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Growth, production and water use efficiency of chicory (*Cichorium endivia* L.) in hydroponic systems using brackish waters

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Abstract: Plants response to the same level of salinity can be increased in hydroponic cultivation compared to under soil conditions. The study aimed at evaluating the chicory growth in DFT (Deep Flow Technique) hydroponic system using brackish water, comparing the results with those obtained in NFT (Nutrient Film Technique) system. The experiment was carried out in a randomized block design with eight replicates. Each plot (replicate) was represented by a hydroponic channel with 15 plants. Four treatments were used, consisting of plants grown in the DFT system submitted to three levels of electrical conductivity of nutrient solution - ECsol (2.57, 3.43 and 4.75 dS/m) and in the NFT system under ECsol of 2.57 dS/m. Plant height, number of leaves, fresh and dry matter of shoot, water consumption, water use efficiency and water content in shoot at 20 and 25 days after transplanting (DAT) were evaluated. In each harvest, a mean value was obtained per plot through of the harvest collection of five plants. At 25 DAT, the largest reductions in production and water use efficiency of chicory were observed under higher salinity (ECsol 4.75 dS/m). In the DFT system no symptoms of toxicity that could be attributed to salinity were observed.

1. Introduction

Under natural conditions, plants are frequently exposed to complex interactions which involve numerous environmental factors (Rejeb *et al.*, 2014; Zribi *et al.*, 2017; Prisa, 2019), such as salinity, water deficit, temperature and others (Ramakrishna and Ravishankar, 2011; Szareski *et al.*, 2018).

In arid and semi-arid regions of different parts of the world, such as the Brazilian Northeast (Rocha Neto *et al.*, 2017), among the various abiotic stresses, saline stress, which expresses the concentration of soluble salts in the soil or water (Breś *et al.*, 2016), has been pointed out as the main cause for the decrease of yield in most agricultural crops (Younis *et al*., 2013; Boughalleb *et al*., 2017; Rezaei *et al*., 2017).

Soil salinization can be of primary origin (natural) and/or secondary origin, caused by anthropic activity, such as the use of saline water in irrigation (Shahrayini *et al*., 2018; Sienkiewicz-Cholewa *et al*., 2018). Secondary salinization is a consequence of inadequate irrigation management because natural drainage in the semi-arid regions is limited due to the low rainfall (Endo *et al*., 2011; Suassuna *et al*., 2017), which is not sufficient to leach the salts from the root zone to deeper soil layers and thus maintain compatible levels of salts in the root zone of crops (Ünlükara *et al*., 2008; Shrivastava and Kumar, 2015).

Plant species respond differently to salt stress (Tabatabaei and Ehsanzadeh, 2016). Some are able to produce satisfactory yields under saline conditions, while others are not (Zrig *et al*., 2016; Qrunfleh *et al*., 2017). The responses of plants are variable among the different organs, species/cultivars, development stages and duration of exposure to the salts (Parvaiz and Satyawati, 2008; Abbas *et al*., 2015), which usually lead to reductions in phytomass production, yield or survival rates (Munns and Tester, 2008; Xu *et al*., 2018).

Salt stress can limit the exploitation of most agricultural crops, making the agricultural activity economically unviable. To mitigate the problems of salinity, hydroponic cultivation (soilless cultivation) has been pointed out as a technique suitable for the use of saline water because the response of plants to salinity is better than in soil, when irrigated with the same water (Silva *et al*., 2018 a). In this system, there is higher and immediate availability of water and nutrients to plants because there is no matric potential, which is one of the main causes of reduction in the free energy of water in the soil.

Studies on the tolerance of several species to salinity in hydroponic systems have demonstrated that, through adequate management of water and cultivation practices, it is possible to produce commercially using brackish waters (Dias *et al*., 2011), especially leafy vegetables such as lettuce (Soares *et al*., 2015; Cova *et al*., 2017; Silva *et al*., 2018 b). In this context, other crops of economic potential, such as chicory, have been investigated using brackish waters under hydroponic conditions (Tzortzakis, 2009, 2010; Atzori *et al*., 2016, 2019 a). Atzori *et al*. (2016) reported that chicory crop proved to have a considerable higher tolerance to salinity compared to lettuce in hydroponics. According to Cecílio Filho *et al*. (2015), on average chicory is a more profitable crop than lettuce, and its requirements in terms of management in hydroponic systems are similar.

In Brazil and in several parts of the world, the NFT (Nutrient Film Technique) hydroponic system is the most used commercially. NFT is an active system which requires pumping to recirculate the nutrient solution, usually at 15 min intervals (Zanella *et al*., 2008). Thus, the use of NFT system may be limited in places where there are frequent interruptions in supply of electricity (Santos Júnior *et al*., 2015; Silva *et al*., 2016). To overcome this problem, some researchers adopted the DFT (Deep Flow Technique) system in PVC pipes (Santos Júnior *et al*., 2015; Silva *et al*., 2016; Cova *et al*., 2017; Campos Júnior *et al*., 2018 a; Gondim Filho *et al*., 2018; Martins *et al*., 2019 a, b; Santos *et al*., 2019; Silva Júnior *et al*., 2019), in which plant roots remain continually immersed in the nutrient solution which is recirculated but not as frequently as in NFT. Thus, in case of short interruptions in electricity supply plants do not undergo water restriction (Silva *et al*., 2018 a).

Therefore, this study aimed to evaluate the growth, production, water consumption, water use efficiency and quality of plants of the chicory (*Cichorium endivia* L.) using nutrient solutions prepared in brackish waters in DFT system, comparing the results with those obtained using solution prepared in fresh water in NFT system.

2. Materials and Methods

Experiment location

The study was carried out in a greenhouse (East-West orientation), from June to August (Fall-Winter) of 2016. The greenhouse was 7.0 m wide and 24 m long, with ceiling height of 2.8 m, protected on the sides by black shade (50% luminosity) screen and covered with low density polyethylene film, with anti-ultraviolet additive and with a thickness of 150 microns. The study site was in the Experimental Area of the Graduate Program in Agricultural Engineering of the Federal University of Recôncavo of Bahia, located in the municipality of Cruz das Almas, Bahia, Brazil (12° 40’ 19” S, 39° 06’ 23” W, and at an elevation of 220 m a.s.l).

Treatments, experimental design and structure

The experiment was carried out in a randomized block design, with four treatments and eight replicates. Chicory plants were submitted to three levels of electrical conductivity of nutrient solution - ECsol (2.57, 3.43 and 4.75 dS/m) in hydroponics DFT and under ECsol of 2.57 dS/m in hydroponics NFT, being cultivated 15 plants in each cultivation channel in the central part. Nutrient solutions were prepared by adding adequate amounts of fertilizer salts according to recommendation of Furlani *et al*. (1999). The nutrient solution of 2.57 dS/m was obtained by addition of only fertilizer salts to public-supply water (0.34 dS/m). For ECsol levels of 3.43 and 4.75 dS/m, the nutrient solutions were prepared in waters with EC of 1.5 and 3.0 dS/m obtained by addition of NaCl to public-supply water, which were also used to replace the volume consumed by the plants in the respective treatments during the cultivation period.

In both systems, channels made of PVC pipes (6-m length and 0.075 m in diameter) were used, with circular holes of 0.05 m in diameter, spaced 0.25 m apart. Benches with trestles made of PVC pipes of 0.05 m in diameter were used to support the hydroponic channels. Three hydroponic channels were used per bench, with horizontal spacing of 0.30 m. One corridor (0.5-m width) was left between the benches to facilitate transit and operability.

In the DFT hydroponic system, caps were attached at both ends of each hydroponic channel installed with zero slope, and a drain was installed in the caps to maintain a mean level of the nutrient solution of 0.02 m, conducting the excess solution through a hose back to the solution tank. In the NFT system the hydroponic channels were installed with a 4% slope.

Each experimental unit consisted of an independent hydroponic channel, containing a plastic tank (60-l capacity) to store the nutrient solution, and an electric pump to inject the nutrient solution into the channel. The tank had a ballcock valve to maintain a volume of 50 l of the solution and connected to water reservoir, built with PVC pipes of 0.15 m in diameter. A transparent hose with a tape ruler was installed vertically on the outside of the reservoir to verify the water level. The reservoir and supply tank were connected by a hose; the water level was manually controlled through a ball valve which was opened daily at prefixed hours to maintain the water level in the reservoir and quantify water consumption.

Crop conduction and nutrient solution management

Seeds of broad-leaved chicory cv. 'Dafne' were sown on phenolic foam (2 x 2 x 2 cm), by planting one seed per cell. After germination, seedlings were daily irrigated with public-supply water until 10 days after sowing (DAS). After this period, the seedlings were transferred to a nursery (NFT system), where they received nutrient solution (Furlani *et al*., 1999) at 50% concentration for 15 days. Irrigations in the nursery were controlled by an analog timer at intermittent intervals of 15 min, from 06:00 to 18:00 h. During the period from 18:00 to 06:00 h, the nutrient solution was recirculated once every 2 h, with duration of 15 min. The seedlings were transplanted to the definitive cultivation system with mean height of 0.133 m and four true leaves.

The programming to control circulation of the nutrient solution in the cultivation channels in both systems (NFT and DFT) was similar to that used during the initial stage i.e. at intervals of 15 min, from 06:00 to 18:00 h. During the period from 18:00 to 06:00 h, the nutrient solution was recirculated once every 2 h, with duration of 15 min.

During the experiment, ECsol and pH of the solution were monitored in the central position of each hydroponic channel, using portable conductivity and pH meter. At the end of the experiment, the ECsol means values were 1.88 and 2.03 dS/m for the treatment under ECsol de 2.57 dS/m, respectively in the NFT e DFT systems, and of 3.24 and 4.88 dS/m for the treatments under ECsol de 3.43 e 4.75 dS/m in the DFT system, with no replacement of nutrient to the solution during the cycle. When the pH values were outside the ideal range (between 5.5 and 6.5) for hydroponic cultivation, corrections were made by addition of calcium hydroxide.

Variables evaluated

Harvests were performed at 20 and 25 days after transplanting (DAT). The strategy of performing two harvests along the experiment was to identify the best period for plant harvest, and also to evaluate the absolute growth rate of plants under different treatments before harvest and to assess possibility of early harvest. In each harvest, a mean value was obtained per plot (hydroponic channel) through of the harvest of five plants for the determination of plant height, number of leaves and shoot fresh matter. Immediately after weighing the plants, the fresh material was placed in paper bags and dried in an air circulation oven at temperature of 65°C until constant weight, to quantify shoot dry matter.

The volume evapotranspired per plant was determined daily by dividing the volume of nutrient solution consumed in the plot by the number of plants under cultivation at that moment in the plot, according to equation described by Lira *et al*. (2018). Cumulative water consumption was calculated for the periods of 1 to 20 and 1 to 25 DAT. Water use efficiency (WUE) was based on the relationship between shoot fresh (SFM) or dry matter (SDM) production and the cumulative water consumption per plant, according to equation 1:

$$WUE\ (g/l) = (SFM\ or\ SDM)/WC \quad (1)$$

where SFM is shoot fresh matter, in g; SDM is shoot dry matter, in g; WC is cumulative water consumption during the period, in l/plant.

The water content in shoot (WCS) was calculated according to equation 2:

$$WCS\ (\%) = [(SFM - SDM)/SFM] \times 100 \quad (2)$$

The absolute growth rate (AGR) of SFM was calculated according to equation 3:

$$AGR\ (g/day) = (SFM2 - SFM1)/(T2 - T1) \quad (3)$$

where SFM_1 and SFM_2 are shoot fresh matter at times T_1 (20 DAT) and T_2 (25 DAT), in g.

Statistical analysis

The results were subjected to analysis of variance by F test and the means were compared by Tukey test (P = 0.05). The standard deviations of means were also calculated.

3. Results

Visual symptoms of the chicory plants

Under salt stress no symptoms of toxicity by the ions Na^+ and/or Cl^- were observed which could compromise the visual quality of chicory plants (Fig. 1 A). Only in the NFT system without salt stress (ECsol of 2.57 dS/m), after 20 DAT, chicory leaves exhibited necrosis on the edges (Fig. 1 B), an abnormality known as tipburn. Although tipburn symptoms were observed in all plots of this system, but only in some plants.

Growth and production of the chicory

The F-test of the analysis of variance showed a significant effect of the treatments on the number of leaves, plant height, shoot dry matter and water consumption, only at 25 DAT. For shoot fresh matter the treatments had significant effect at 20 and 25 DAT, and only at 20 DAT on the water content in shoot, water use efficiency and the absolute growth rate (20-25 DAT) based on shoot fresh matter (Tables 1 and 2).

At 20 DAT, the overall mean for the number of leaves was 8.2, regardless of the hydroponic systems

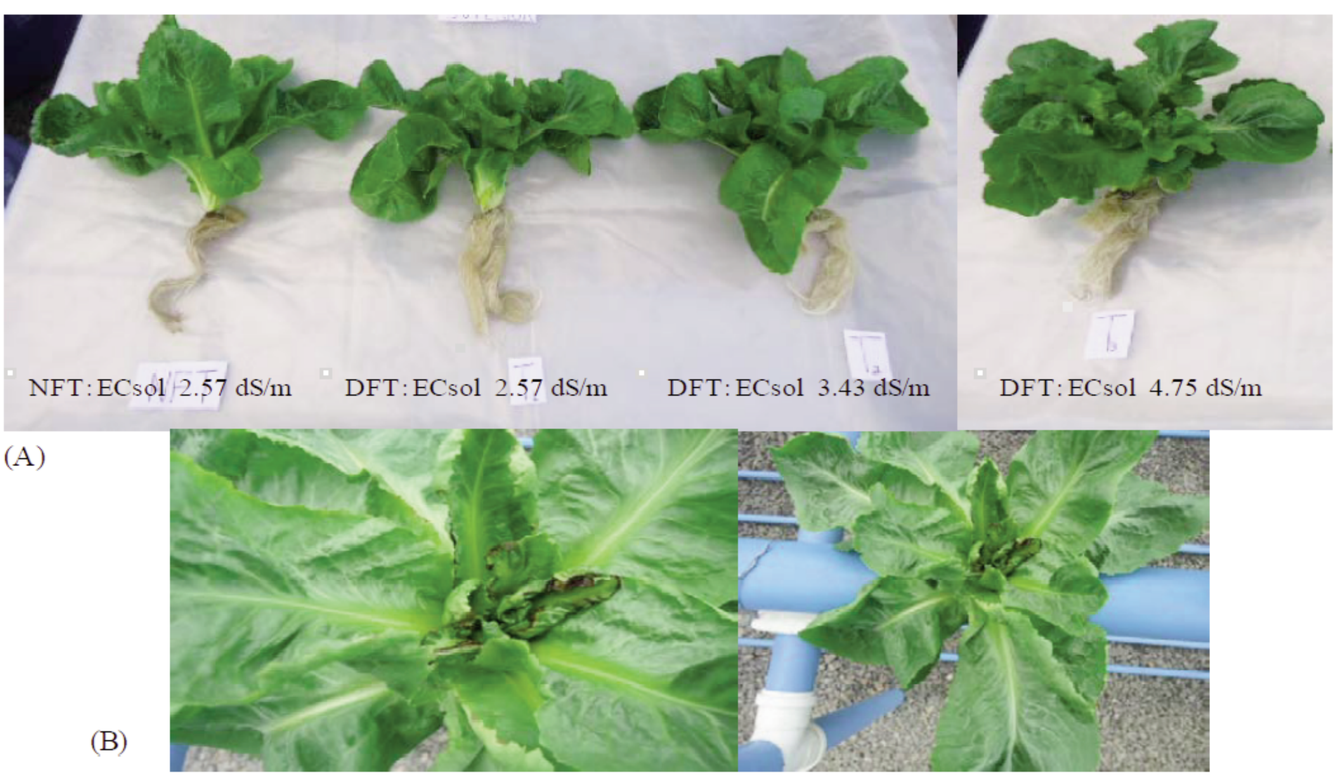

Fig. 1 - Visual aspect of chicory (*Cichorium endivia* L. cv. Dafne) plants in the NFT (without salt stress) and DFT (with and without salt stress) hydroponic systems, at 25 days after transplanting (A) and plants with tipburn in NFT system without salt stress (B).

Table 1 - Summary of the F-test for number of leaves (NL), plant height (PH), shoot fresh matter (SFM), shoot dry matter (SDM) and absolute growth rate of SFM (AGR-SFM) of chicory cultivated under different treatments in hydroponic systems, at 20 and 25 days after transplanting (DAT)

SV	df	Days after transplanting (DAT)								
		NL		PH		SFM		SDM		AGR-SFM
		20	25	20	25	20	25	20	25	20-25
Blocks	7	NS	NS	*	**	*	*	NS	**	*
Treatment	3	NS	**	NS	*	**	**	NS	**	**
Error	21	-	-	-	-	-	-	-	-	-
CV (%)		9.40	9.47	3.30	3.01	9.38	10.04	17.00	15.09	15.81

SV= Source of variation; df= degrees of freedom; CV= coefficient of variation; *, ** significant respectively at P<0.05 and P<0.01; NS= not significant.

Table 2 - Summary of the F-test for water content in shoot, water consumption (WC), and water use efficiency based on shoot fresh matter - SFM (WUE-SFM) and shoot dry matter - SDM (WUE-SDM) of chicory cultivated under different treatments in hydroponic systems, at 20 and 25 days after transplanting (DAT)

SV	df	Days after transplanting (DAT)							
		Water content		WC		WUE-SFM		WUE-SDM	
		20	25	20	25	20	25	20	25
Blocks	7	NS	NS	**	**	**	NS	NS	NS
Treatments	3	**	NS	NS	*	*	NS	NS	NS
Error	21	-	-	-	-	-	-	-	-
CV (%)		0.77	0.63	15.25	14.22	16.20	15.27	19.92	19.87

SV= Source of variation; df= degrees of freedom; CV= coefficient of variation; *, ** significant respectively at P<0.05 and P<0.01; NS= not significant.

and water salinity levels. At 25 DAT, the lowest number of leaves (9.4) was observed in plants under the highest salinity (ECsol of 4.75 dS/m) compared with the other treatments (12.3, 11.9 and 11.1 leaves) (Fig. 2 A). Within a 5-day interval (20 to 25 DAT), under the highest salinity (ECsol of 4.75 dS/m) in the DFT system the increase in the number of leaves did not exceed by 2.0 leaves, while in the NFT system without salt stress (ECsol of 2.57 dS/m) the increase reached approximately 4.0 leaves.

In general, plant height was little influenced by the treatments. On average, plant height at 20 DAT was approximately 30.0 cm. Within a 5-day interval (20 to 25 DAT), the maximum increment of height occurred in the NFT system (2.7 cm), whereas in the DFT system (without and with salt stress) the increments did not exceed 1.0 cm. At ECsol of 2.57 dS/m and regardless of the hydroponic system, the means did not differ statistically, as well as there was no significant difference among the means of the DFT system under different salinity levels (Fig. 2 B).

Differently from the growth variables (Fig. 2 A and 2 B), at 20 DAT, the shoot fresh matter in the DFT system was 26.4% higher than in the NFT system under cultivation conditions without salt stress (ECsol of 2.57 dS/m). In the DFT system even under salt stress conditions (ECsol of 3.43 and 4.75 dS/m), the means of 70.16 and 65.03 g/plant did not differ statistically from that obtained in the NFT system without salt stress (Fig. 2 C). Since the means for shoot dry matter at 20 DAT did not differ statistically (Fig. 2 E), the superiority in the production of shoot fresh matter obtained in the DFT system can be explained by the higher water content in the tissues (Fig. 3 A), since plants responded similarly in terms of number of leaves and height.

In a marked manner, within the interval of only 5-days (from 20 to 25 DAT), the accumulation of fresh matter in plants grown in the NFT system was superior to that recorded during the first 20 days, with growth rate of 16.20 g/day (Fig. 2 D), totaling 144.63 g/plant at 25 DAT (Fig. 2 C). This value was statistical-

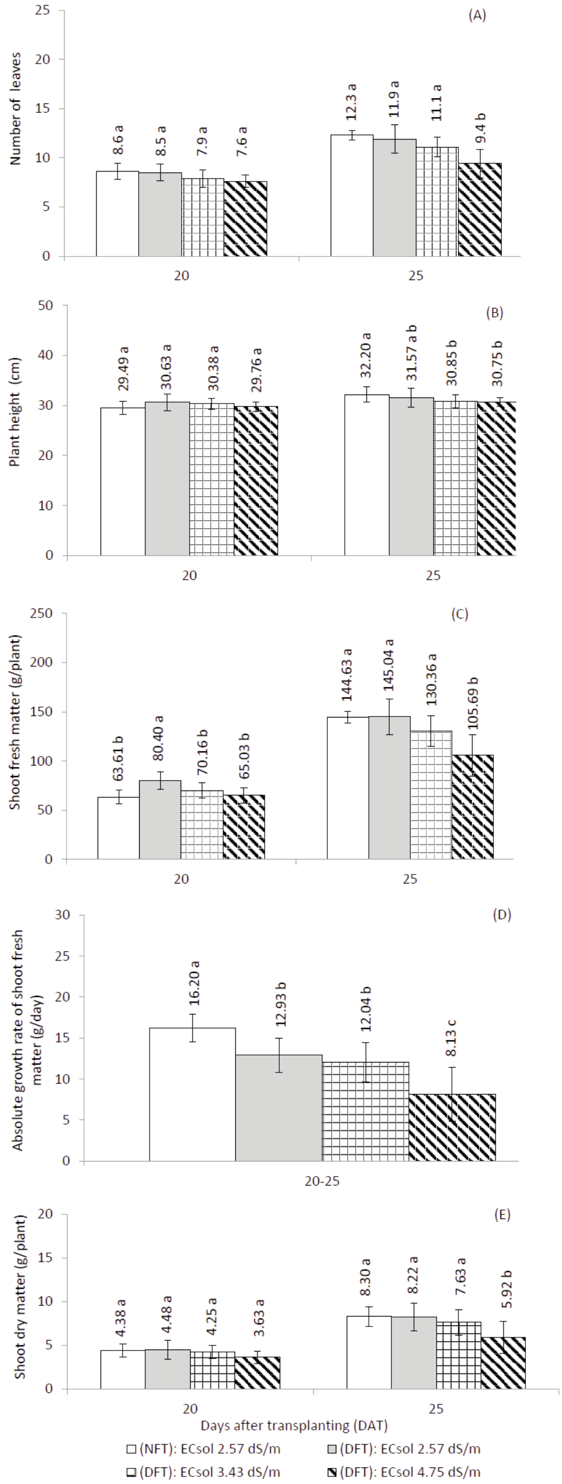

Fig. 2 - Mean number of leaves (A), plant height (B), shoot fresh matter (C), and shoot dry matter (E) of chicory (*Cichorium endivia* L. cv. Dafne) plants in the NFT (without salt stress) and DFT (with and without salt stress) hydroponic systems, at 20 and 25 days after transplanting (DAT) and absolute growth rate of shoot fresh matter during the period 20-25 DAT (D). Means followed by different letters indicate significant differences at 0.05 probability level (Tukey-test). Bars indicate the standard deviations of the means of the eight replicates.

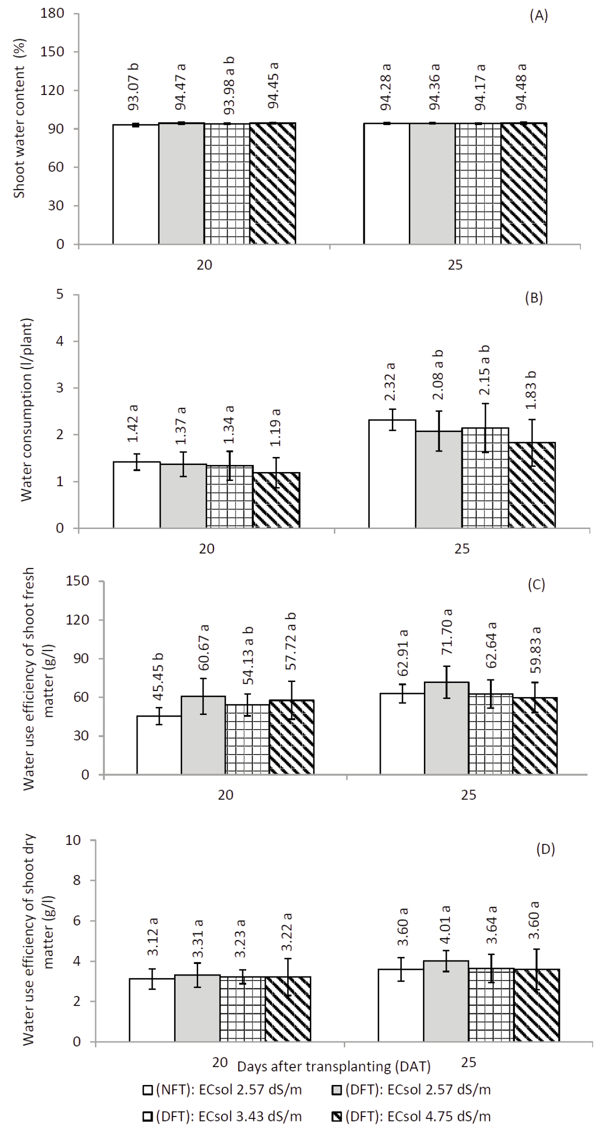

Fig. 3 - Mean water content in shoot (A), water consumption (B) and water use efficiency of shoot fresh matter (C) and shoot dry matter (D) of chicory (*Cichorium endivia* L. cv. Dafne) plants in the NFT (without salt stress) and DFT (with and without salt stress) hydroponic systems, at 20 and 25 days after transplanting (DAT). Means followed by different letters indicate significant differences at 0.05 probability level (Tukey-test). Bars indicate the standard deviations of the means of the eight replicates.

ly similar to the means obtained in the DFT system at ECsol of 2.57 and 3.43 dS/m (145.04 and 130.36 g/plant), with the respective growth rates of 12.93 and 12.04 g/day. At the highest salinity level (ECsol of 4.75 dS/m), the mean of 105.69 g/plant was statistically inferior to those of the other treatments. Based on the results, plants should be harvested at 25 days after transplanting in the hydroponic system, totaling a 50-days cycle from sowing. For the studied cultivar of chicory, on average, the cycle ranges from 45 to 55 days.

At 25 DAT, a similar behavior to that of fresh matter was observed for shoot dry matter (Fig. 2 E). The reduction in shoot dry matter was due to the decrease in the number of leaves and plant height, since the mean water content in the shoots of plants under different treatments did not differ statistically (Fig. 3 A).

Consumption, water use efficiency and water content of the chicory

The F-test of the analysis of variance showed a significant effect of the treatments on the water content in shoot and water use efficiency based on shoot fresh matter for the first evaluation period (20 DAT). For the second evaluation period (25 DAT), there was a significant effect only on the water consumption (Table 2).

For the cumulative water consumption in the period of 20 days, the mean consumption was 1.38 l/plant (Fig. 3 B) and it was not affected by studied treatments. Thus, higher water use efficiency (60.67 g/l) in the DFT system compared to the NFT system (45.45 g/l) (Fig. 3 C) is due to the greater accumulation of fresh matter (Fig. 2 C). In the DFT system, at ECsol levels of 3.43 and 4.75 dS/m, the means of water use efficiency (54.13 and 57.72 g/l) did not differ from those in the condition without salt stress (ECsol of 2.57 dS/m).

At 25 DAT, the water consumption of chicory plants in the DFT system (2.08 l/plant) was similar to that of the NFT system (2.32 l/plant) for the condition without salt stress (ECsol of 2.57 dS/m), with significant reduction only at the highest salinity level (ECsol of 4.75 dS/m) (Fig. 3 B). Within a 5-day interval (20 to 25 DAT), plants increased water use efficiency based on shoot fresh matter, i.e., within five days the consumed water volume was converted to greater biomass accumulation, with overall mean of 64.27 g/l, regardless of the hydroponic systems and salinity levels of nutrient solution (Fig. 3 C). The means of water use efficiency based on shoot dry matter were of 3.22 and 3.71 g/l at 20 and 25 DAT, regardless of hydroponic systems and salinity levels of nutrient solution (Fig. 3 D).

4. Discussion and Conclusions

In the present study (Fig. 1 B), the occurrence of tipburn observed in the NFT system using nutrient solution (ECsol of 2.57 dS/m) prepared in fresh water is due to the higher absolute growth rate significantly higher (16.20 g/day) in comparison to other treatments in the period between 20 and 25 DAT (Fig. 2 D), increasing the demand for calcium. Tipburn symptoms have been reported in other studies with chicory under different conditions of cultivation (Feltrim *et al*., 2008; Sá and Reghin, 2008; Kowalczyk *et al*., 2016 a).

Regarding the visual aspect of chicory plants in the DFT system, with the level of ECsol of 4.75 dS/m there were no symptoms of toxicity due to salinity (Fig. 1 A). In some regions of the world, waters with high salt concentrations are the only source of water available for irrigation of the crops (Cova *et al*., 2020), causing serious problems of toxicity when the concentrations of Na^+ and/or Cl^- inside the plant are sufficiently high (Talhouni *et al*., 2019), resulting in necrosis of older leaves (Parvaiz and Satyawati, 2008; Tavakkoli *et al*., 2010). This occurs because plants virtually lose only water by transpiration, thus leading to accumulation of these ions in the leaves (Acosta-Motos *et al*., 2017; Ismail and Horie, 2017). The time for the damage by toxicity to be manifested depends on the Na^+ and/or Cl^- content in the leaves and on the effectiveness in the compartmentalization of these ions in leaf tissues and cells (Parvaiz and Satyawati, 2008; Giuffrida *et al*., 2013).

The data shown in figure 2 C demonstrate that the production of shoot fresh matter was not affected until 20 DAT, regardless of hydroponic systems and water salinity levels. In the DFT system, plants were supplied with water and nutrients all the time and this favored plants at young age (with smaller size) to produce more fresh matter than those in the NFT system until 20 DAT. After this period, as the volume of roots increased, the oxygen dissolved was depleted more rapidly, thus decreasing the growth rate (Fig. 2 D). With the increase in the volume of roots, there is greater demand for oxygen, according to Kläring and Zude (2009) and Mobini *et al*. (2015); therefore, reductions in oxygen concentrations are expected to occur in the adult stage of the plants (Kiferle *et al*., 2012; Niñirola *et al*., 2014).

The results of present study show that it is possible to produce chicory using brackish waters with reduction of about 27 and 28% in fresh or dry matter, with plants harvested at 25 days after transplanting (Fig. 2 C and 2 E). Such reduction in the yield under salt stress can be compensated by cultivating plants in the system for a longer period, because plants continue to accumulate biomass. Another strategy to compensate the reduction of yield may be by reducing spacing between plants, because under conditions of stress plants occupy a smaller area allowing cultivating more plants per meter length of hydroponic channel as shown by Silva *et al.* (2019) in case of basil. Yet another possibility is to cultivate more than one plant per hole maintaining the spacing of 0.25 m to reach the ideal weight of the bunch for marketing.

In other studies under hydroponic conditions (NFT system), the cultivation of chicory with brackish waters was viable. There was no significant effect on the fresh matter and number of leaves at concentrations of 100 mM (Tzortzakis, 2009) and 40 mM of NaCl (Tzortzakis, 2010) in the nutrient solution, compared to the condition without stress (0 mM of NaCl). The concentration of 30 mM of NaCl did not cause significant effect on the fresh matter and/or number of leaves (Kowalczyk *et al*., 2012; Kowalczyk *et al*., 2016 b).

Chicory plants positively responded to the cultivation in the DFT system adapted in PVC pipes, with a constant 0.02-m depth of nutrient solution (approximately 6.0 l). With this volume of solution in each cultivation channel and assuming mean daily consumption of 0.144 l/plant, if there are interruptions in electricity supply, the system will be able to maintain 15 plants without water restriction for about three days. These results complement other studies which have shown feasibility for the cultivation of different plant species in the DFT system in tubes, such as lettuce (Cova *et al*., 2017), rocket (Campos Júnior *et al*., 2018 b), coriander (Silva *et al*., 2018 a), parsley (Martins *et al*., 2019 a) and chives (Silva Júnior *et al*., 2019). In studies with basil, there was no significant difference in the growth and production variables when plants were cultivated in the DFT and NFT in tubes using nutrient solution prepared in wastewater (Alves *et al*., 2019) and using nutrient solution prepared in fresh water (Santos *et al*., 2019).

The lack of significant effect on water use efficiency based on shoot dry matter, regardless of hydroponic systems and water salinity, demonstrates that the significant differences in shoot fresh matter were due to storage of water in plant tissues (Fig. 3 A). Under salt stress conditions, plants use stomatal closure as a strategy, reducing transpiration due to lower absorption of water (Aroca *et al*., 2012; Moosavi, 2012), which results in increased water use efficiency (Acosta-Motos *et al*., 2017; Morais *et al*., 2018; Soares *et al*., 2018), as reported in various studies under salt stress (Soares *et al*., 2010; Diniz *et al*., 2013; Santos Júnior *et al*., 2013; Soares *et al*., 2015; Lima *et al*., 2017; Coelho *et al*., 2018; Atzori *et al*., 2019 a).

The low water volume used to produce one chicory plant demonstrates high water use efficiency in the hydroponic cultivation, which corroborates with Atzori *et al*. (2019 b) who reported an increase in water use efficiency of chicory in hydroponics compared to conventional soil cultivation. Still in the present study, the quantification of water consumption along the crop cycle can contribute to better planning and use of water resources at places with low water availability because it is possible to estimate in advance the water volume required to produce a certain number of plants within a given period of time. Potentially, in hydroponic cultivation there is greater possibility of using water more efficiently which is not possible in conventional planting.

In conclusion, the data show that the variables of growth, production, water consumption and water use efficiency of chicory under conditions without salt stress (ECsol of 2.57 dS/m) were not significantly affected by the NFT and DFT hydroponic systems. Nutrient solution with salinity of up to 4.75 dS/m prepared in brackish water (NaCl) can be used in chicory cultivation in DFT system, despite small reductions in growth and production, but without any negative effects on the commercial quality of the product.

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