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Rosemary growth and nutrient balance: Leachate fertigation with leachates versus conventional fertigation

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ABSTRACT

The free discharge of drainage water from greenhouse horticultural production to the environment is a current environmental concern due to its capacity to contribute to environmental pollution. This has led to the search of sustainable alternatives for its reuse in the production of other crops. However, before the large-scale use of such horticultural leachates in ornamental plants, the effects of such fertigation treatments on ornamental plants need to be evaluated. Plants of rosemary were grown in pots with a mixture of sphagnum peatmoss and Perlite and subjected to three fertigation treatments: T_0 (a standard nutrient solution or control), T_1 (raw leachates from *Cucumis melo*) and T_2 (a mixture of raw leachates from *C. melo* and tap water 1:1 v/v, over a period of 9 weeks. At the end of the experiment, the growth parameters, color of leaves as well as water and nutrient uptake efficiencies and their losses were assessed for each fertigation treatment. The total dry weight and the water use efficiency of rosemary plants decreased under the fertigation with raw and diluted leachates. In addition, rosemary plants were shorter compared to the control but there were no differences in leaf color between the fertigation treatments. The uptake of N, P and K were affected by the applied fertigation treatments in a different manner. The use of horticultural leachates in the production of ornamental plants (as shown here for melon and rosemary) is feasible and presents a viable option to reduce water and nutrient input in plant production.

1. Introduction

Greenhouse production on the southeastern (SE) Mediterranean coast of Spain is associated with appreciable negative impacts on water resources, especially through nutrient leaching losses resulting in an environmental pollution and aquifer overexploitation (Granados et al., 2013). Reviewing in previous literature, there are many references concerning the release of nutrients (g m^{-2}) in several horticultural crops such as tomato (28 (N), 1 (P), 6 (K)) in a mulching sandy soil and melon (6 (N), 0.03 (P), 7 (K)) and watermelon (16.5 (N), 1.4 (P), 16 (K)) in soilless systems (García-Caparrós et al., 2017a) and in ornamental plants such as *Cordyline fruticose* L. ((1.5 (N), 1.0 (P), 7 (K)) (Plaza, 2013), *Aloe vera* L. Burm, *Kalanchoe blossfeldiana* Poelln and *Gazania splendens* Lem (ranges from 0.5 to 1.5 (N), 0.3 to 0.6 (P) and 2 to 6 (K) (García-Caparrós et al., 2017b) and Rhododendron sp. (1 (N), 0.5 (P)) (Ristvey et al., 2007).

Greenhouse crops in closed hydroponic systems can substantially reduce the pollution of water resources, while contributing to a reduction in water and fertilizer consumption (Carmassi et al., 2005). Nevertheless, nearly all soilless cropping systems in the greenhouses of this area are free-draining, also known as “open”, systems that drain directly into underlying soil (Pardossi et al., 2004; Thompson et al., 2013). In these cropping systems, an appreciable proportion of the applied water is drained; drainage fractions are commonly between

Abbreviations: ANOVA, analysis of variance; DW, dry weight; EC, electrical conductivity; FW, fresh weight; H_2O_2, hydrogen peroxide; HPLC, high performance liquid cromatography; LSD, least significant difference; NUE, nitrogen uptake efficiency; PUE, phosphorous uptake efficiency; PAR, photosynthetically active radiation; KUE, potassium uptake efficiency; RH, relative humidity; LWR, relative leaf weight ratio; SWR, relative stem weight ratio; RWR, relative root weight ratio; RGB, red, green and blue; SBC, serial biological concentration; TDW, total dry weight

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20–40% (Schröder and Lieth, 2002). The recirculation of drainage is seldom mainly due to the high investment cost and the frequent replenishment of recirculating nutrient solutions due to the salinity of the groundwater used for irrigation (Magan et al., 2008). Another possible reasons for not recycling water and nutrients in greenhouse production systems include the concern of diseases produced by phytopathogens (Prenafeta-Boldú et al., 2017) and the risk of reduced yields (Grewal et al., 2011).

As a consequence, the study of different management strategies of reusing the drainage water is required in order to reduce the pollution generated by the drainage water. Among these strategies are the sequential reuse or the blending of the drainage (Grattan et al., 2012) with water or nutrient solution. The sequential reuse of the drainage is based on its utilization to grow increasingly salt tolerant crops while concentrating the drainage to a manageable level. This treatment system is known as Serial Biological Concentration (SBC) (Bethune et al., 2004). Blending is based on the combination of two sources of irrigation water to produce irrigation water of suitable quality while increasing the overall irrigation water supply (Grattan and Oster, 2003).

Rosemary (*Rosmarinus officinalis* L., Lamiaceae) is a perennial woody plant species, originating from the Mediterranean region, which currently can be found and cultivated in all continents as aromatic and ornamental plant (Díaz-Maroto et al., 2007). It is a shrub reaching up to 2 m of height with leaves and flowers with a strong characteristic fragrance due to the volatile compounds accumulated in peltate and capitate glandular trichomes (Ribeiro-Santos et al., 2015). Rosemary is well known for its resistance to drought stress (Munné-Bosch et al., 1999) and also for its relative tolerance to salt stress (Tounekti et al., 2008).

There is a little information on the effects of horticultural leachates on the growth of ornamental plants (Plaza et al., 2016, 2017). Similarly, even though there are many studies on the effects of different irrigation conditions or levels of salinity on the growth and nutrient concentrations in rosemary (Nicolás et al., 2008; Zhen et al., 2014; Langroudi and Sedaghathoor, 2012; Tounekti et al., 2011), very little is known about the effects of horticultural leachates on its growth. Therefore, in this trial, a pot experiment with rosemary plants was established in order to determine the effects of the reuse of leachates from melon production on biomass, water and nutrient uptake efficiencies and their losses. Such information can be used for optimizing the rosemary management with horticultural leachates and at the same time the production of horticultural and ornamental crops under different integrated management strategies.

2. Material and methods

2.1. Plant material and experimental conditions

The present study was carried out at the facilities of the University of Almeria (Spain) in two contiguous greenhouses (36°49´N, 2°24´W). One of the greenhouses was a multitunnel greenhouse of 400 m^2 with *Cucumis melo* L. plants (leachates source) whereas the other greenhouse used was a tunnel greenhouse of 150 m^2, where rosemary plants were cultivated.

Melon seedlings 'Abellan FI' were grown from 91 days between February and May 2014 into coir grow bag (Pelemix GB1002510 coir grow bag, 100·25·10 cm, L·H·W), with three plants per cultivation unit, a cultivation volume of 25 L and planting density of 1 plant m^{-2} following the recommendations established by Urrestarazu (2004).

Rooted cuttings of rosemary (20 cm high and 1.4 g of dry weight $plant^{-1}$ in average) were obtained from a local nursery and transplanted into 1.5 L polyethylene pots containing a mixture of sphagnum peat-moss and Perlite 80:20 (v/v). Rosemary cultivation started a month after the melon sowing and lasted 9 weeks. The planting density was 12 plants/m^2.

Average day temperature inside the rosemary greenhouse was 20.3 ± 2.3 °C, relative humidity (RH) 64.3 ± 3.5% and photosynthetically active radiation (PAR) 90.5 ± 9.1 µmol m^{-2} s^{-1} (monitored by HOBO SHUTTLE sensors, H 08-004-02).

2.2. Experimental design and treatments

The experiment was focused on the irrigation of rosemary plants with three different fertigation treatments: a standard nutrient solution (Sonneveld and Straver, 1994) namely the control treatment (T_0) and two sequential reuse treatments: one of them was composed of raw leachates from *C. melo* (T_1) and the other was a diluted leachate treatment prepared by blending the raw leachates from *C. melo* with 50% of tap water (T_2). The tap water had the following composition: 1.1, 3.5, 2.0, 1.4 and 2.6 mmol L^{-1} of S, Cl, Ca, Mg and Na, respectively; and EC was 0.9 dS m^{-1}. The plants were irrigated manually with a test tube and 40 mL of the respective solution was poured in each pot every day, totaling 2.5 L pot^{-1} $treatment^{-1}$. The experimental design consisted of three fertigation treatments, four blocks and four plants (pots) per block giving a total of 48 plants of rosemary.

2.3. Yield and water use efficiency in melon and rosemary

Eight cultivation units, each containing three melon plants, were randomly selected in the greenhouse and the fresh weight of marketable fruits of melon plants was recorded. Water use efficiency of melon plants represents the fresh weight of fruit per unit of applied water (expressed in kg m^{-3}). The volume of applied irrigation water during the 13 weeks of melon growth was 254.3 L m^{-2} producing 5.5 kg m^{-2} of fresh melon fruit, giving a water use efficiency of 22.1 kg of fresh melon fruit m^{-3} of applied irrigation water.

The water use efficiency in rosemary plants, expressed by grams of fresh weight (FW) per liter of water applied for each treatment was calculated as the difference between plant FW after 9 weeks and the initial plant FW divided by the volume of water applied during the experimental period.

2.4. Monitoring of irrigation and runoff water composition

The samples of nutrient solution applied to melon were collected weekly at the entry point of the greenhouse by collecting water from four of the drippers used to irrigate melon. Leachates were collected randomly from 4 collection trays (one tray per 2 cultivation units). The buckets for collecting nutrient solutions and the trays for collecting drainage were covered with white polyethylene sheeting to reduce incoming radiation thereby minimizing evaporation. Leachates from *C. melo* plants were collected weekly and then used to prepare fertigation treatments for rosemary plants. The leachate fraction obtained from melon production in our experiment was 28%.

To determine the volume of leachate from the rosemary plants, four pots were randomly selected. The leachate of each container was collected weekly by placing a plastic collection bucket under each pot. The buckets were tightly fitted to the pots to prevent evaporation of leachate between collection events and pots were also elevated to prevent them from sitting in the leachate.

Each sample of nutrient solution or leachate was composed by aliquots of 15 mL, filtered through 0.45 µm membrane filters and frozen until nutrient analyses were conducted. In each aliquot, the concentrations of NO_3^--N, $H_2PO_4^-$, and K^+ were determined by high-performance liquid chromatography (HPLC) [model 883 Basic IC Plus, anions ion exchange column model Metrosep A SUPP 4, cations ion exchange column model Metrosep C4 100, IC conductivity detector range (0–15,000 µS cm^{-1}); Metrohm, Herisau, Switzerland)] as described by Csáky and Martínez-Grau (1998). During the experimental growing period, nutrients supplied and leached per plant (in milligrams) were calculated by multiplying the nutrient concentration in the