2.84 meq g^{-1} for C1, C2 and C3, respectively; water-soluble organic C < 1.5% (1.12% for C1, 1.04% for C2 and 1.25% for C3) and absence of phytotoxicity, according to the germination index (GI) >50% (73.8% for C1, 83.1% for C2 and 73.1% for C3).

2.2. Experimental design

The experiment was carried out on seven different growing media, consisting of traditional mixture of peat and perlite (PP) combined with increasing proportions, 25% or 50% (v/v) of the mature composts C1, C2 and C3. The mixture of perlite and peat was used as control treatment. The seven treatments can be summarized as:

- PP (100%): Control treatment.
- C1 (25%) + PP (75%): A.
- C1 (50%) + PP (50%): B.
- C2 (25%) + PP (75%): C.
- C2 (50%) + PP (50%): D.
- C3 (25%) + PP (75%): E.
- C3 (50%) + PP (50%): F.

Thyme (*T. vulgaris* L.), an aromatic herb, was grown in a heated greenhouse under controlled temperature (25 °C) conditions, at the Agricultural Experimental Station of the Instituto Valenciano de Investigaciones Agrarias (IVIA), located in Elche (Alicante, Spain). Commercial seedlings (4–5 cm tall) were planted in 1 L pots, containing either of the substrates. The growing media (treatments) elaborated were established in a completely randomised plot design (four replicates per treatment). The pots were watered regularly and the humidity in all the post was maintained gravimetrically at 50% of their field capacity throughout the experiment; also, no extra fertilization was applied. At the end of the experiment, on day 126, when the plants reached approximately the commercial transplanting size, all the plant material (shoots) were harvested and before washing and drying transplants to determine dry weight (at 60 °C in an air-forced oven for 72 h), fresh weight of the shoots of the thyme plants was determined.

2.3. Compost analyses

The physical properties of the substrates elaborated were determined according to the methods described by Bustamante et al. (2008). Electrical conductivity (EC) and pH of the substrates were measured in a water-soluble extract and suspension (1:5, v/v), respectively. The maturity-related characteristics of the composts were determined using the methods described by Bustamante et al. (2008). All the analyses were conducted in triplicate.