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Water and Nutrient Balance in an Ornamental Cascade Cropping System

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Abstract: Seedlings of *Chrysalidocarpus lutescens*, *Dracaena deremensis* and *Dracaena marginata* were grown in plastic containers filled with sphagnum peat-moss to assess the effects of three different water systems on plant growth, water saving and nutrient removal during the experimental period. The experiment lasted for 8 weeks and consisted of three water systems. These consisted of an open draining system fertigated with a standard nutrient solution (system T_0) and two closed systems: sequential reuse of the leachate (system T_1) and sequential reuse of the leachate with the addition of H_2O_2 (system T_2). Over the course of the experiment, samples of water and supplies generated in each water treatment were collected weekly, and from these data water volume and nutrient loads were calculated. The addition of H_2O_2 to the leachate resulted in an enhancement in plant dry weight in *Dracaena deremensis* and *Dracaena marginata.* Regarding anion loads (Cl^-, $NO_3{}^-$, $H_2PO_4{}^-$, $SO_4{}^{2-}$) in these water systems, there was a removal rate of 42%, 28%, 27% and 28%, respectively, in the closed systems compared to the open system. For the cation loads (Na^+, K^+, Ca^{2+} and Mg^{2+}) in these water systems, there was a removal rate from 28% to 29%, respectively, in the closed systems compared to the open system.

Keywords: biomass; closed draining system; *Dracaena deremensis*; *Dracaena marginata*; open draining system; water saving

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1. Introduction

The increasing surface of greenhouses in Southern Europe and the Mediterranean region has led to several side effects such as environmental pollution, mainly associated with the release of water and nutrients as wastewater into the environment [1,2]. This has become even more aggravated, since the majority of soilless cropping systems in the greenhouses in this area are open or free draining—draining the leachate directly into the soil [3,4]. The leakage of nutrients, such as nitrate and phosphorous, from fertigation in greenhouses into the environment is usually greater than the thresholds established by environmental guidelines, causing the contamination of water resources [5,6].

High-tech, sophisticated greenhouse systems can obtain a return in the use of inputs such as water and nutrients, through, for instance, the collection of the drainage generated by a crop for further irrigation in another, or the same crop [7,8]. Nevertheless, the implementation of this type of methodology has several disadvantages, such as the high investment cost and the continuous replenishment of recirculating nutrient solutions due to the increasing electrical conductivity of the groundwater used for irrigation [9,10]. Moreover, reduced yields associated with the increase in salinity in the root zone, and the risk of pathogen propagation throughout the fertigation system, entail more drawbacks for its implementation [11,12]. Another management strategy for reusing the drainage and reducing the pollution generated is the sequential reuse of the leachate to irrigate increasingly salt-tolerant crops [13]. This fertigation strategy is known as a cascade cropping system, and it is based on the collection of the drainage from beneath one crop to fertigate the salt-tolerant crop that is above it in the series, aiming to almost entirely reduce the volume of leachate of the last crop [14]. It is worth mentioning that in this fertigation system, each subsequent crop must be able to tolerate the accumulated salts from the previous crop in order to avoid plant damage and death [15].

Although the implementation of this type of growing system (cascade cropping) is still in its early stages, based on recent literature, there are some models with different combinations of open and closed systems. For instance, Muñoz et al. [16] conducted an experiment with horticultural crops in which beef tomato was the donor crop, or the first stage of the cascade cropping system, and lettuce, tomato and endive were then the receiving crops, or second stage of the cascade cropping system. Similarly, García-Caparrós et al. [17] conducted a cascade cropping system that involved simultaneously growing one horticultural and one ornamental species, with *Cucumis melo* being the donor crop and *Rosmarinus officinalis* the receiving crop. Analogously, Plaza et al. [18,19] carried out an experiment with *Citrullus lanatus* being the donor crop and *Cordyline fruticose* the receiving crop. In this latter experiment with horticultural and ornamental species, the differences between an open and closed systems under the implementation of the cascade cropping system were also assessed.

Besides the disinfectant power of hydrogen peroxide, its employment in irrigation water or fertigation to improve oxygenation in the root zone is increasing among growers, since it improves both the yield and the crop quality [20–22]. Nevertheless, there is little information about the supplies of H_2O_2 in an ornamental cascade cropping system and its effects on crops. Therefore, in this study, a pot experiment with *Chrysalidocarpus lutescens*, *Dracaena deremensis* and *Dracaena marginata* was established in order to discern the effects of different water treatments on plant growth, water saving and nutrient removal under cascade cropping systems, including the application of H_2O_2 in fertigation treatment.

2. Materials and Methods

2.1. Plant Material and Growing Conditions

Previous experiments with similar conditions were conducted with the same species in the facilities of the University of Almeria (36°49′ N, 2°24′ W). Seedlings of *Chrysalidocarpus lutescens*, *Dracaena deremensis* and *Dracaena marginata* were purchased from a local nursery and then transplanted into 1.5 L plastic containers filled with sphagnum peat-moss. The climatic conditions during the experimental period were recorded with HOBO SHUTTLE sensors (model H 08-004-02, Onset Computer Crop., Bourne, MA, USA). The recordings reported an average temperature of 16.5 ± 1.5 °C, a relative humidity (RH) of 55.6 ± 2.9%, and photosynthetically active radiation (PAR) of 55.4 ± 4.4 µmol m^{-2} s^{-1}. All the experiments lasted for 8 weeks following the advice given by local nursery growers to produce saleable plants of all three species.

2.2. Experimental Water Systems

The experiment consisted of three water systems. These included an open draining system fertigated with a standard nutrient solution (system T_0), and two closed systems: sequential reuse of the leachate (system T_1) and sequential reuse of the leachate with the addition of H_2O_2 (system T_2). Each water system consisted of four replicates with four plants (one plant per pot) per species, and stage with a planting density of 6 plants per m^2. In the T_0 water system, seedlings of each species were fertigated with a standard nutrient solution for ornamental plants (fertigation treatment 1) recommended by Jimenez and Caballero [23]. In the two closed systems, *C. lutescens* plants (first stage) were fertigated with the standard nutrient solution (fertigation number 1), but in each closed system the leachate generated by this species was used in a different way. In water system (T_1), the sequential reuse treatment, the drainage of *C. lutescens* plants (fertigation number 2) was used directly to fertigate *D. deremensis*, from which the drainage generated (fertigation number 3) was reused to fertigate *D. marginata*. In the case of T_2, fertigation numbers 2 and 3 were supplied with H_2O_2 (1.2 M) at 1% (*v*/*v*) to result in fertigation treatments numbers 4 and 5, respectively (Figure 1).

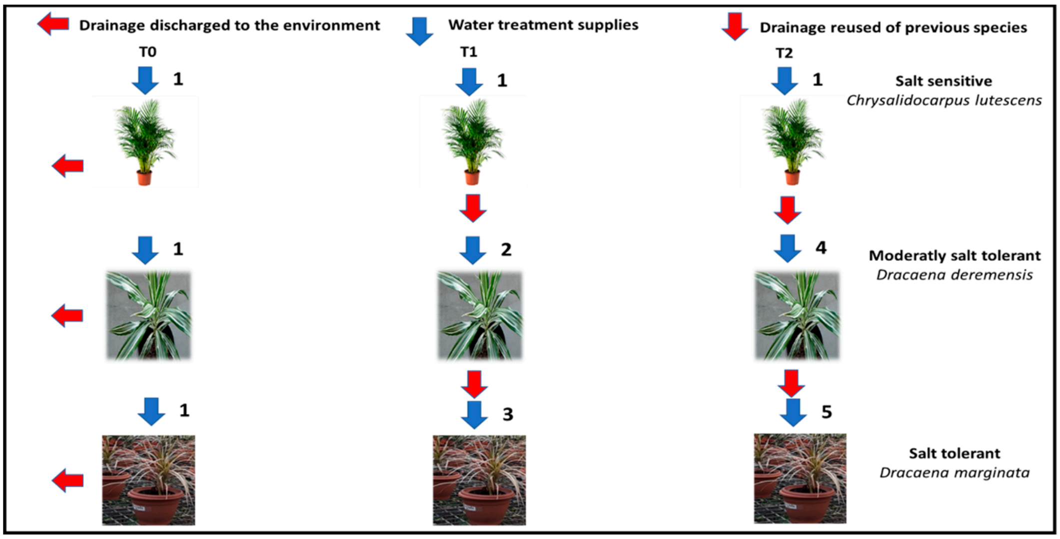

Figure 1. Schematic layout of the different water treatments. Number 1: standard nutrient solution; number 2: drainage from fertigation of *C. lutescens* fertigated with nutrient solution; number 3: drainage from fertigation of *D. deremensis* fertigated with water number 2 used to fertigate *D. marginata*; number 4: drainage from fertigation of *C. lutescens* fertigated with nutrient solution supplied with H_2O_2; number 5: drainage from fertigation of *D. deremensis* fertigated with water number 4 supplied with H_2O_2 used to fertigate *D. marginata*.

2.3. Chemical Composition of Fertigation Treatments

Collection of the drainage discharged by each species in the different fertigation treatments was performed weekly. The nutrient solutions and drainage samples consisted of 5 mL aliquots, filtered using membrane filters (0.45 µm), and frozen for further analysis. To determine the pH and EC values of the samples obtained, both a pH meter and a conductivity meter were used (models Milwaukee pH52 and C66) (Milwaukee Instruments, USA), respectively. The determination of the chemical composition of the nutrient solution or drainage (anions and cations concentration) was performed 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 mS cm^{-1}); Metrohm, Herisau, Switzerland)) as described by Csaky and Martinez-Grau [24].

After recording these determinations, and together with the values of volume noted for the nutrient solution and drainage generated (expressed in L m^{-2}), the amounts of nutrient supplied and discharged from each crop (expressed in grams per m^{-2}) were calculated by multiplying them. The comparison between the water systems was conducted taking into account the distribution ratio of each water system and the planting density.

2.4. Model Development

The comparison between the water treatments required the determination of the number of plants and the water supplies needed in each water system, which were calculated following the equations given by Garcia-Caparros et al. [17,25]. Data used for the model and its calibration were collected from previous experiments conducted under similar conditions.

From the results obtained in these experiments, the following equations were defined in order to determine the number of plants needed in each stage of the different water Treatments (1), and the nutrient solution supplies for the species in each stage of the different drainage water Treatments (2):

$$P_i = \frac{P_{i-1} \times Wupt_{i-1} \times Xlea_{i-1}}{Wupt_i \times (1 + Xlea_i)} \quad (1)$$

$$Wsup_i = \sum_{i=1}^{n} P_i \times Wupt_i \quad (2)$$

The use of subscript ($_{i-1}$) refers to the previous stage in the different drainage water systems.

The main inputs of this model are the following: water uptake of the species in each stage of the different water systems ($Wupt_i$), and the percentage of leachate in the previous stage of the different drainage water systems ($Xlea_i$). The main outputs of the model are the number of plants needed in each stage of the different drainage water systems (P_i), and water supply for the species in each stage of the different drainage water systems ($Wsup_i$).

Finally, with the values obtained using Equations (1) and (2), the distribution ratio (DR) was determined. In our experiment, the results obtained showed that the distribution ratio (DR) of each species (expressed as number of plants per m^2) that can be simultaneously grown in each water system was 1/1.34/0.42 for both system T_1 and T_2, which was also applied to T_0 to compare the data recorded between the different water systems.

2.5. Statistical Analysis

The experiment was analysed as a completely randomized block design, where the values obtained were considered as independent replicates. Unifactorial variance (ANOVA) was performed, and Fisher's Least significant difference (LSD) tests ($p < 0.05$) were used to assess the differences between the water treatments. All the statistical analyses were performed using Statgraphics Centurion XVI.II (Statpoint Technologies, Inc., Warrenton, VA, USA).

3. Results

3.1. Chemical Composition of Fertigation Treatments

The chemical composition of the fertigation treatments showed a significant increase in the pH and EC of fertigation treatments Nos. 2, 3, 4 and 5 compared to fertigation treatment No. 1, mainly associated with the increase in concentrations of Cl^-, NO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+} (Table 1).

Table 1. Chemical composition of the fertigation treatments. Electrical conductivity (EC) was expressed in dS m^{-1} and nutrient concentration in mmol L^{-1}. Treatment number 1: standard nutrient solution; number 2: drainage from fertigation of *C. lutescens* fertigated with nutrient solution; number 3: drainage from fertigation of *D. deremensis* fertigated with water number 2 used to fertigate *D. marginata*; number 4: drainage from fertigation of *C. lutescens* fertigated with nutrient solution supplied with H_2O_2; number 5: drainage from fertigation of *D. deremensis* fertigated with water number 4 supplied with H_2O_2 used to fertigate *D. marginata*. Data represent the means ± standard deviation of four samples per treatment. For water numbers 2–5, the values are the average values of the different chemical parameters assessed weekly during the experimental period. In each row, different letters indicate significant differences ($p < 0.05$).

Parameters	1	2	3	4	5
pH	6.60 ± 0.10 b	7.96 ± 0.11 a	8.03 ± 0.08 a	7.88 ± 0.12 a	8.12 ± 0.08 a
EC	1.90 ± 0.12 b	4.55 ± 0.24 a	5.11 ± 0.45 a	4.61 ± 0.25 a	5.21 ± 0.42 a
Cl^-	3.50 ± 0.11 b	20.94 ± 2.85 a	25.98 ± 2.50 a	20.88 ± 2.63 a	25.93 ± 2.41 a
NO_3^-	6.05 ± 0.51 b	15.87 ± 1.61 a	16.26 ± 1.61 a	14.32 ± 1.54 a	15.98 ± 1.53 a
$H_2PO_4^-$	0.70 ± 0.06 a	0.30 ± 0.03 b	0.78 ± 0.05 a	0.26 ± 0.03 b	0.75 ± 0.05 a
SO_4^{2-}	2.01 ± 0.04 a	1.69 ± 0.09 b	2.03 ± 0.15 a	1.68 ± 0.11 b	2.11 ± 0.09 a
Na^+	2.60 ± 0.08 b	12.12 ± 0.88 a	12.05 ± 1.14 a	12.28 ± 0.98 a	11.96 ± 1.10 a
K^+	3.08 ± 0.06 b	8.14 ± 0.50 a	8.82 ± 0.70 a	8.18 ± 0.45 a	8.76 ± 0.74 a
Ca^{2+}	2.03 ± 0.05 b	9.55 ± 0.55 a	9.41 ± 0.78 a	9.53 ± 0.54 a	9.55 ± 0.85 a
Mg^{2+}	1.41 ± 0.04 b	4.44 ± 0.38 a	5.19 ± 0.48 a	4.40 ± 0.32 a	5.24 ± 0.50 a

3.2. Plant Biomass

Fertigation of *D. deremensis* and *D. marginata* with T_1 resulted in a decline of 13% and 20% in DW, respectively, compared to the control treatment (T_0), whereas the fertigation of these species with T_2 resulted in a significant increase of 16% and 18% in DW, respectively, compared to T_0 (Table 2).

Table 2. Biomass itemized by species plants under the three water treatments considering the respective distribution ratio (DR) of the number plants of the three species. In each column, different letters indicate significant differences ($p < 0.05$).

		Dry Weight (g)		
	Systems	***C. lutescens***	***D. deremensis***	***D. marginata***
DR (1:1.34:0.42)	T_0	125.91 ± 12.01 a	14.20 ± 0.95 a	2.93 ± 0.21 a
	T_1	125.91 ± 12.01 a	12.28 ± 0.73 b	2.34 ± 0.18 b
DR (1:1.34:0.42)	T_0	125.91 ± 12.01 a	14.20 ± 0.95 b	2.93 ± 0.21 b
	T_2	125.91 ± 12.01 a	16.48 ± 1.13 a	3.45 ± 0.24 a

System (T_0) is an open draining system fertigated with standard nutrient solution and two closed systems (sequential reuse of the leachate (system T_1) and sequential reuse of the leachate with the addition of H_2O_2 (system T_2).

3.3. Application of Model Development to Water and Nutrient Management

Considering the water volume and nutrient loads of each system, systems T_1 and T_2 both consumed 45.2 L m^{-2}, resulting in a water saving of 28% compared to T_0 (62.9 L m^{-2}). The T_0 system generated a leachate volume of 17.7 L m^{-2}, whereas neither T_1 nor T_2 generated any leachate.

The anion loads in the drainage were also calculated; comparing T_1 and T_2 with T_0, there was a removal of 42% of Cl^- (9.7 g m^{-2} in T_0 and 5.6 g m^{-2} in T_1 and T_2), 28% of NO_3^- (23.4 g m^{-2} in T_0 and 16.8 g m^{-2} in T_1 and T_2), 27% of $H_2PO_4^-$ (4.2 g m^{-2} in T_0 and 3.1 g m^{-2} in T_1 and T_2), and 28% of SO_4^{2-} (12.1 g m^{-2} in T_0 and 8.6 g m^{-2} in T_1 and T_2), respectively. There was no generation of pollution in T_0, whereas in T_1 and T_2 there was a discharge to the environment of 12.5 g m^{-2} of Cl^-, 11.6 g m^{-2} NO_3^-, 1.3 g m^{-2} of $H_2PO_4^-$ and 2.7 g m^{-2} SO_4^{2-}.

As for the cation loads, the comparison of T_1 and T_2 against T_0 reported that there was a removal of 28% Na^+ (3.8 g m^{-2} in T_0 and 2.7 g m^{-2} in T_1 and T_2), 28% K^+ (7.4 g m^{-2} in T_0 and 5.3 g m^{-2} in T_1 and T_2), 28% Ca^{2+} (5.0 g m^{-2} in T_0 and 3.6 g m^{-2} in T_1 and T_2), and 29% Mg^{2+} (2.1 g m^{-2} in T_0 and 1.5 g m^{-2} in T_1 and T_2), respectively. There was no generation of pollution in T_0, whereas in T_1 and T_2 there was a discharge to the environment of 3.8 g m^{-2} of Na^+, 4.3 g m^{-2} of K^+, 4.6 g m^{-2} of Ca^{2+} and 1.8 g m^{-2} of Mg^{2+}(Figure 2).

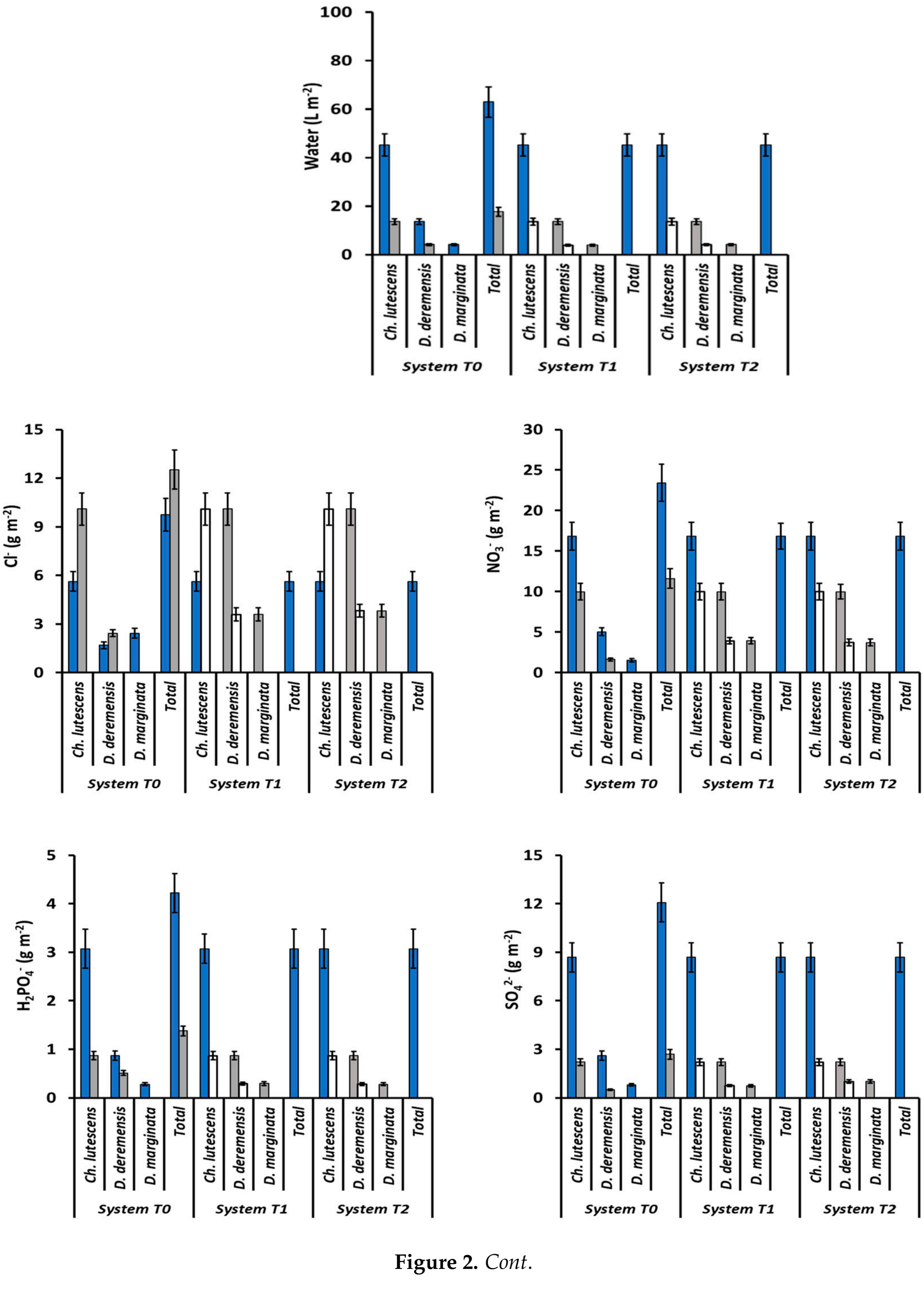

Figure 2. *Cont.*

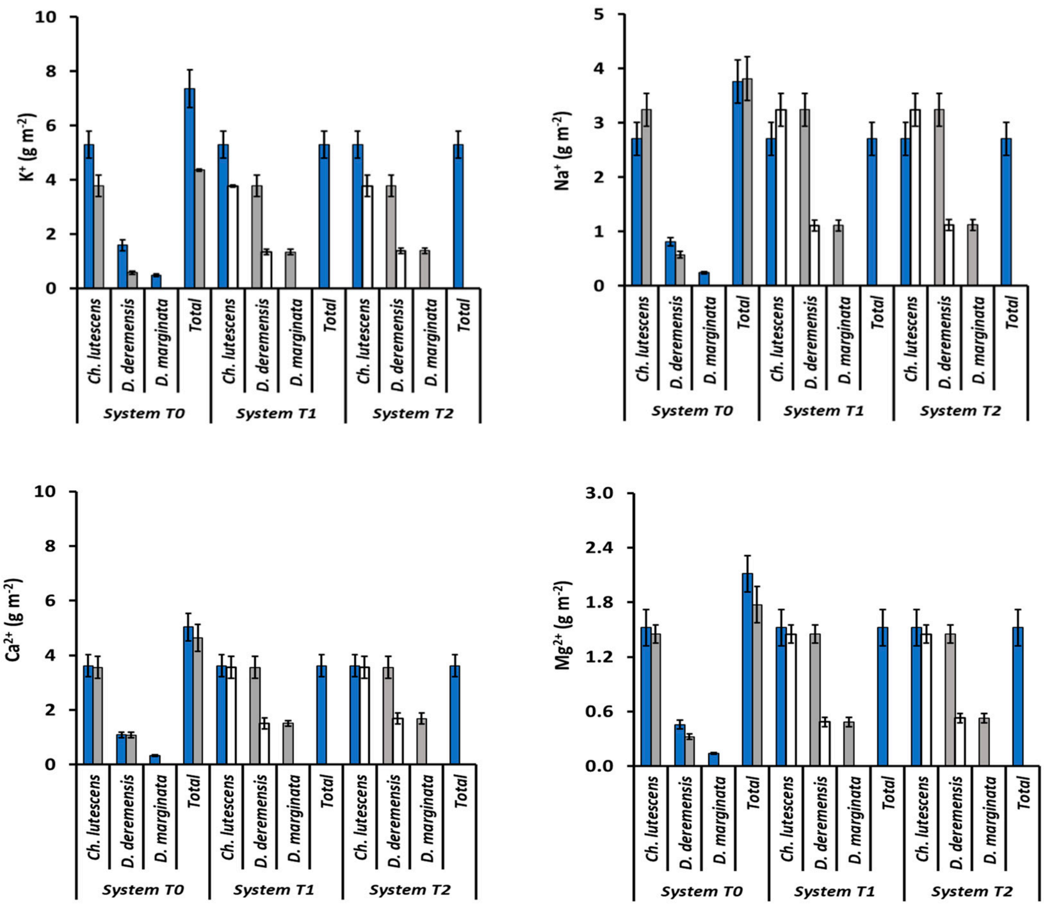

Figure 2. Water volume, anion and cation loads of each water system. System (T_0) is an open draining system fertigated with standard nutrient solution and two closed systems (sequential reuse of the leachate (system T_1) and sequential reuse of the leachate with the addition of H_2O_2 (system T_2)). Blue bar is the water supply, grey bar is the drainage water and white bar is the reusable drainage water for the irrigation of the next crop in the system.

4. Discussion

The chemical analysis of the different water systems revealed a significant increase in EC and pH values as well as in Cl^-, NO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+} concentrations in the fertigation treatments compared to the standard nutrient solution. The increasing value of these parameters can be associated with the reuse of the drainage and the accumulation of these nutrients due to differences in water uptake between the treatments, as reported by Carmassi et al. [26] and Grewal et al. [27]. The lowest values of $H_2PO_4^-$ and SO_4^{2-} reported in fertigation treatments 2 and 4 can be associated with a preferential uptake of these nutrients for *Dracaena deremensis*, as reported Zulfiqar et al. [28].

Fertigation with the sequential reuse of the leachate resulted in a clear reduction in dry weight in *D. deremensis* and *D. marginata* plants. Nevertheless, the additional supply of H_2O_2 to the leachate notably increased the dry weight in both species. Similar results concerning the ameliorative effect of the addition of H_2O_2 have been reported in different crops such as wheat [29], zucchini, soybean, and cotton [30], mainly due to the increase in oxygenation conditions.

It is necessary to point out that the addition of H_2O_2 did not result in significant differences in water saving and nutrient removal between the closed systems assessed (T_1 and T_2). The comparison between the closed systems (systems T_1 and T_2) and the open system (T_0) showed a clear reduction in water volume as well as nutrient loads. The reduction in water volume in our experiment (28%) was greater compared to the results obtained by other researchers in cascade cropping systems (around 18%) [17,25]. An increase in the reduction in the water volume for irrigation is highly advantageous in areas of water scarcity, such as the Mediterranean area [31]. Considering high pollutants, such as nitrate and phosphates, the comparison between the water systems revealed a clear removal of these nutrients with values of around 28%, which are slightly lower in comparison to the data reported in other cascade cropping systems (around 30%) [17,25]. These high rates of nitrate and phosphate removal discharged into the environment are beneficial for the adequate maintenance of water resources, since both nutrients are the main cause of water eutrophication processes [32]. In our experiment, in the case of sulfates (28%), the rate of removal is similar to the range proposed by other researchers in a cascade cropping system with *Cucumis melo* and *Rosmarinus officinalis* [32] in the different water systems assessed (from 27 to 39%). Regarding chloride, the removal rate in our experiment (42%) was much greater than in previous experiences [17,25], with values of around 12%. This higher rate of chloride removal can be associated with the uptake of these salts for an enhancement of crop growth, as reported by Garcia Caparros et al. [33], since the choice of the species for a cascade cropping system is mainly based on the species' increasing salt tolerance capacity.

As for the cation loads, it is necessary to point out that in our experiment the rate of removal between the different cations assessed was similar, with values of around 28%. These removal values were within the ranges noted by other researchers in similar growing systems, such as those reported by Garcia-Caparros et al. [17,25]. The removal of cations, especially sodium, is of crucial importance in order to avoid the salinization of the soil and the aquifers [34]. Moreover, the higher rate of removal of these cations can be ascribed to the nutrient requirements of the species selected, which are involved in crucial physiological processes in plant growth and development [35–37].

5. Conclusions

The results obtained show that fertigation with the sequential reuse treatment resulted in a clear reduction in the dry weights of *D. deremensis* and *D. marginata* plants. Nevertheless, the addition of H_2O_2 to the leachate enhanced the growth of these species, resulting in a higher dry weight. The comparison between open and closed systems revealed a greater water saving along with greater nutrient removal in the closed systems compared to the open draining system. These results suggest that future experiments on cascade cropping systems should include different volumes of H_2O_2 to check if the ameliorative effect is similar, or even better.

Author Contributions: P.G.-C.: investigation, data curation and writing—original draft preparation; A.L.: investigation and data curation; C.V.: investigation and data curation, M.T.L.: conceptualization, supervision and project administration. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Salas, M.D.C.; Montero, J.L.; Diaz, J.G.; Berti, F.; Quintero, M.F.; Guzmán, M.; Orsini, F. Defining optimal strength of the nutrient solution for soilless cultivation of saffron in the Mediterranean. *Agronomy* **2020**, *10*, 1311. [CrossRef]
2. Massa, D.; Magán, J.J.; Montesano, F.F.; Tzortzakis, N. Minimizing water and nutrient losses from soilless cropping in southern Europe. *Agric. Water Manag.* **2020**, *241*, 106395. [CrossRef]
3. Pardossi, A.; Falossi, F.; Malorgio, F.; Incrocci, L.; Bellocchi, G. Empirical models of macronutrient uptake in melon plants grown in recirculating nutrient solution culture. *J. Plant Nutr.* **2005**, *27*, 1261–1280. [CrossRef]
4. Thompson, R.B.; Gallardo, M.; Rodríguez, J.S.; Sánchez, J.A.; Magán, J.J. Effect of N uptake concentration on nitrate leaching from tomato grown in free-draining soilless culture under Mediterranean conditions. *Sci. Hortic.* **2013**, *150*, 387–398. [CrossRef]
5. Headley, T.R.; Huett, D.O.; Davison, L. The removal of nutrients from plant nursery irrigation runoff in subsurface horizontal-flow wetlands. *Water Sci. Technol.* **2001**, *44*, 77–84. [CrossRef] [PubMed]

6. Taylor, M.D.; White, S.A.; Chandler, S.L.; Klaine, S.J.; Whitwell, T. Nutrient management of nursery runoff water using constructed wetland systems. *HortTechnology* **2006**, *16*, 610–614. [CrossRef]
7. Agung Putra, P.; Yuliando, H. Soilless culture system to support water use efficiency and product quality: A review. *Agric. Agric. Sci. Procedia* **2015**, *3*, 283–288. [CrossRef]
8. Rufí-Salís, M.; Petit-Boix, A.; Villalba, G.; Sanjuan-Delmás, D.; Parada, F.; Ercilla-Montserrat, M.; Arcas-Pilz, V.; Muñoz-Liesa, J.; Rieradevall, J.; Gabarrell, X. Recirculating water and nutrients in urban agriculture: An opportunity towards environmental sustainability and water use efficiency? *J. Clean. Prod.* **2020**, *261*, 121213. [CrossRef]
9. De Pascale, S.; Maggio, A. Sustainable protected cultivation at a mediterranean climate. Perspectives and challenges. *Acta Hortic.* **2005**, *691*, 29–42. [CrossRef]
10. Magan, J.J.; Gallardo, M.; Thompson, R.B.; Lorenzo, P. Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in green-houses in Mediterranean climatic conditions. *Agric. Water Manag.* **2008**, *95*, 1041–1055. [CrossRef]
11. Varlagas, H.; Savvas, D.; Mouzakis, G.; Liotsos, C.; Karapanos, I.; Sigrimis, N. Modelling uptake of Na^+ and Cl^- by tomato in closed-cycle cultivation systems as influenced by irrigation water salinity. *Agric. Water Manag.* **2010**, *97*, 1242–1250. [CrossRef]
12. Prenafeta-Boldú, F.X.; Trillas, I.; Viñas, M.; Guivernau, M.; Cáceres, R.; Marfà, O. Effectiveness of a full-scale horizontal slow sand filter for controlling phytopathogens in recirculating hydroponics: From microbial isolation to full microbiome assessment. *Sci. Total Environ.* **2017**, *599*, 780–788. [CrossRef] [PubMed]
13. Su, N.; Bethune, M.; Mann, L.; Heuperman, A. Simulating water and salt movement in tile-drained fields irrigated with saline water under a serial biological concentration management scenario. *Agric. Water Manag.* **2005**, *78*, 165–180. [CrossRef]
14. Incrocci, L.; Pardossi, A.; Malorgio, F.; Maggini, R.; Campiotti, C.A. Cascade cropping system for greenhouse soilless culture. *Acta Hortic.* **2003**, *609*, 297–301. [CrossRef]
15. Grattan, S.; Oster, J.; Benes, S.; Kaffka, S. Use of saline drainage waters for irrigation. In *Agricultural Salinity Assessment and Management*, 2nd ed.; Wallender, W.W., Tanji, K.K., Eds.; American Society of Civil Engineers (ASCE): Reston, VA, USA, 2011; pp. 687–719.
16. Muñoz, P.; Flores, J.S.S.; Antón, A.; Montero, J.I.I. Combination of greenhouse and open-field crop fertigation can increase sustainability of horticultural crops in the Mediterranean region. *Acta Hortic.* **2017**, *1170*, 627–634. [CrossRef]
17. García-Caparrós, P.; Llanderal, A.; Maksimovic, I.; Lao, M.T. Cascade cropping system with horticultural and ornamental plants under greenhouse conditions. *Water* **2018**, *10*, 125. [CrossRef]
18. Plaza, B.M.; Soriano, F.; Jiménez-Becker, S.; Lao, M.T. Nutritional responses of *Cordyline fruticosa* var. 'Red Edge' to fertigation with leachates vs. conventional fertigation: Chloride, nitrogen, phosphorus and sulphate. *Agric. Water Manag.* **2016**, *173*, 61–66. [CrossRef]
19. Plaza, B.M.; Paniagua, F.; Ruiz, M.R.; Jiménez-Becker, S.; Lao, M.T. Nutritional responses of *Cordyline fruticosa* var.'Red Edge' to fertigation with leachates vs. conventional fertigation: Sodium, potassium, calcium and magnesium. *Sci. Hortic.* **2017**, *215*, 157–163. [CrossRef]
20. Pendergast, L.; Bhattarai, S.P.; Midmore, D.J. Benefits of oxygation of subsurface drip-irrigation water for cotton in a Vertosol. *Crop Pasture Sci.* **2013**, *64*, 1171–1181. [CrossRef]
21. Pendergast, L.; Bhattarai, S.P.; Midmore, D.J. Evaluation of aerated subsurface drip irrigation on yield, dry weight partitioning and water use efficiency of a broad-acre chickpea (*Cicer arietinum* L.) in a vertosol. *Agric. Water Manag.* **2019**, *217*, 38–46. [CrossRef]
22. Li, Y.; Niu, W.; Dyck, M.; Wang, J.; Zou, X. Yields and nutritional of greenhouse tomato in response to different soil aeration volume at two depths of subsurface drip irrigation. *Sci. Rep.* **2016**, *6*, 39307. [CrossRef] [PubMed]
23. Jiménez, R.M.; Caballero, M.R. *El Cultivo Industrial de Plantas en Maceta*; Horticultura, S.L., Ed.; Ediciones de Horticultura: Reus, Spain, 1990; 664p.
24. Csáky, A.G.; Martínez-Grau, M.A. *Técnicas Experimentales en Síntesis Orgánica*; Ed. Síntesis: Madrid, Spain, 1998.
25. García-Caparrós, P.; Llanderal, A.; El-Tarawy, A.; Maksimovic, I.; Lao, M.T. Crop and irrigation management systems under greenhouse conditions. *Water* **2018**, *10*, 62. [CrossRef]
26. Carmassi, G.; Incrocci, L.; Maggini, R.; Malorgio, F.; Tognoni, F.; Pardossi, A. Modeling salinity build-up in recirculating nutrient solution culture. *J. Plant Nutr.* **2005**, *28*, 431–445. [CrossRef]
27. Grewal, H.S.; Maheshwari, B.; Parks, S.E. Water and nutrient use efficiency of a low-cost hydroponic greenhouse for a cucumber crop: An Australian case study. *Agric. Water Manag.* **2011**, *98*, 841–846. [CrossRef]
28. Zulfiqar, F.; Younis, A.; Asif, M.; Abideen, Z.; Allaire, S.E.; Shao, Q.S. Evaluation of container substrates containing compost and biochar for ornamental plant *Dracaena deremensis*. *Pak. J. Agric. Sci.* **2019**, *56*, 613–621.
29. Hameed, A.; Shafqat, F.; Nayyer, I.; Rubina, A. Influence of exogenous application of hydrogen peroxide on root and seedling growth on wheat (*Triticum aestivum* L.). *Int. J. Agric. Biol.* **2004**, *6*, 366–369.
30. Bhattarai, S.P.; Huber, S.; Midmore, D.J. Aerated subsurface irrigation water gives growth and yield benefits to zucchini, vegetable soybean and cotton in heavy clay soils. *Ann. Appl. Biol.* **2004**, *144*, 285–298. [CrossRef]
31. Iglesias, A.; Garrote, L.; Flores, F.; Moneo, M. Challenges to manage the risk of water scarcity and climate change in the Mediterranean. *Water Res. Manag.* **2007**, *21*, 775–788. [CrossRef]
32. Nazari-Sharabian, M.; Ahmad, S.; Karakouzian, M. Climate change and eutrophication: A short review. *Eng. Technol. Appl. Sci. Res.* **2018**, *8*, 3668. [CrossRef]

33. García-Caparrós, P.; Llanderal, A.; Pestana, M.; Correia, P.J.; Lao, M.T. Tolerance mechanisms of three potted ornamental plants grown under moderate salinity. *Sci. Hortic.* **2016**, *201*, 84–91. [CrossRef]
34. Greene, R.; Timms, W.; Rengasamy, P.; Arshad, M.; Cresswell, R. Soil and aquifer salinization: Toward an integrated approach for salinity management of groundwater. In *Integrated Groundwater Management*; Springer: Cham, Switzerland, 2016; pp. 377–412.
35. Wang, Y.; Wu, W.H. Regulation of potassium transport and signaling in plants. *Cur. Opin. Plant Biol.* **2017**, *39*, 123–128. [CrossRef] [PubMed]
36. Thor, K. Calcium-Nutrient and messenger. *Front. Plant Sci.* **2019**, *10*, 440. [CrossRef] [PubMed]
37. Tränkner, M.; Tavakol, E.; Jákli, B. Functioning of potassium and magnesium in photosynthesis, photosynthate translocation and photoprotection. *Physiol. Plant* **2018**, *163*, 414–431. [CrossRef] [PubMed]