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Original article

Growth and water use efficiency of potted *Murraya paniculata* as affected by irrigation system and container size

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Summary

Irrigation system and pot size can affect the growth and development of containerized ornamental crops. A greenhouse experiment was carried out from November 2011 till July 2012, in order to determine the influence of two irrigation systems (closed drip-irrigation or subirrigation) and two pot sizes (∅ 14 or 18 cm) on growth, chlorophyll content, leaf gas exchanges and water use efficiency (WUE) of potted *Murraya paniculata*. Subirrigation offered promising potential for *M. paniculata* when compared to drip-irrigation given the similar growth and the higher WUE. Lower variation of the electrical conductivity in the subirrigation in comparison to drip-irrigation represents a crucial aspect for the simplification of the nutrient solution management. Increasing the pot size from 14 to 18-cm diameter yielded plants with 156%, 30%, 43%, and 138% more shoot biomass, height, leaf number and area, respectively. Best performance of plants grown in 18 cm-pots was attributed to higher net photosynthesis and SPAD index (by 35% and 16%, respectively), suggesting that suitable manipulation of container volume and switching from drip-irrigation to subirrigation will yield high quality potted *M. paniculata* and improve WUE.

Keywords

closed loop system, drip-irrigation, photosynthesis, pot size, SPAD index, subirrigation

Significance of this study

What is already known on this subject?

- A wide range of closed soilless systems have been developed for potted ornamental plants. Drip-irrigation is the most common irrigation practice in potted ornamental and vegetable crops. Recently, there is a high interest in subirrigation as an efficient alternative to drip-irrigation systems for potted ornamental production.

What are the new findings?

- Subirrigation should be preferred due to similar biomass of drip-irrigation, higher WUE and less variation of EC in the nutrient solution leading to a simplification of nutrient management in closed soilless systems. The results also demonstrated that increasing container volume resulted in larger *Murraya paniculata* plants and higher WUE.

What is the expected impact on horticulture?

- These findings might play a crucial role in management decisions by growers, thereby contributing to enhanced ornamental production.

Introduction

Over the last three decades closed-loop soilless system has become more and more popular among horticultural growers, since this high-tech practice represents an effective tool to face recent and upcoming changes in legislation concerning water and nutrient management in Europe (Rouphael et al., 2004; Savvas et al., 2007; Katsoulas et al., 2015). A wide range of closed soilless systems have been developed for potted ornamental plants. Drip-irrigation is the most common irrigation practice in potted ornamental and vegetable crops (Rouphael et al., 2006, 2008). In closed systems based on drip irrigation, the water is generally distributed in excess, and consequently the nutrients not taken by the crop are removed from the substrate by drainage water and tend to accumulate in the recirculating nutrient solution, which has to be flushed out regularly, representing a negative environmental impact (Incrocci et al., 2006; Rouphael and Colla, 2009). Recently, there is a high interest in subirrigation as an efficient alternative to drip-irrigation systems for potted ornamental production (Cox, 2001; Rouphael et al., 2008; Cardarelli et al., 2010). In fact, subirrigation delivers nutrients in a uniform manner, offers greater flexibility in pot spacing and sizing, reduces the run-off of nutrients, simplifies the nutrient solution management, and increases the nutrient and water use efficiencies (Montesano et al., 2010). However, nutrient accumulation in the upper part of the media is a major handicap of this cultural technique, especially when high fertilizer rates or low quality water is used (Zheng et al., 2004).

In ornamental production, the size of the pots used or substrate volumes are crucial and play an important role on crop performance (Godoy and Cardoso, 2005; Davis et al., 2008). The use of smaller pots allows production of more plants on the same area unit. In this way, the cultivation area is used more effectively, the amount of substrate can be decreased and consequently the production costs are reduced. However, the use of small pots may also have disadvantages, arising from biological constraints. A small container implies a small quantity of available substrate per plant that may reduce plant growth, chlorophyll content, net photosynthesis, due to restrictions in water and nutrient availability (Hagen et al., 2013).

Murraya paniculata (L.) Jack, also known as Orange Jasmine, is an evergreen tropical shrub belonging to the family of *Rutaceae*, native in Southeast Asia. Potted orange jasmines are of major importance for the Italian ornamental plant industry due to the high demand of this product on national and European market (Olawore et al., 2005). Despite the importance of orange jasmine in ornamental production, to our knowledge no published data is available concerning the effects of irrigation system and pot sizes on morphological and physiological parameters of *M. paniculata*.

The aim of the current work was to assess the influence of irrigation system (drip-irrigation or subirrigation) and pot size (∅ 14 or 18 cm) on plant growth parameters, SPAD index, leaf gas exchanges and water use efficiency of potted *M. paniculata*. These findings might play a crucial role in management decisions by growers thereby contributing to enhanced ornamental production.

Materials and methods

Plant material, growth conditions and treatments

The experiment was carried out during 2011–2012, under greenhouse conditions at the Research Unit for Mediterranean Flower Species, Palermo, Italy (38°5'N, 13°30'E, 23 m above sea level). Six-month-old seedlings of *Murraya paniculata* (L.) Jack were planted in plastic pots of 14 cm and 18 cm diameter containing respectively 2 and 4 L of brown peat and perlite in a 2:1 volume ratio. Pots were placed on aluminum benches at a plant density of 9 and 7 plants m^{-2} for the 14 and 18-cm pots, respectively. Planting was accomplished in November 4, 2011. The experiment was laid out in a randomized complete-block design with three replications. Each replication consisted of one bench containing 20 plants (Figure 1). The treatments were defined by a factorial combination of two irrigation systems (drip-irrigation or subirrigation) and two pot dimensions (14 or 18 cm in diameter).

Nutrient solution management

The concentrations of ions in the irrigation water expressed as mM were: 0.6 mM Ca, 0.6 mM Mg, 0.4 mM K, 0.7 mM Na, and 0.4 mM Cl. Values of pH and electrical conductivity of the irrigation water were 6.6 and 0.41 dS m^{-1}, respectively. All plants were fed with the same nutrient solution having the following macro and micro composition: 12.8 mM NO_3-N, 1.6 mM P, 5.1 mM K, 3.0 mM Ca, 2.4 mM Mg, 20 µM Fe, 3.0 µM Cu, 3.0 µM Zn, 5.0 µM Mn, 18 µM B, 0.3 µM Mo. The electrical conductivity of the nutrient solution was 1.8±0.5 dS m^{-1}. When EC value of the recycled nutrient solution exceeded the threshold of 2.5 dS m^{-1}, water was added to the fresh nutrient solution in order to restore the EC value to the original starting point (1.8 dS m^{-1}). The pH of the nutrient solution was maintained between 5.8 and 6.3 by adding nitric acid. In both irrigation systems, the nutrient solution was pumped from independent tanks (one tank per replication) having a volume capacity of 60 L. In the closed drip irrigation system, the nutrient solution was supplied through one emitter per plant (flow rate of 2 L h^{-1}). The subirrigation system was equipped with a capillary mat and the nutrient solution was supplied through micro perforated hoses integrated into the mat. The excess of nutrient solution in both irrigation systems was captured and returned back to individual tanks for recirculation. In both systems, irrigation scheduling was performed using electronic low-tension tensiometers (Tensioswitch, Tensio-Technik, Germany) connected to an electronic programmer, that controlled irrigation based on substrate matric potential (Rouphael and Colla, 2005a). Tensiometers have been placed at about the midpoint of the pots. In each replication, two tensiometers were installed, and were located in different pots to provide a representative reading of the moisture tension. Tensiometers were connected to an electronic programmer that controlled the beginning (-5 kPa) and the end of irrigation (-1 kPa), which correspond to high and low tension set-points for the major part of substrates (Kiehl et al., 1992). The timing varied from 2–6 fertigations per day lasting 15–25 min for the subirrigation and from 3–7 fertigations per day of 1–3

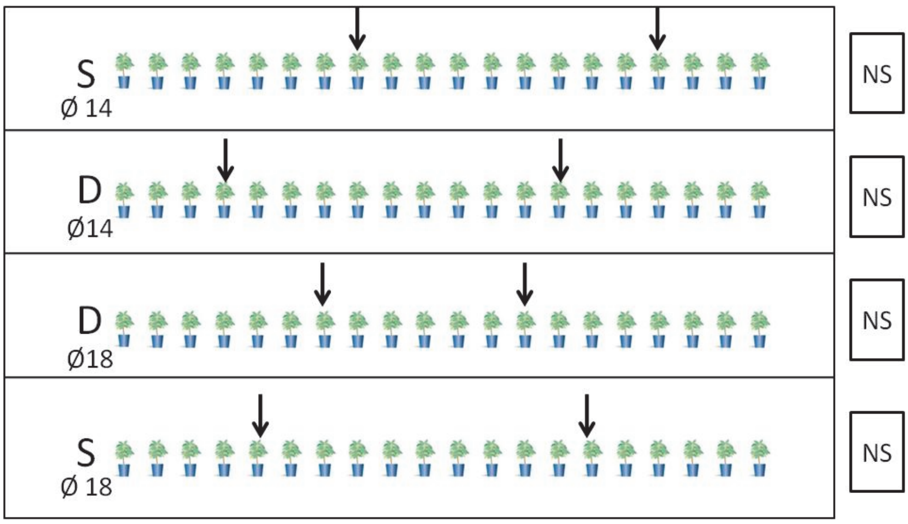

Figure 1. Experimental layout (one replication) was defined by a factorial combination of two irrigation systems: drip-irrigation (D) or subirrigation (S) and two pot dimensions (14 or 18 cm in diameter). Each replication consisted of one bench containing 20 plants. The nutrient solution (NS) was pumped from independent tanks having a volume capacity of 60 L. In each replication, two tensiometers (arrows) were installed to provide a representative reading of the substrate moisture tension.

min for the drip-irrigation. Nutrient solution supply with the drip-irrigation system ended when leachate was equal to 30% of nutrient solution applied; the 30% excess of the solution applied was collected for recycling. Typically, leaching fractions of 20–30% are needed to maintain the EC in the substrate at recommended level. In subirrigated pots at the end of each irrigation event, the substrate surface appeared to be wetted.

SPAD index and gas exchange measurements

At the end of the experiment (July 30, 270 days after transplanting), leaf chlorophyll was estimated by measuring the SPAD index on ten fully expanded leaves per replication, using a chlorophyll meter (SPAD 502, Konica Minolta Sensing, Inc., Osaka, Japan). Net CO_2 assimilation (A_{CO2}) and stomatal conductance (g_s) were also determined using a portable photosynthesis system (LI-6200; LI-COR Inc., Lincoln, NE, USA): measurements were made just before harvest on most recent fully expanded leaves between 10 am and 12 am on sunny day, using six replicate leaves per treatment. The LI-6200 was equipped with a stirred leaf chamber with constant-area inserts and fitted with a variable intensity red source (leaf temperature chamber was 30±2°C, leaf-air vapor pressure difference was 2.6±0.3 kPa, and CO_2 concentration was 365±10 µl L^{-1}).

Plant growth measurements

On July 31 (271 days after transplanting), ten plants per experimental unit were sampled and separated into leaves, stems, and roots. Dry mass of each organ was measured after oven-drying at 80°C for 72 h. The shoot dry mass was calculated as sum of leaf and stem dry mass. The final leaf area (LA) was measured using a digital area meter (WinDIAS 2; Delta-T Devices Ltd., Cambridge, U.K.). Plant height, number of leaves, length of the longest root, and root-to-shoot ratio were also recorded.

Water use and water use efficiency

Each day during the growing cycle, the nutrient solution in all independent tanks were brought to their initial volume to replace the water lost by evapotranspiration, and the volume of the refill fresh solution in the different tanks was determined by a flow-meter (Spagnol, Treviso, Italy). Water use efficiency (WUE) was calculated as total plant dry mass divided by the water losses due to evapotranspiration.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using SPSS statistical program and means were compared by Duncan's Multiple Range Test (DMRT) at P=0.05 significance level.

Results and discussion

Agronomical and physiological responses

Shoot and root dry mass, plant height, number of leaves per plant, total leaf area, SPAD index and stomatal conductance were not significantly influenced by the irrigation systems compared in the present trial (Tables 1 and 2). These results indicate that *Murraya paniculata* can be successfully grown in containers using subirrigation yielding plants of similar crop performance to drip-irrigation. The similarity in agronomical and physiological responses to subirrigation and drip-irrigation is in line with previous results recorded by Rouphael et al. (2008) and Cardarelli et al. (2010), who observed no differences in shoot and root dry mass of potted zonal geranium and petunia grown under closed subirrigation and drip-irrigation systems. It is well established that substrate electrical conductivity (ECs) may more increase with subirrigation than with drip irrigation (Pinto et al., 2008; Dumroese et al., 2011), due to the unidirectional flow of nutrient solution inside the subirrigated media leading to a progressive accumulation of salts in the upper portion of the substrate. The high EC_s in the substrate may negatively affect crop performance. This was not the case in the current study since no significant differences between the irrigations systems in EC_s were observed (data not shown). An explanation of this phenomenon could be the low NaCl concentration in the irrigation water, the moderate EC of the fertilizer solution adopted (1.8 dS m^{-1}), and also the growing season (winter-spring)

Table 1. Effects of pot size and irrigation system on shoot and root dry mass, root-to-shoot ratio (R/S), plant height, number of leaves, total leaf area, and root length of *Murraya paniculata* grown during the 2011–2012 season.

Pot size	Irrigation system	Shoot dry mass (g $plant^{-1}$)	Root dry mass (g $plant^{-1}$)	R/S	Plant height (cm)	Number leaves (no. $plant^{-1}$)	Leaf area (cm^2 $plant^{-1}$)	Root length (cm)
Ø 14 cm	Drip-irrigation	4.6	2.1	0.46	30.8	39.5	263	23.3
	Subirrigation	5.0	2.9	0.58	28.6	43.9	275	18.3
	Mean	*4.8 b*	*2.5 b*	*0.52*	*29.7 b*	*41.7 b*	*269 b*	*20.8*
Ø 18 cm	Drip-irrigation	13.6	6.1	0.44	38.2	61.3	734	25.8
	Subirrigation	11.0	7.4	0.67	39.3	58.1	551	23.9
	Mean	*12.3 a*	*6.7 a*	*0.55*	*38.7 a*	*59.7 a*	*643 a*	*24.8*
Significance[a]								
Irrigation system (I)		NS	NS	*	NS	NS	NS	NS
Pot size (P)		***	***	NS	*	*	**	NS
I × P		NS	NS	NS	NS	NS	NS	NS

characterized by a reduced evaporative demand of the environment (lower global radiation and air temperature), which contributed to keep the EC_s of subirrigated plants within the optimal range (1.25–2.25 dS m^{-1}) (Rouphael et al., 2008; Cardarelli et al., 2010).

Plants undergo many morphological and physiological modifications in response to reduced rooting volume which will affect consequently the crop performance (Poorter et al., 2012). In the current experiment, shoot and root dry mass, plant height, leaf number and area of *M. paniculata* plants increased by 156%, 168%, 30%, 43%, and 138%, respectively with increasing the pot size from 14 to 18-cm diameter (Table 1), in agreement with many greenhouse studies on vegetables and ornamentals such as potato, tomato, poinsettia, and white cedar (Derby and Hinesley, 2005; Goreta et al., 2008; Vanaei et al., 2008). Moreover, in a recent meta-analysis study Poorter et al. (2012) observed that on average, plants increased by 43% in weight for every doubling in pot size, with no significant differences in response between herbaceous and woody species. Reduced crop performance under root restricting conditions could possibly be due to the reduced rate of photosynthesis and thereby growth. The decrease (by 26%, Table 2) in net assimilation of CO_2 in response to decreased rooting volume was coupled with reduced leaf chlorophyll (by 14%, Table 2) in agreement with the findings of Kasai et al. (2012) on soybean. An explanation of the reduced photosynthesis is that pots of smaller dimensions can be placed at a higher density, with less available radiation (Poorter et al., 2012). Another possible cause of photosynthesis and growth differences in root restrictions experiments is nutrient availability: a smaller pot size will decrease the nutrient content in the pot, low N and P availability are known to decrease photosynthesis and consequently growth (Poorter et al., 2012).

Water use efficiency and electrical conductivity in the nutrient solution

Subirrigation has frequently been shown to reduce water consumption when compared to drip-irrigation (Rouphael and Colla, 2005b; Rouphael et al., 2008). In the present study, the water requirement was only affected (P<0.01) by the irrigation system, where the daily water use of *M. paniculata* with subirrigation (avg. 1.4 L $plant^{-1}$) was reduced by 26% compared with the drip-irrigation system (avg. 1.9 L $plant^{-1}$). These results are consistent with the findings of Rouphael et al. (2008) who reported an 11% water saving for subirrigated zonal geranium compared with drip-irrigated plants, whereas Rouphael and Colla (2005b) demonstrated a 20% reduction in water use for zucchini squash. WUE was higher in subirrigated plants than in drip-irrigated plants (Figure 2), whereas plants in 18 cm pots exhibited higher WUE than plants in 14 cm pots. Moreover, increasing the pot size from 14 to 18 cm diameter increased the WUE in drip-irrigation and subirrigation by 168% and 102%, respectively (Figure 2). These results indicate the importance of subirrigation for sustainability and efficient use of resources (e.g., water and nutrients), in agreement with a previous report of Rouphael and Colla (2005b), which is crucial in the Mediterranean areas, where water supplies are limited.

The EC of the recycled nutrient solution for subirrigated plants did not exceed the threshold (2.5 dS m^{-1}) in both pot sizes (Figure 3), whereas with drip-irrigation, the EC exceeded the maximum limit two times during the growing cycle, and water was added in order to restore the EC to the target values (Figure 3). The shorter variation of the EC in the nutrient solution supplied to subirrigated containers could be attributed to the minimal drainage from the containers, and consequently the accumulation of salts in the substrate rather than in the nutrient solution (Montesano et al., 2010). Reduced variation of EC represents an advantage which simplifies nutrient solution management in closed soilless systems.

Conclusions

As conclusive remarks, outcomes from the present study indicated that subirrigation should be preferred due to similar biomass production of drip-irrigation, higher WUE and less variation of EC in the nutrient solution leading to a simplification of nutrient management in closed soilless systems. The results also demonstrated that increasing container volume resulted in larger *M. paniculata* plants and higher WUE. The greater crop performance of plants grown in 18-cm pots was attributed to higher net assimilation rates and SPAD index. Even though the use of small pots will generally increase the number of plants produced and will reduce the cost for production, there were no particular benefits on vegetative growth and ornamental quality that could justify the use of 14-cm pots for *M. paniculata*.

Table 2. Effects of pot size and irrigation system on SPAD index, net CO_2 assimilation (A_{CO2}), and stomatal conductance (g_s) of *Murraya paniculata* measured before final harvesting (270 days after transplanting).

Pot size	Irrigation system	SPAD index	A_{CO2} (μmol CO_2 m^{-2} s^{-1})	g_s (mmol m^{-2} s^{-1})
Ø 14 cm	Drip-irrigation	51.8	7.0	55.1
	Subirrigation	46.1	5.1	34.5
	Mean	*48.9 b*	*6.0 b*	*44.8 b*
Ø 18 cm	Drip-irrigation	58.9	8.4	78.2
	Subirrigation	54.3	7.8	82.2
	Mean	*56.6 a*	*8.1 a*	*80.2 a*
Significance[a]				
Irrigation system (I)		NS	*	NS
Pot size (P)		*	**	**
I × P		NS	NS	NS

[a] NS, *, ** Nonsignificant or significant at P<0.05, and 0.01 respectively. Within columns, means followed by lower case letter are significant according Duncan's multiple range test. *P*=0.05.

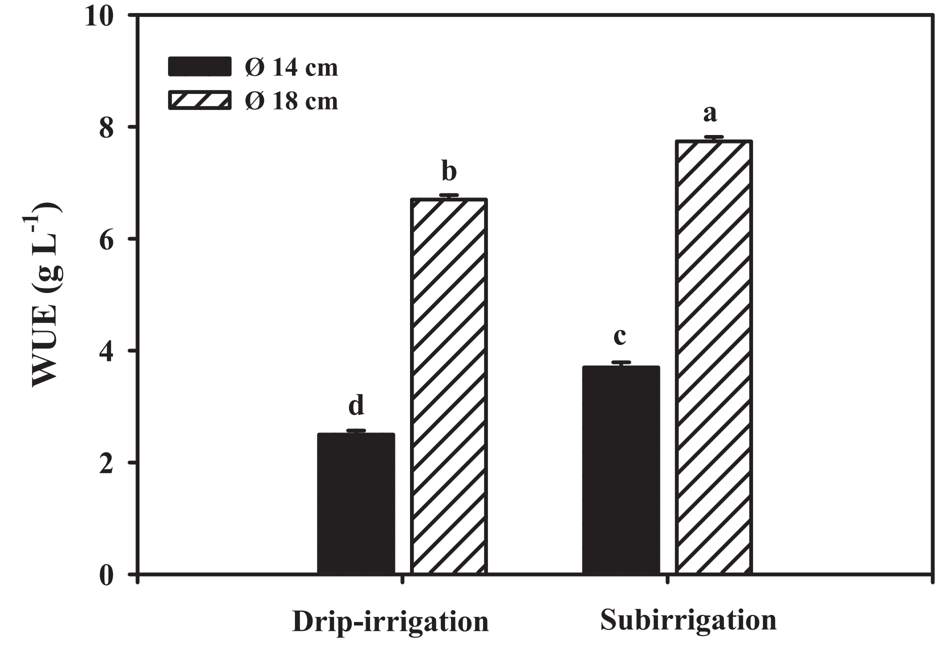

Figure 2. Effects of pot size and irrigation system on water use efficiency (WUE, total plant dry mass/water loss) of *Murraya paniculata* grown during the 2011–2012 season. Different letters indicate significant differences according to Duncan's test (P=0.05).

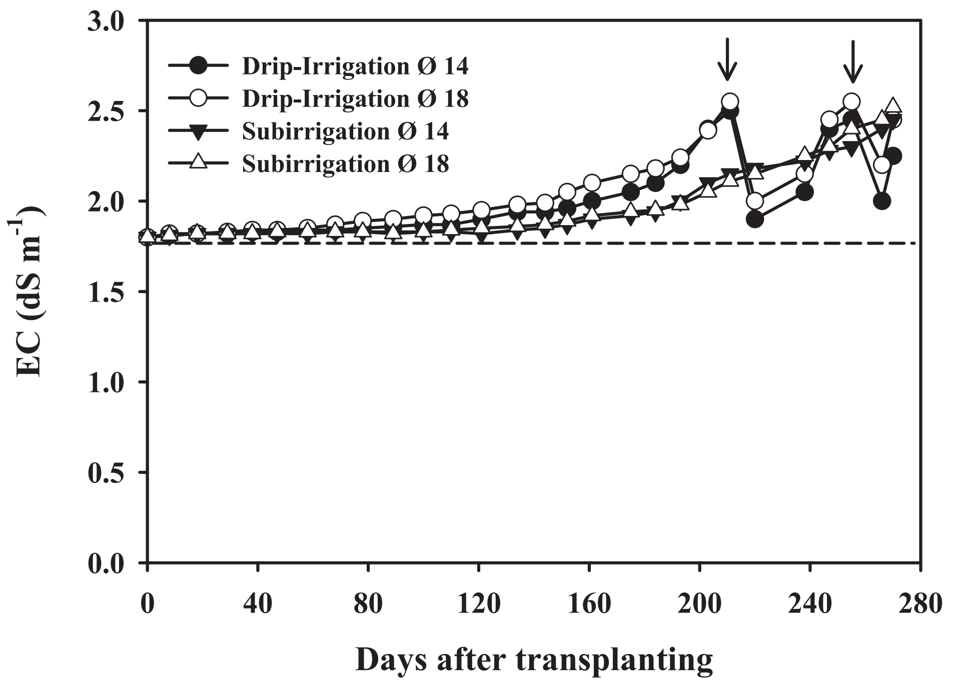

Figure 3. Changes in the electrical conductivity (EC) of the recirculating nutrient solution as affected by pot size and irrigation system of *Murraya paniculata* grown during the 2011–2012 season. The arrows indicate when the EC exceeded the threshold values of 2.5. The EC of the solutions was restored to the target value by adding water.

References

Cardarelli, M., Rouphael, Y., Rea, E., Salerno, A., and Colla, G. (2010). Nutrient solution concentration and growing season affect growth and quality of potted petunia in a recirculating subirrigation and drip-irrigation system. J. Food Agric. Environ. *8*, 312–320.

Cox, D.A. (2001). Growth, nutrient content, and growth medium electrical conductivity of poinsettia irrigated by subirrigation or from overhead. J. Plant Nutr. *24*, 523–533. http://dx.doi.org/10.1081/PLN-100104977.

Davis, A.S., Jacobs, D.F., Overton, R.P., and Dumroese, R.K. (2008). Influence of irrigation method and container type on northern red oak seedling growth and media electrical conductivity. Native Plants J. *9*, 4–13. http://dx.doi.org/10.2979/NPJ.2008.9.1.4.

Derby, S.A., and Hinesley, L.E. (2005). Growth of Atlantic white cedar seedlings as affected by container volume, substrate, fertilizer, and water regime. HortScience *40*, 1755–1759.

Dumroese, R.K., Davis, A.S., and Jacobs, D.F. (2011). Nursery response of Acacia koa seedlings to container size, irrigation method, and fertilization rate. J. Plant Nutr. *34*, 877–887. http://dx.doi.org/10.1080/01904167.2011.544356.

Godoy, M.C., and Cardoso, A.I.I. (2005). Cauliflower production depending on age of seedling and cell size of trays. Hort. Brasil. *23*, 837–840.

Goreta, S., Batelja, K., and Perica, S. (2008). Growth of poinsettia as affected by cultivar, thinning, and pot size. HortTech. *18*, 122–129.

Hagen, E., Nambuthiri, S., Fulcher, A., and Geneve, R. (2013). Comparing substrate moisture-based daily water use and on-demand irrigation regimes for oak leaf hydrangea plants grown in two container sizes. Acta Hort. *1014*, 160–162. http://www.actahort.org/books/1014/1014_34.htm.

Incrocci, L., Malorgio, F., Della Bartola, A., and Pardossi, A. (2006). The influence of drip irrigation or subirrigation on tomato grown in closed-loop substrate culture with saline water. Sci. Hort. *107*, 365–372. http://dx.doi.org/10.1016/j.scienta.2005.12.001.

Kasai, M., Koide, K., and Ichikawa, Y. (2012). Effect of pot size on various characteristics related to photosynthetic matter production in soybean plants. Int. J. Agron. Vol. 2012, 1–7. http://dx.doi.org/10.1155/2012/751731.

Katsoulas, N., Savvas, D., Kitta, E., Bartzanas, T., and Kittas, C. (2015). Extension and evaluation of a model for automatic drainage solution management in tomato crops grown in semi-closed hydroponic systems. Comp. Electron. Agric. *113*, 61–71. http://dx.doi.org/10.1016/j.compag.2015.01.014.

Kiehl, P.A., Lieth, J.H., and Burger, D.W. (1992). Growth response of chrysanthemum to various container medium moisture tension levels. J. Am. Soc. Hort. Sci. *117*, 224–229.

Montesano, F., Parente, A., and Santamaria, P. (2010). Closed cycle subirrigation with low concentration nutrient solution can be used for soilless tomato production in saline conditions. Sci. Hort. *124*, 338–344. http://dx.doi.org/10.1016/j.scienta.2010.01.017.

Olawore, N.O., Ogunwande, I.A., Ekundayo, O., and Adeleke, K.A. (2005). Chemical composition of the leaf and fruit essential oils of *Murraya paniculata* (L.) Jack. (Syn. *Murraya exotica* Linn.). Flavour Frag. J. *20*, 54–56.

Pinto, J.R., Chandler, R., and Dumroese, R.K. (2008). Growth, nitrogen use efficiency, and leachate comparison of subirrigated and overhead irrigated pale purple coneflower seedlings. HortScience *42*, 897–901.

Poorter, H., Bühler, J., Van Dusschoten, D., Climent, J., and Postma, J.A. (2012). Pot size matters: a meta-analysis of the effects of rooting volume on plant growth. Funct. Plant Biol. *39*, 839–850. http://dx.doi.org/10.1071/FP12049.

Rouphael, Y., Colla, G., Battistelli, A., Moscatello, S., Proietti, S., and Rea, E. (2004). Yield, water requirement, nutrient uptake and fruit quality of zucchini squash grown in soil and closed soilless culture. J. Hort. Sci. Biotech. *79*, 423–430.

Rouphael, Y., Colla, G. (2005a). Radiation and water use efficiencies of greenhouse zucchini squash in relation to different climate parameters. Eur. J. Agron. *23*, 183–194. http://dx.doi.org/10.1016/j.eja.2004.10.003.

Rouphael, Y., and Colla, G. (2005b). Growth, yield, fruit quality and nutrient uptake of hydroponically cultivated zucchini squash as affected by irrigation systems and growing seasons. Sci. Hort. *105*, 177–195. http://dx.doi.org/10.1016/j.scienta.2005.01.025.

Rouphael, Y., Cardarelli, M., Rea, E., Battistelli, A., and Colla, G. (2006). Comparison of the subirrigation and drip-irrigation systems for greenhouse zucchini squash production using saline and non-saline nutrient solutions. Agric. Water Mgt. *82*, 99–117. http://dx.doi.org/10.1016/j.agwat.2005.07.018.

Rouphael, Y., Cardarelli, M., Rea, E., and Colla, G. (2008). The influence of irrigation system and nutrient solution concentration on potted geranium production under various conditions of radiation and temperature. Sci. Hort. *118*, 328–337. http://dx.doi.org/10.1016/j.scienta.2008.06.022.

Rouphael, Y., and Colla, G. (2009). The influence of drip-irrigation or subirrigation on zucchini squash grown in closed-loop substrate culture with high and low nutrient solution concentrations. HortScience *44*, 306–311.

Savvas, D., Mantzos, N., Barouchas, P.E., Tsirogiannis, I.L., Olympios, C., and Passam, H.C. (2007). Modelling salt accumulation by a bean crop grown in a closed hydroponic system in relation to water uptake. Sci. Hort. *111*, 311–318. http://dx.doi.org/10.1016/j.scienta.2006.10.033.

Vanaei, H., Kahrizi, D., Chaichi, M., Shabani, G., and Zarafshani, K. (2008). Effect of genotype, substrate combination and pot size on minituber yield in potato (*Solanum tuberosum* L.). American-Eurasian J. Agric. Envir. Sci. *3*, 818–821.

Zheng, Y., Graham, T., Richard, S., and Dixon, M. (2004). Potted gerbera production in a subirrigation system using low-concentration nutrient solutions. HortScience *39*, 1283–1286.

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