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Use of olive mill waste mix as peat surrogate in substrate for strawberry soilless cultivation

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ABSTRACT

The aim of paper was to evaluate the suitability of olive mill waste mixture (OMWM) as growth media for strawberry soilless cultivation. OMWM was used at the rate of 0, 25, 50, 75% (v/v) as peat substitute. In order to assess nutrient supply to plants by OMWM, the experimental design included fertigated (standard) and unfertigated sets. Some of the chemical and physical parameters of the growth media were analysed at the beginning and end of cultivation, while plant nutrient uptake was assessed by means of petiole- and leaf blade-tissue analyses for the main macro- (N, K, Ca, Mg, Na) and micro- (Fe, Mn, Zn, Cu) elements. Quantitative and qualitative assessments of yield were also made. Plants grown on OMWM amended substrate showed an initial slight phytotoxicity particularly at higher rate (75%) probably as a consequence of the high values of electrical conductivity recorded in the OMWM water extract. Successive water leaching caused by irrigation or fertigation reduced EC towards values compatible to strawberry cultivation. Yield data and tissues analyses showed that OMWM performed adequately as a substitute for peat and satisfied the plant nutrient needs in the fertigated trial. However, it appeared that nitrogen provided by OMWM was insufficient in achieving adequate yield in the unfertigated trial. The use of OMWM showed high compatibility in soilless strawberry cultivation being an effective and cheap alternative to peat; therefore, a realistic cost reduction for growers was evident. The relatively high amount of nutrients found in the growth media at the end of strawberry cultivation meant that it can be recycled in agriculture as soil amendment.

1. Introduction

Olive oil production worldwide poses several environmental challenges. Olive mills produce, within a short time large amounts of waste rich in polyphenols and high in organic load (Niaounakis and Halvadakis, 2006). It is a recalcitrant waste material high in biological and chemical oxygen demands and difficult to biodegrade. The lack of feasible and cost-effective management technology for olive mill waste (OMW) compounds this problem. Spreading OMW on farm lands may be a cost-effective solution to its disposal provided lack of suitable and accessible land close to the mill and high cost of transportation can be overcome (Altieri and Esposito, 2008).

Therefore, methods to transform OMW into value-added products, have recently received increasing attention (Felipó, 1996; Sequi, 1996). ISAFoM-CNR recently developed a new technology, named MATReFO (WO/2005/082814), which has the capacity to convert raw olive mill effluents into a non-leaching and non-odorous organic matter useful for agronomic applications. The MATReFO system involves mixing destoned olive husk with hygroscopic additives such as straw, wool waste, sawdust, olive leaves, twigs and olive pruning residues. This relatively dry organic product is subjected to a short period of aerobic storage and maturation before agronomic use.

MATReFO mixtures have been widely experimented as amendment in open field cultivations such as olive orchards and short term crops like tomato and lettuce, showing good yield and growth performances (Altieri and Esposito, 2008, 2010). Furthermore, MATReFO mixture was also tested successively as an ingredient in the preparation of substrate for the cultivation of *Agaricus bisporus* on a commercial-scale (Altieri et al., 2009).

The growing attention to environmental sustainability, the need to dispose of ever-increasing amounts of waste and reduce the consumption of nonrenewable resources have encouraged the use of agro-industrial by-products in agriculture. Examples of successful value-added organic waste recycling have been reported recently in literature where compost made from such organic wastes have been used as peat substitute in nursery cultivation

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(Bugbee, 2002; Papafotiou et al., 2004; Benito et al., 2005; Raviv et al., 2005; Grigatti et al., 2007; Caballero et al., 2009).

Peat is the most widely used substrate for potted plant production in nurseries and accounts for a significant portion of the materials used (Abad et al., 2001).

Because of concerns about destruction of peat bogs, other organic materials have been investigated for their potential as substitutes for peat in growing media used for container or soilless crops (Marfá et al., 2002). Some of them are characterized by high fertility. Macro- and micro-nutrient contents are important constituents in potting mix (Alburquerque et al., 2004) and OMW therefore presents itself as a potential ingredient for the production of growth media in nursery cultivation (Raviv et al., 2007).

The aim of this paper is to evaluate the use of OMW as a substitute for peat in the preparation of growth media for soilless cultivation of strawberries and assess its potential for nutrient supply and consequent reduction in fertilizer usage.

2. Materials and methods

OMW used in this work was sourced from a two-phase mill at the Cooperativa Nuova Cilento (S. Mauro Cilento, Salerno, Italy). According to MATReFO technology destoned OMW was mixed with hygroscopic organic waste in a prototype machine, as follows: 72% destoned OMW, 11% wool waste, 8.5% wheat straw and 8.5% sawdust (fresh weight). The olive mill waste mix (OMWM) was packaged in net sacks and stored outdoors on pallets in stacks under aerobic conditions and protected from rain to avoid leachate. After three months of storage, OMWM was used as peat substitute in the preparation of the strawberry (*Fragaria* × Ananassa Duch., cv Patty) cultivation medium.

2.1. Strawberry soilless cultivation technique

The strawberry soilless cultivation trial was conducted in Martorano, Cesena (eastern Po Valley, Italy, lat. 44°10′, long. 12°15′, alt. 23 m) using cold stored plants with crowns of 14 mm diameter (plants type A^+). The plantlets were grown in plastic trays (50 × 30 × 10 cm) under greenhouse condition to mimic soilless cultivation technique. The experimental design (Table 1) consisted of randomized complete blocks replicated three times. The plants were divided into two sets: 1) fertigated with a standard nutritive solution; 2) unfertigated: this set of plants was watered with a citric acid solution at the same pH (5.5–6.2) of the standard nutritive solution.

Set of plants fertigated received a nutritive solution derived from dilution (0.5–1% v/v) of the standard stock solution prepared (Table 2).

The standard stock solution was prepared using $CaNO_3$, EDTA-Fe, KNO_3, K_2SO_4, KH_2PO_4, $MgSO_4$, $MnSO_4$, $ZnSO_4$ $CuSO_4$, $Na_2B_4O_7$. Ca and Fe. They were mixed in separate tanks to prevent salt precipitation.

Fertigation and irrigation were carried out by means of a localized drip system, providing till 6 applications per day and maximum 20–25% water leaching per application; the number of applications was based on evapotranspiration and nutrient needs of the plants during the cultivation phases.

The trials were managed according to recommendations laid down for annual commercial crops published by Regione Emilia Romagna, Italy (2009) to avoid pathogens and pests diseases.

2.2. Substrate analyses

After three months of aerobic storage, OMWM samples were collected in triplicate for chemical, physical and biological analyses. Moisture content was determined as weight loss upon drying at 105 °C in an oven for 24 h. Electrical conductivity (EC) and pH were measured using water extract 1:10 (w/v). Ash content was determined on samples previously oven-dried at 105 °C and ashing at 650 °C for 24h in a muffle furnace. Total organic content (TOC) was determined by the Springer–Klee method and total nitrogen by the Kjeldhal method, both as reported in DI.VA.P.R.A (1992). Phosphorus (P) was measured after acid digestion and color-metering of phosphorus as molybdovanadate phosphoric acid (Murphy and Riley, 1962). Flame atomic absorption spectroscopy (Perkin Elmer, AAnalyst 200) was used to measure K, Ca, Mg, Na, Fe, Mn, Cu, Zn on acid digested samples. Water-soluble polyphenols were determined in water extracts (1:10 w/v) using Folin–Ciocalteu method as reported by Singleton et al., (1971). A protocol based on germination of *Lepidium sativum* L. was used for testing phytotoxicity of the OMWM: deionized water was added to samples to achieve 65% of water content (wet weight); they were shaken for 1 h and extracts obtained by centrifugation and filtration through a 0.45 micron membrane filter. The extracts were diluted (30%) and used as the germination medium. A Whatman filter paper (no. 42), placed inside a 9 cm Petri dish, was wetted by 1 ml of the medium and 9 seeds of *L. sativum* were placed on the paper. Pure deionized water was used as the control germination medium and five replicates were used for each treatment. The dishes were wrapped in Parafilm® M, to minimize water loss and allow air penetration, and kept in the dark for 42 h at 24 °C. At the end of incubation, the number of germinated seeds and primary root lengths were measured and expressed as percentage of the control (Germination Index).

The Dynamic Respiration Index (DRI) was determined according to UNI/TS 11184 method (2006). The Specific Oxygen Uptake Rate (SOUR) and Oxygen Demand (OD) were determined by measuring the changes in the concentration of dissolved oxygen in aqueous mixture suspension under condition ensuring optimum microbial activity and maximum reaction rates over a period of 24h (Lasardi and Stentiford, 1998). The SOUR was calculated by means of linear

Table 1
Experimental design of strawberry soilless cultivation trial conducted under fertigated and unfertigated conditions: plantlets were grown in plastic trays (1 tray = 1 plot = 6 plants).

Treatments
Control = 100% peat
25OMWM = 75% peat + 25% OMWM
50OMWM = 50% peat + 50% OMWM
75OMWM = 25% peat + 75% OMWM

Table 2
Standard stock solution of nutrients used, at 0.5 or 1% (v/v) dilution rate, for fertigation during different strawberry cultivation phases.

Phase		Vegetative	Productive
		macro-nutrients	
$N-NO_3^-$	g l^{-1}	5.5	6.2
P		4.7	5.4
K		14.6	24.4
Ca		6.6	5.7
Mg		3.7	3.1
S		4.9	6.5
		micro-nutrients	
Fe	mg l^{-1}	139.5	
Mn		37.0	
B		23.1	
Zn		13.4	
Cu		1.5	

pH of the nutrient solution was adjusted at 5.5–6.2 with HNO_3 30% (v/v) and electrical conductivity was kept at 1.4 and 1.2 dS m^{-1} during vegetative and productive phases, respectively.