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ORIGINAL PAPER

Coriander cultivation under different nutrient solution depths in hydroponic systems: a comparison between conventional DFT and adapted DFT with PVC pipes

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Abstract: Due to the water scarcity in arid and semi-arid regions, hydroponic cultivation can be an alternative for these areas since it requires less water than traditional cultivation systems. Thus, this study aimed to evaluate the growth, production, water consumption, water use efficiency, and visual quality of coriander using the Deep Flow Technique (DFT) under different nutrient solution depths. We conducted two experiments concurrently in an entirely randomized block design and a factorial arrangement in a split plot. In the main plots, we evaluated two nutrient solution depths (0.02 and 0.03 m in the hydroponic channel of the adapted DFT system with PVC pipes) and three solution depths (0.013, 0.017, and 0.025 m in wooden tanks of the conventional DFT system), with two coriander cultivars (Tabocas and Verdão) in the sub-plots. At 20 and 25 days after transplanting following variables were determined: plant height, water content in the shoot, shoot fresh matter, shoot dry matter, water consumption, and water use efficiency. In general, coriander Verdão was more productive than coriander Tabocas. Lower depths of nutrient solution in the hydroponic channels or in the tanks promoted responses in the evaluated variables similar to those obtained under higher solution depths, thus reducing the volume of solution and production cost for growing coriander.

Keywords: *Coriandrum sativum* L., soilless cultivation, water resources.

Introduction

Irrigated agriculture has several benefits, e.g., it has made possible higher crop yields compared to traditional rainfed agriculture (Jaramillo et al., 2020; Temesgen et al., 2022). However, in arid and semiarid regions, this activity may be unviable due to the scarcity of low-salinity water (Silva et al., 2020a; Santos et al., 2021). Thus, the transition to other cultivation systems, such as hydroponics, has been a solution to overcome problems of water scarcity (Silva et al., 2016a; Martinez-Mate et al., 2018).

In hydroponics, there is greater water use efficiency; therefore, it demands less water volume, as reported in a compendium prepared by Silva et al. (2021) with several studies. According to the data compiled by authors, to produce 1 kg of fresh biomass, on average, in a hydroponic system, the

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water volume was less by approximately 70% (lettuce and parsley), 80% (chicory), and 85% (coriander) compared to conventional cultivation. In addition, hydroponic cultivation can be performed in small areas, allowing good-quality production throughout the year, efficient use of nutrients, free from pesticides, and free from pests/weeds, among other advantages (Sardare and Admane, 2013; Sambo et al., 2019; Sapkota et al., 2019; Tüzel et al., 2019; Suryaningprang et al., 2021).

Several techniques are employed to expose plant roots to a nutrient solution (Janeczko and Timmons, 2019). Despite the wide range of hydroponic systems described in the specialized literature, the NFT (Nutrient Film Technique) and DFT (Deep Flow Technique) systems, for some time, were considered to have proven commercial viability (Son et al., 2016; Rodríguez-Ortega et al., 2019; Freitas et al., 2021). At present, there are several other hydroponic systems, that are mainly derived from these two systems (Putra et al., 2018; Grigas et al., 2020).

In the NFT system, a thin layer of the nutrient solution runs through the cultivation channels (van Os et al., 2019; Sulaiman et al., 2021), usually at alternating periods of 15 minutes or even shorter (Alves et al., 2019a; Freitas et al., 2021). In this system, the plant roots are partly submerged in the solution, while the other part is in contact with the air, from which the plants also get oxygen (Putra and Yuliando, 2015; Trimbo, 2019; Jan et al., 2020). Therefore, this dependence on electricity for solution circulation in the hydroponic channels may limit the expansion of hydroponic cultivation in locations where the infrastructure is inadequate to conduct electricity (Silva et al., 2016b; Roy et al., 2018; Alves et al., 2019b), that is, in case of short interruptions in electricity supply, the plants suffer water restriction, potentially leading to total production losses (Fecondini et al., 2010; Alves et al., 2021; Wang et al., 2022).

Whereas in the DFT system, the roots are immersed in the nutrient solution (NS) at depths ranging from 5 to 15 cm (van Os et al., 2019), conferring a high NS volume per plant (Mouroutoglou et al., 2021). This volume is sufficient to overcome considerable periods without power and, therefore, without recirculation of the solutions (Freitas et al., 2021). In this system, the larger volume of solution around the roots gives greater buffering to temperature oscillation also. However, the plants only absorb a relatively small part of the solution (van Os et al., 2019).

Therefore, the greater volume of NS used in conventional DFT, compared to the NFT system, can increase production costs with water and mineral fertilizers. Thus, depending on the species cultivated, it is possible to work with smaller depths on the cultivation benches. Aiming to use the advantage of the conventional DFT system, which continuously provides the nutrient solution to the plants, this system was adapted in tubular growing channels by several authors in Northeast Brazil (Santos Júnior et al., 2015; Silva et al., 2016ab; Silva et al., 2018). The structure of the adapted DFT in PVC pipes has been similar to that employed in the NFT hydroponic system, differing only in the arrangement of the hydroponic channels. While in DFT the channels are installed at zero-slope (Silva et al., 2018; Silva et al., 2020a), in the NFT system the channels are installed with a certain slope, which can be up to 10% depending on the region (Dalastra et al., 2020).

The first studies on the adapted DFT system occurred with coriander (*Coriandrum sativum* L.) grown under NS depths of 0.040 m (Santos Júnior et al., 2015) and 0.045 m (Silva et al., 2016ab; Silva et al., 2018) in hydroponic channels with nominal diameters of 0.100 and 0.075 m, respectively. While in cited studies the NS depths were not the object of study, Silva et al. (2020a) evaluated the 0.02 and 0.03 m depths in 0.075 m hydroponic channels in the cultivation of Tabocas and

Verdão coriander cultivars; according to the results reported, larger solution volume in the channel (0.03 m depth) did not result in yield gains for coriander, therefore, it was preferable to use a smaller solution volume (0.02 m depth), which enable to save water and fertilizer in the preparation of nutrient solutions.

Given the above, the present study aimed to evaluate the growth, yield, water consumption, water use efficiency, and visual quality of coriander grown in the DFT hydroponic systems conventional and adapted with PVC pipes under different depths of nutrient solution.

Material and Methods

Study site and growing conditions

The study was conducted between March and April 2017 (summer-autumn), in the experimental area of the Graduate Program in Agricultural Engineering at the Soil and Water Engineering Nucleus of the Federal University of Recôncavo da Bahia/UFRB, in Cruz das Almas, Bahia, Brazil (12º 40’ 19” S, 39º 06’ 23” W, altitude of 220 m above mean sea level).

Two experiments with coriander were conducted concurrently, one in the DFT hydroponic system adapted with PVC pipes (Figure 1A) and the other in the conventional DFT on wooden tanks (Figure 1B), in adjacent greenhouses. Details of the greenhouse with the conventional DFT system are available in Silva et al. (2017), where, inside, mean air temperature and relative humidity were 26.6°C and 89.2%, respectively, obtained using a DHT22 sensor connected to the Arduino Uno. Inside the greenhouse with the adapted DFT system (details available in Silva et al., 2020a), mean air temperature and relative humidity were 25.8°C and 80.5%, respectively, obtained using an HMP45C thermo-hygrometer sensor (Vaisala, Inc.; Helsinki, Finland) connected to a CR1000 model data logger (Campbell Scientific, Inc.; Logan, Utah, USA).

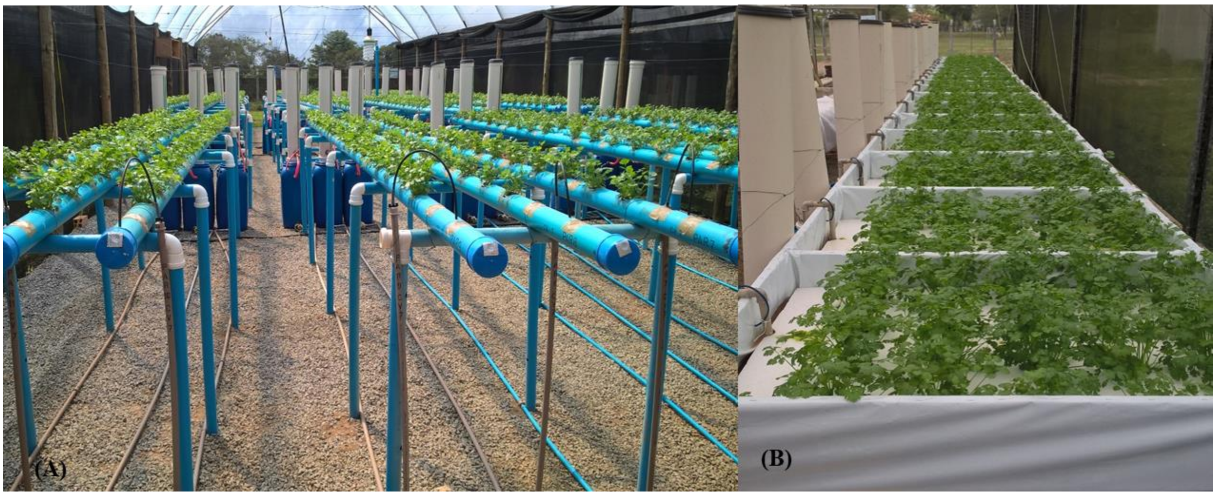


Figure 1: Overall view of coriander plants grown in the DFT hydroponic system adapted with PVC pipes (A) and the conventional DFT on wooden tanks (B).

Experimental structure and design

The experiments were conducted in a completely randomized block design with a factorial arrangement in a split plot, with five and six replicates in the adapted DFT with PVC pipes and conventional DFT, respectively. In the main plots, we evaluated two nutrient solution depths (0.02 and 0.03 m in the hydroponic channel of the adapted DFT system with PVC pipes) and three nutrient solution depths (0.013, 0.017, and 0.025 m in wooden tanks of the conventional DFT system), with two coriander cultivars (Tabocas and Verdão) in the sub-plots.

In the adapted DFT system, the hydroponic channels were PVC pipes, 6-m-long with a nominal diameter of 0.075 m

(Figure 1A). Three channels per bench were installed, at zero-slope with a spacing of 0.25 m × 0.30 m between bunch of plants and channels, respectively. Coriander bunches were planted in circular holes of 0.05 m in diameter. Details of the experimental structure were described earlier by Silva et al. (2020a).

In the conventional DFT system, the structure consisted of wooden tanks lined with double-sided plastic films. Each hydroponic plot (wooden tank) had the dimensions of 1.2 m × 0.8 m. To support the plants a styrofoam plate (0.015 m thick) was placed on each tank over the nutrient solution (Figure 1B). Coriander bunches were planted, 0.25 m × 0.25 m apart, in circular holes of 0.05 m diameter.

In both experiments, each plot consisted of a plastic tank (60-L capacity) to store the nutrient solution and an electric pump to inject the nutrient solution into the hydroponic channel or wooden tank. Details are described in Silva et al. (2020a). Circulation of the nutrient solution was controlled with an analog timer at intermittent 15-minute intervals, from 6 a.m. to 6 p.m. From 6 p.m. to 6 a.m., the nutrient solution was recirculated once every 2 hours for 15 minutes.

Crop conduction and nutrient solution management

On March 14, 2017, seeds of Tabocas and Verdão coriander cultivars were sown in 80-mL disposable plastic cups containing coconut fiber as substrate. Separately, 15 seeds of each coriander cultivar were sown per cup and covered with the substrate up to the cup top. Seedlings were irrigated manually until transplanting with municipal supply water of electrical conductivity (ECw) of 0.41 dS m^{-1}. Coriander seedlings were transplanted to the hydroponic systems at 10 days after sowing, when the treatments started. Before transplanting, thinning was carried out, leaving 12 seedlings per recipient (cup), according to recommendations of Silva et al. (2016a). Each hydroponic channel or wooden tank had 20 coriander bunches (10 of each cultivar).

Nutrient solutions were prepared by dissolving fertilizer salts in the municipal supply water (ECw 0.41 dS m^{-1}) according to the recommendations of Furlani et al. (1999) for leafy vegetables, resulting in electrical conductivity values of the solutions (ECsol) of 2.37 dS m^{-1} (adapted DFT system) and 2.42 dS m^{-1} (conventional DFT system). The initial pH of the nutrient solution for both systems was 5.8.

Variables evaluated

Temperature and dissolved oxygen concentration in the nutrient solutions

At 6, 11, 14, 17, 19, and 24 days after transplanting (DAT), temperatures and dissolved oxygen (DO, in mg L^{-1}) concentrations were measured in the nutrient solutions using an HI 98193 model oximeter (Hanna Instruments Inc.; Woonsocket, Rhode Island, USA). The measurements were carried out in the hydroponic channel of the adapted DFT system and in the wooden tanks of the conventional DFT system. The measurements were conducted in the mornings and afternoons, so these variables were analyzed in a split plot arrangement.

Growth, yield, and water content in the shoot of coriander

In both experiments, harvests were performed at 20 and 25 DAT. In each plot, five coriander bunches of each cultivar were harvested, each with 12 plants, to determine: plant height (PH, cm) and shoot fresh matter (SFM, g bunch^{-1}) of the bunch of plants. Immediately after weighing, the material was placed in paper bags and dried in a forced-air circulation oven at 65ºC until constant weight to quantify shoot dry matter (SDM, g bunch^{-1}). PH was measured using a tape measure from the substrate level up to the apex of the plants.

The yield in kg m^{-2} was also calculated from the mean SFM yields, considering an area occupied per coriander bunch of 0.075 m^2 in adapted DFT (spacing of 0.25 m ×

0.30 m between a bunch of plants and hydroponic channels, respectively) and of 0.0625 m^2 in conventional DFT (spacing of 0.25 m × 0.25 m between rows of a bunch of plants).

The water content in the shoot (WCS, %) based on the relationship (WCS = [(SFM – SDM)/SFM] × 100) was determined, as described by Nguyen et al. (2020) and Silva et al. (2022).

Water consumption and water use efficiency of the coriander

The water consumption (WC) was calculated based on the volume consumed in the plot divided by the number of bunches of plants in the plot, for periods of 1-20 and 1-25 DAT, according to the equation described by Santos et al. (2018). Water use efficiency (WUE) was also determined, based on the ratio between SFM or SDM production and the WC, according to the equation described by Silva et al. (2020b). The WC and the WUE were established together for the two coriander cultivars.

Statistical analysis

Statistical analysis was performed separately for each experiment. The data were subjected to analysis of variance by the F test, and the means were compared with Tukey’s test at $p \leq 0.05$.

Results and Discussion

Dissolved oxygen concentration and temperature of the nutrient solutions, and coriander quality

In studies conducted in Brazilian Northeast with coriander (Santos Júnior et al., 2015; Silva et al., 2015; Silva et al., 2016b; Zamora et al., 2019) grown under protected environment conditions, the maximum daytime temperatures exceed 30°C.

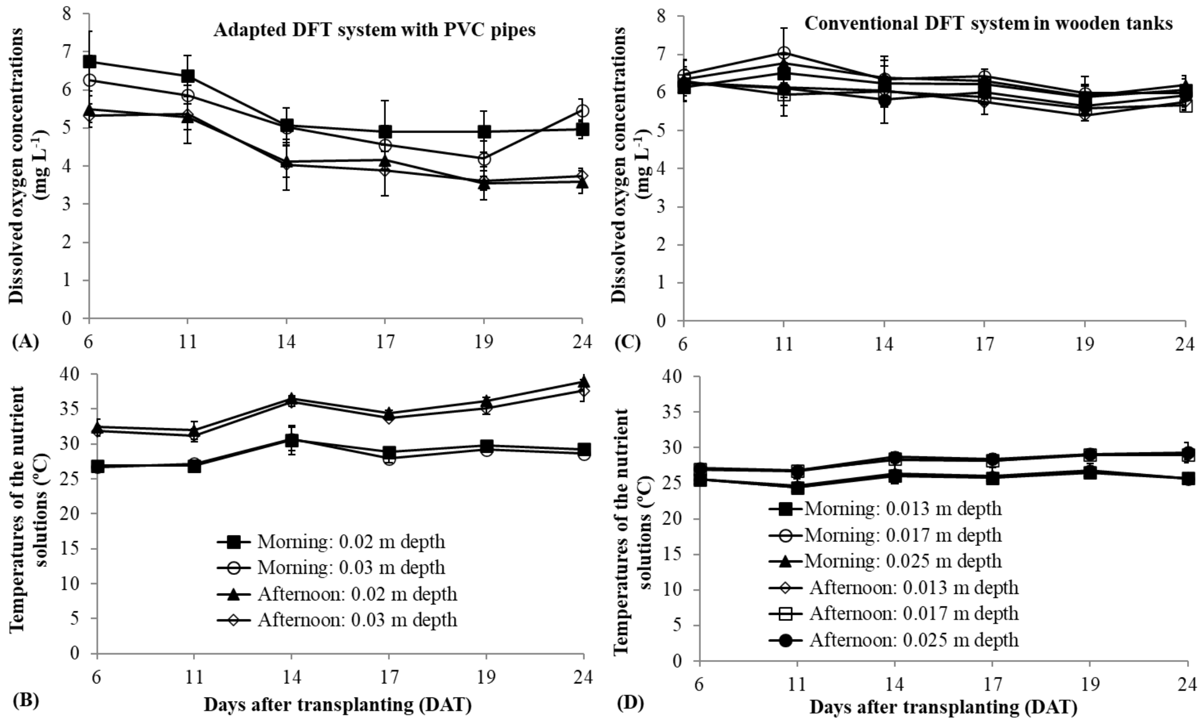
The dissolved oxygen (DO) concentrations (Figures 2A and 2C) and temperatures of the nutrient solutions – Tsol (Figures 2B and 2D) were measured simultaneously at 6, 11, 14, 17, 19, and 24 days after transplanting (DAT) in the mornings and afternoons. Except DO in the evaluation performed at 6 DAT in the conventional DFT system, in the other evaluations, DO concentrations and Tsol were significantly influenced by the times of their measurements in both hydroponic systems. Tsol at 17, 19, and 24 DAT were significantly influenced by the nutrient solution depths in the hydroponic channels of the adapted DFT system (Figure 2B). In the conventional DFT system, a significant effect of the solution depth was recorded in the DO concentrations only at 24 DAT (Figure 2C).

The mean values of DO in the solutions were higher in the mornings than in the afternoons in both hydroponic systems (Figures 2A and 2C). This behavior was influenced by the higher temperatures of the solutions in the afternoons, thus reducing the availability of oxygen in the rhizosphere of the plants (Figures 2B and 2D), as recorded in other studies (Suyantohadi et al., 2010; Al-Rawahy et al., 2019; Silva et al., 2020a; Langenfeld and Bugbee, 2021). The DO concentrations are inversely correlated with solution temperature (López-Pozos et al., 2011; Sakamoto et al., 2016), i.e., as temperature increases throughout the day, a reduction in DO concentration occurs (Silva et al., 2020a).

As expected, the highest DO concentrations were recorded at the beginning of the crop, when, at 6 DAT, a general average of 6.29 mg L^{-1} was recorded in the conventional DFT system (Figure 2C). In the adapted DFT system with pipes (Figure 2A), a similar average was recorded in the mornings (DO of 6.51 mg L^{-1}), while in the afternoons, as previously mentioned, the increase in temperature reduced the DO concentrations, which resulted in an average of 5.41 mg L^{-1}.

At 11, 14, 17, 19, and 24 DAT, in the conventional DFT system (Figure 2C), the highest DO concentrations were 6.78, 6.33, 6.31, 5.92, and 6.08 mg L^{-1}, respectively, in the mornings. In the afternoons, the average

DO values were 6.06, 5.96, 5.88, 5.54, and 5.78 mg L^{-1}, respectively. At 11, 14, 17, and 19 DAT, regardless of the solution depths in the wooden tanks, the average DO values were 6.42, 6.15, 6.09, and 5.73 mg L^{-1}, respectively. At 24 DAT, there was little variation in DO values (between 5.82 – 6.06 mg L^{-1}) as a function of the solution depths.



Vertical bars indicate the means ± standard deviation (n = 5 in the adapted DFT and n = 6 in the conventional DFT).

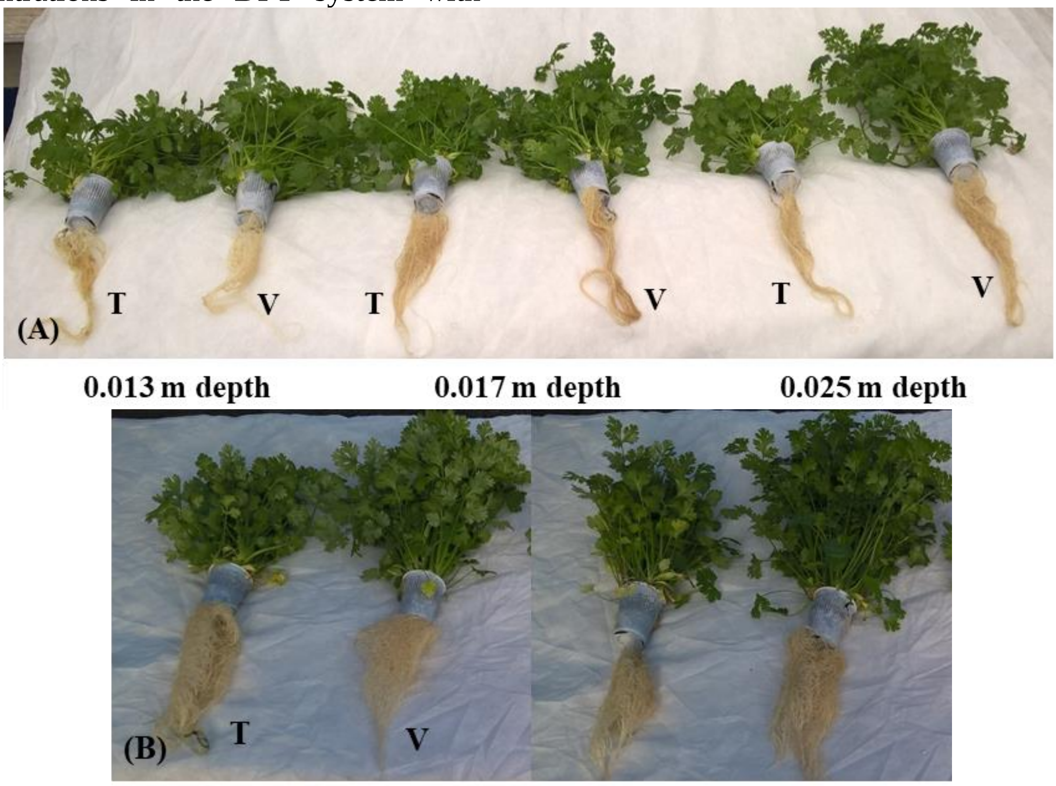
Figure 2: Dissolved oxygen concentrations and temperatures of the nutrient solutions in the hydroponic channels of the adapted DFT system (A and B) and in the wooden tanks of the conventional DFT system (C and D) for the coriander grown under different nutrient solution depths, in the mornings and afternoons.

In the adapted DFT (Figure 2A), in the mornings, the average DO values were 6.11, 5.05, 4.74, 4.55, and 5.22 mg L^{-1} at 11, 14, 17, 19, and 24 DAT, respectively. In the afternoons, DO concentrations were 5.33, 4.08, 4.02, 3.59, and 3.66 mg L^{-1}, respectively. Regardless of the solution depths in the hydroponic channels, DO means were 5.97, 5.72, 4.57, 4.38, 4.07, and 4.50 mg L^{-1} at 6, 11, 14, 17, 19, and 24 DAT, respectively.

Reductions in DO concentrations were recorded from the middle of the coriander growing cycle onward, especially in the adapted DFT system with pipes (Figure 2A). This is due to the increased volume of active roots, consequently promoting higher oxygen demand, as reported in other studies (Niñirola et al., 2014; Mobini et al., 2015; Al-Rawahy et al., 2019; Silva et al., 2020a; Navarro et al., 2022). In both hydroponic systems, there was a slight increase in DO concentrations in the measurements carried out at 24 DAT. This is a consequence of the number of bunches of plants per plot (hydroponic channel or wooden tank), because, at 20 DAT, of the 20 bunches of plants, 10 bunches were harvested, thus reducing the number of plants competing for oxygen in the nutrient solution.

In general, the lowest DO concentrations were found in the adapted DFT system with pipes (Figure 2A). It is evident, therefore, that the materials employed in these systems were determinants for the attenuation of the solution temperatures. For example, due to the low thermal transmittance of the styrofoam plates in the conventional DFT system (Figure 1B), the heating of the solution was lower compared to the DFT system with pipes (Figure 1A). In the DFT with pipes, there was a higher incidence of radiation on the hydroponic channel, therefore, favoring heat exchange with the nutrient solution in the afternoons, the temperatures of the solutions were, in general, higher than 30°C. In the mornings, solution temperatures did not exceed 30°C (Figure 2B). In the conventional DFT system on wooden tank (Figure 2D), the temperatures of the solutions did not exceed 30ºC, regardless of the measurement times (mornings and afternoons).

As with the conventional DFT system (Figure 3A), despite the low DO concentrations in the DFT system with pipes from the middle of the coriander cycle onward, the visual quality of the plants (roots and shoot), as well as fresh biomass production, were not affected (Figure 3B). Lenzi et al. (2011) recorded low DO concentrations under spinach cultivation in non-aerated solutions, when, at harvest the DO values were 1.92 mg L^{-1} in the summer and 2.83 mg L^{-1} in the autumn; despite the low DO concentrations, productivity was not affected because of the short cycle of the crop (22 and 30 days in the respective experiments). Therefore, according to Conesa et al. (2015) and Silva et al. (2020a), sensitivity to the content of oxygen in the root zone is variable among species and within the same species.



0.02 m depth 0.03 m depth

Figure 3: Visual aspect of Verdão (V) and Tabocas (T) coriander cultivars grown in wooden tanks of the conventional DFT system (A) and hydroponic channels of the adapted DFT system (B) under different nutrient solution depths.

Growth, yield, and water content in shoot

At 20 and 25 days after transplanting (DAT), the study evaluated plant height (PH), shoot fresh matter (SFM), SFM yield (SFMY), shoot dry matter (SDM), and water content in the shoot (WCS) (Table 1). In both hydroponic systems, there was no significant interaction (p > 0.05) between the factors for any variable in the two evaluations.

Table 1: Summary of the F test of the analysis of variance and mean values for plant height (PH), shoot fresh mass (SFM), shoot dry mass (SDM), SFM yield (SFMY), and water content in the shoot (WCS) of the coriander grown in the adapted and conventional DFT hydroponic systems at different nutrient solution depths, 20 and 25 days after transplanting (DAT)

SV	PH (cm)		SFM (g bunch^{-1})		SDM (g bunch^{-1})		SFMY (kg m^{-2})		WCS (%)	
	20	25	20	25	20	25	20	25	20	25
	Adapted DFT system with PVC pipes									
Depths (D)	ns	ns	ns	*	ns	ns	ns	**	ns	*
Cultivars (C)	**	**	**	**	ns	**	**	**	**	**
D × C	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
D: CV_1 (%)	6.57	9.63	18.30	17.43	16.79	12.97	18.31	17.45	0.82	0.70
C: CV_2 (%)	6.60	11.05	9.19	14.21	6.92	11.65	9.16	14.20	0.51	1.19
	Means									
0.02 m	21.76a	26.53a	32.65a	62.20a	3.92a	6.76a	0.435a	0.829a	87.87a	88.85a
0.03 m	20.24a	23.91a	26.85a	49.76b	3.36a	5.81a	0.358a	0.663b	87.39a	88.04b
Verdão	22.75A	28.40A	31.79A	63.95A	3.76A	7.01A	0.424A	0.852A	88.10A	88.83A
Tabocas	19.25B	22.04B	27.71B	48.01B	3.51A	5.57B	0.369B	0.640B	87.16B	88.07A
	Conventional DFT system in wooden tanks									
Depths (D)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cultivars (C)	**	**	**	**	**	**	**	**	**	**
D × C	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
D: CV_1 (%)	7.00	8.42	14.74	11.85	11.49	10.32	14.37	11.52	0.93	0.93
C: CV_2 (%)	6.48	4.48	18.00	11.39	14.94	8.13	18.01	11.42	0.96	0.70
	Means									
0.013 m	23.23a	30.26a	27.64a	50.59a	2.25a	3.81a	0.443a	0.811a	91.80a	92.34a
0.017 m	22.84a	29.30a	24.71a	47.41a	2.06a	3.67a	0.394a	0.759a	91.56a	92.11a
0.025 m	22.53a	30.06a	25.49a	49.79a	2.06a	3.88a	0.408a	0.797a	91.70a	92.15a
Verdão	24.11A	32.63A	30.32A	54.31A	2.42A	3.96A	0.485A	0.870A	91.98A	92.66A
Tabocas	21.63B	27.11B	21.58B	44.22B	1.83B	3.61B	0.345B	0.708B	91.39A	91.74B

SV – source of variation; CV_1 and CV_2 – coefficients of variation of the errors 1 (depths) and 2 (cultivars), respectively; ** and * significant at $p < 0.01$ and $p < 0.05$, respectively, and ns – not significant by F-test; within a column the lowercase letters compare the means of the nutrient solution depths and uppercase letters compare the means of the coriander cultivars for the isolated effects; means followed by the same letter are not significantly different by the Tukey's test at $p \leq 0.05$.

Except for the SDM (at 20 DAT) and WCS (at 25 DAT) in the adapted DFT system with pipes, and WCS (at 20 DAT) in the conventional DFT system, the other variables were significantly influenced by the coriander cultivars in the two evaluations.

Only in the adapted DFT system with pipes and at 25 DAT, there was a significant effect on the variables SFM, SFMY, and WCS in function of the nutrient solution depths in the hydroponic channels. The highest means of 62.20 g (for a bunch of 12 plants), 0.829 kg m^{-2}, and 88.85%, respectively, were obtained with a smallest nutrient solution depth in the hydroponic channels (0.02 m) compared to the 0.03 m depth (Table 1). Therefore, these results show that it was feasible to produce coriander under smaller solution depths (resulting in water and fertilizer savings), especially in the traditional DFT system, which is characterized by the use of high solution volumes, however, as mentioned by van Os et al. (2019), the plants only absorb a relatively small part of the solution.

In general, the highest PH means were observed for coriander Verdão in comparison to the coriander Tabocas (Table 1). The highest PH values of the coriander Verdão contributed to the greater biomass accumulation. For the adapted DFT system with pipes, at 20 and 25 DAT, the SFM means of coriander Verdão were 31.79 and 63.95 g $bunch^{-1}$, respectively. For coriander Tabocas, SFM means were lower by approximately 13 and 25%, respectively. For the conventional DFT system in wooden tanks, SFM values of coriander Verdão were 30.32 and 54.31 g $bunch^{-1}$ at 20 and 25 DAT, respectively; while for the coriander Tabocas these values were 28.82 and 18.58% lower.

As for SDM, the means of coriander Tabocas compared to coriander Verdão were lower by 6.90 and 20.54% in the adapted DFT system with pipes, and 24.38 and 8.58% in the conventional DFT system, at 20 and 25 DAT, respectively (Table 1).

Coriander Verdão production potential was recorded by Silva et al. (2020c) about 45.63% higher compared to coriander Tabocas. The mentioned study was conducted with an NFT hydroponic system in the summer season, in which coriander was grown without the stresses of salinity and root-zone temperatures. Different results were found by Soares et al. (2017) in NFT hydroponics with coriander bunches spaced at 0.25 m × 0.30 m when they recorded an SFM value for coriander Tabocas 20.72% higher than that of coriander Verdão at 32 DAT.

At 25 DAT, SFM production for coriander Verdão of 63.95 g $bunch^{-1}$ (Table 1) was higher compared to other studies using DFT hydroponic system with PVC tubes (nominal diameter of 0.075 m). For example, Silva et al. (2016b) and Silva et al. (2018) recorded SFM yields for coriander Verdão of 50.33 and 44.05 g (bunch with 12 plants) in studies conducted in the summer and winter seasons, respectively. These results were obtained with coriander grown without salt stress for 25 days. Even lower was the SFM yield of coriander Verdão recorded by Navarro et al. (2022) using a DFT hydroponic system with 0.100 m PVC pipes, of the order of 39 g $bunch^{-1}$ (with 15 plants) under cultivation without salt stress, at 30 days after sowing in the summer season. In the present study, the higher yields of coriander can be explained by the larger spacing between coriander bunches in the hydroponic channel, which was 0.25 m apart. While in the first two studies, the coriander bunches were spaced equidistantly by 0.07 m and by 0.14 m in the last study. Therefore, there was less competition between the coriander plants in the present study.

Due to the larger spacing in this study, the individual fresh biomass gains in the coriander plant bunches were not offset in gains per unit area, e.g., SFM yields did not exceed 1 kg m^{-2} in both hydroponic systems at 25 DAT (Table 1). Santos Júnior et al. (2015) recorded an SFM yield of 5.90 kg m^{-2} for coriander Tabocas for bunches formed from sowing 1 g of seed at 28 days after sowing. This study was conducted in the winter season and the coriander bunches were 0.07 m apart in the hydroponic channel of the adapted DFT system. The study carried out by Silva et al. (2016a) with bunches of coriander Verdão spaced by 0.07 m in the hydroponic channel of the DFT system, was estimated an SFM yield of 3.19 kg m^{-2} at 25 DAT in the spring season.

In the evaluation periods (at 20 and 25 DAT), water consumption (WC) and water use efficiency (WUE) based on the SFM (WUE-SFM) and SDM (WUE-SDM) were not significantly influenced ($p > 0.05$) by the nutrient solution depths in the hydroponic channels of the adapted DFT system or in wooden tanks of the conventional DFT system (Table 2).

Table 2: Summary of the F test of the analysis of variance and mean values for water consumption (WC) and water use efficiency (WUE) based on the SFM (WUE-SFM) and SDM (WUE-SDM) of the coriander grown in the adapted and conventional DFT hydroponic systems at different nutrient solution depths, 20 and 25 days after transplanting (DAT)

SV	WC (L $bunch^{-1}$)		WUE-SFM (g L^{-1})		WUE-SDM (g L^{-1})	
	20 DAT	25 DAT	20 DAT	25 DAT	20 DAT	25 DAT
	Adapted DFT system with PVC pipes					
Depths	ns	ns	ns	ns	ns	ns
CV (%)	16.68	15.41	16.42	4.89	14.24	8.04
	Means					
0.02 m	2.19a	3.03a	14.87a	20.33a	1.79a	2.23a
0.03 m	1.93a	2.49a	14.13a	20.10a	1.78a	2.38a
Mean	2.06	2.76	14.50	20.21	1.78	2.30
	Conventional DFT system in wooden tanks					
Depths	ns	ns	ns	ns	ns	ns
CV (%)	26.52	21.65	25.58	24.18	23.79	21.33
	Means					
0.013 m	0.95a	1.53a	29.72a	35.84a	2.42a	2.64a
0.017 m	0.91a	1.56a	27.87a	30.68a	2.33a	2.39a
0.025 m	1.04a	1.44a	27.02a	35.69a	2.15a	2.79a
Mean	0.97	1.51	28.20	34.07	2.30	2.61

SV – source of variation; CV – coefficient of variation; ns – not significant by F-test; means followed by the same letter are not significantly different by the Tukey's test at $p \leq 0.05$.

On average, higher WC values in the adapted DFT system with pipes compared to the conventional DFT system in wooden tanks were recorded (Table 2). The WC value of 2.76 L to produce a bunch with 12 coriander plants in 25 days (adapted DFT system) was slightly higher than that recorded by Silva et al. (2017) in the NFT hydroponic system, which was 2.21 L (bunch with 24 plants of coriander Verdão) in 24 days in the spring season.

Approximately 2 L (bunch with 12 coriander plants) was recorded by Silva et al. (2020a) under cultivation in the DFT system with pipes and solution recirculations at 15-minute intervals for 25 days in the autumn season. As well as in the conventional DFT system in wooden tanks, when low WC was recorded in 25 days (1.51 L $bunch^{-1}$), it corroborates with 1.45 L (bunch with 12 plants) found by Silva et al. (2016b) in the summer season. Even lower WC values were recorded by Silva et al. (2018), of 0.89 L (bunch with 12 plants) in the winter season, and by Oliveira et al. (2020), of 0.72 L (bunch with 15 plants) in the summer season, both results obtained without salt stress. These last three studies used coriander Verdão grown in the DFT system with pipes.

Conclusions

The highest average values of the variables were obtained for coriander Verdão in comparison to coriander Tabocas.

Smaller depths of nutrient solution in the hydroponic channels (adapted DFT system) or in wooden tanks (conventional DFT system) promoted responses in the evaluated variables similar to those obtained under greater solution depths. Therefore, for coriander cultivation, the solution depths of 0.02 and 0.013 m, respectively, in the adapted and conventional DFT hydroponic systems is feasible and allows for water and fertilizer savings in the preparation of nutrient solutions.

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