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REUSE OF WATER FROM FISH FARMING AND ITS EFFECTS ON GAS EXCHANGE IN HYDROPONIC ARUCLA

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1 RESUMO

O reuso de água para agricultura pode ser uma alternativa importante para expansão do setor. Diante disto, o objetivo deste estudo foi analisar o potencial de águas oriundas da piscicultura em rúcula hidropônica e seus efeitos nas trocas gasosas. A cultura utilizada foi a rúcula “folha larga”. O delineamento experimental foi em parcelas subdivididas (2 x 4), com quatro repetições, sendo as parcelas em diferentes tempos de recirculação (T1 = 15/15 minutos, e T2 = 15/30 minutos) e as subparcelas com quatro misturas de soluções (S1: 75% do efluente da piscicultura (EP) e 25% da solução nutritiva (SN); S2: 50% do EP e 50% da SN; S3: 25% do EP e 75% da SN e S4: 100% da SN). As variáveis obtidas foram: fotossíntese, concentração interna de CO_2 e eficiência do uso da água. A fotossíntese apresentou melhor resposta com tempo de recirculação de 15 minutos. Em relação a concentração interna de CO_2, o tempo de circulação de 15 minutos com 68% de SN e 32% de EP, apresentaram os maiores valores observados. O uso de águas advindas da piscicultura apresentam potencial de uso para produção de rúcula, sem grandes intereferências nas trocas gasosas desta cultura.

palavras-chave: Água residuária, *Eruca sativa*, Fotossíntese.

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2 ABSTRACT

Reusing water for agriculture can be an important alternative for expanding the sector. Given this, the objective of this study was to analyze the potential of water from fish farming in hydroponic arugula and its effects on gas exchange. The crop used was the arugula cultivar “folha larga”. The experimental design was subdivided plots (2 × 4), with four replications,

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with the plots having different circulation times (T1 = 15/15 minutes, and T2 = 15/30 minutes) and subplots with four mixtures of solutions (S1: 75% of the Fish Farming Water - FW and 25% of the nutrient solution: NS; S2: 50% of the FW and 50% of the NS; S3: 25% of the FW and 75% of the NS and S4: 100% of the NS). The variables obtained were photosynthesis, internal CO_2 concentration and water use efficiency. Photosynthesis showed the best response with a recirculation time of 15 minutes, at which point plants reached higher levels with a nutrient solution concentration of 100%. In relation to the internal CO_2 concentration and water use efficiency, the 15-minute circulation time provided higher values with the solution composed of 68% NS and 32% FW. The use of water from fish farming has potential for use in arugula production without major interference in the gas exchange of this crop.

Keywords: Wastewater, *Eruca sativa*, Photosynthesis

3 INTRODUCTIONS

The use of alternative water sources for agriculture has increasingly become a topic of debate around the world. Population growth and constant demand for food are the main causes of the search for alternative sources, in addition to the excessive exploitation of surface waters, as the demand for water resources in this scenario is inevitable (FAO, 2017). Given this, the reuse of water from different economic activities can be a viable option, among which fish farming stands out as an economic activity with high water use (Correa; Monte; Nascimento, 2020); however, the effluent arising from this activity has a high nutrient load, making it viable for reuse in agriculture (Oliveira *et al*., 2023).

Given the challenges of water reuse, cultivation systems that provide lower environmental impacts are necessary to use these effluents (John *et al*., 2022), as they can contaminate groundwater and other water resources. In this sense, hydroponic cultivation has been increasingly used with reused water (Silva *et al*., 2012; Souza, CA *et al*., 2020; Souza, CDS *et al*., 2020), as it consists of growing plants without the presence of soil, making nutrients available through a nutrient solution in profiles. In addition to being able to produce vegetables efficiently, he has the O goal of reducing water consumption (Silva *et al*., 2012), considering that loss to the environment is reduced, becoming a solution to water scarcity, mainly in arid and semiarid regions, where strategies to increase the efficiency of cultivation systems are necessary (Silva *et al*., 2016; Lessa *et al*., 2023).

For the reuse of effluents to truly be a viable solution for agriculture, studies on their effects on plants are essential for ensuring the viability of their use; in this sense, vegetables such as arugula (Euruca *sativa* L.) and lettuce (*Lactuca sativa*), among others, which are hardwoods consumed *fresh*, need to be evaluated under different criteria, mainly with regard to nutrient absorption (Santos *et al*., 2022), gas exchange (Guimarães *et al*., 2022), and growth and income (Oliveira *et al*., 2023; Dantas *et al*., 2019), so that food and health security can be achieved in relation to production for commercial purposes.

In light of the above, the goal of this study was to analyze the potential of water from fish farming in hydroponic arugula and its effects on gas exchange.

4 MATERIALS AND METHODS

4.1 Experimental structure

A search was carried out at the greenhouse measuring 6.5 m wide by 12.0 m long, measuring 3.5 m high on the sides and

4.5 m in the center of the structure. The cover was made of transparent agricultural film (low-density polyethylene) 150 microns thick and treated with ultraviolet (UV) rays, and the sides were made of anti-aphid screens. The structure was localized at Station Agrometeorological, which belongs to the Department of Agricultural Engineering (DENA) of the Federal University of Ceará (UFC), Campus of Pici (coordinates geographical in 3rd 44' S; 38° 33' It is approximately 22 m above sea level. The average temperature recorded in the protected environment was 34.5°C, and the relative humidity was 60% during the production cycles.

The crop used was the arugula (*Eruca sativa*) cultivar "wide leaf", cultivated between November and December 2021 (Cycle I) and February and March 2022 (Cycle II). Sowing was carried out in polyethylene trays containing 200 cells of coconut fiber substrate. After 22 days, the plants were transplanted into a Nutrient Film Technique (NFT)-type hydroponic system, and the treatments began, lasting a 28-day cycle. . The hydroponic profile was composed of a 100 mm diameter PVC tube measuring 2.70 m long with ten 5 cm diameter holes spaced 0.25 m apart, where the plants were grown. The spacing between the profiles was 0.25 m, and each profile operated independently and was installed at an average height of 0.85 m, with a slope of 3.0%. For each profile, a 50 L reservoir was used for storing the solution, and an electric pump (0.25 HP) was used to promote the recirculation of the solution between the profiles. The solution was injected into the profile using a microtube with a flow rate of 1.5 L/min (Santos *et al*., 2022). An analog timer was used to control the frequency and duration of solution recirculation.

The fish farming effluent was obtained from the farming of Nile tilapia (*Oreochromis niloticus*) in an excavated tank covered with canvas and with a volume of 4.8 ^{m3}. The effluent used came from the fattening phase (from 300 to 700 g), during which the plants were fed according to the weight and recommendations of the feed manufacturer (Polinutri®). Cascade aeration in a recirculation system for the tank was carried out with an electric pump (0.5 CV). Effluent filtration was carried out in a decanter filter containing an acrylic geotextile blanket to remove suspended solids and a biological filter filled with expanded clay with nitrifying bacteria. Samples of fish farming effluent were sent to the Soil, Water, Plant Tissue and Fertilizer Analysis Laboratory – FUNCEME/UFC Agreement for chemical characterization (Table 1).

Table 1. Chemical characterization of fish farm effluent used in hydroponics.

Cycle	**Cátions (mmol $_{cL}$ - ^{1})**				**Anions (mmol $_{cL}$ - ^{1})**			**dS m $^{-1}$**	**RAS**	**pH**	**(mg L $^{-1}$)**
	Ca^{2+}	Mg^{2+}	And $^+$	K^+	Cl^-	HCO_3^-	CO_3^{2-}	EC			Dissolved solids
I	1.4	3.0	6.0	0.8	10.5	0.1	0.4	1.11	2.88	10.5	1110
II	1.7	2.8	6.1	0.8	10.9	0.3	0.4	1.18	2.88	9.1	1180

Source: Authors (2023)

4.2 Experimental design

In the experimental design, he was subdivided into four repetitions (two × 4), with the plots consisting of different recirculation times (T1 = 15 minutes with recirculation for 15 minutes off, and T2 = 15 minutes with recirculation for 30 minutes off). The subplots were composed of mixtures of solutions (S1: 75% of the fish farming effluent (PE) and 25% of the solution nutrient (NS); S2: 50% from EP and 50% from SN; S3: 25% from EP and 75% from SN; and S4: 100% from SN), for a total of 32 units, which were composed of an independent hydroponic set with 10 plants per plot.

The standard nutrient solution (SN) used as a control was prepared according to Furlani (1998). The other treatments were obtained by mixing the solutions according to the desired proportions; the mixtures were added to 500 L water tanks and subsequently stored for use throughout the cycle.

4.3 Variables analyzed

Gas exchange was carried out on fully expanded leaves at the end of the cultivation cycles based on the selection of the most representative plants from each hydroponic profile.

Gas exchange measurements were carried out in the central region of completely expanded leaves exposed to sunlight, using a Portable Infrared Gas Analyzer (IRGA) model LCPro+ Portable Photosynthesis System® (ADC BioScientific Limited , UK), the readings were taken from 9:30 am to 11:30 am in the morning, the variables analyzed were : net photosynthesis (*A)* in µmol CO_2 m^{-2} s^{-1}; transpiration (*E)* in mmol H_2O m^{-2} s^{-1}; stomatal water vapor conductance (*gs)* in mol H_2O m^{-2} s^{-1}; internal concentration of CO_2 (*Ci)* in µmol CO_2 mol^{-1} air, efficiency of use from the water (*WUE* - µmol CO_2 m^{-2} s^{-1} [mmol H_2O m^{-2} s^{-1} $]^{-1}$) obtained for the *A/E* ratio ; intrinsic efficiency of water use (*iWUE* - µmol CO_2 m^{-2} s^{-1} [mol H_2O m^{-2} s^{-1} $]^{-1}$) , obtained for the relationship between *A/gs* and instantaneous carboxylation efficiency (*EiC* - µmol CO_2 m^{-2} s^{-1} [µmol H_2O mol^{-1} air$]^{-1}$), obtained by the relationship between *A/Ci* . Readings were taken under saturating light (1200 µmol m^{-2} s^{-1}) with a constant CO_2 concentration (400 ppm) at room temperature.

The data of the variables evaluated were subjected to analysis of variance (ANOVA) for the test. F: 1% and 5% probability ($p<0.01$ and $p<0.05$, respectively). When the analysis of variance was significant, the data were analyzed through regression and by the mean test with Tukey's test. The analyses were carried out using the Microsoft Excel® (version 2023) and ASSISTAT® (version 7.6beta) programs.

5 RESULTS AND DISCUSSION

According to analysis of variance (F test), for the first cycle, no influence of the studied factors on the response variables was observed. For the second cycle, the results obtained for the gases exchange were significant for the interaction between recirculation time (T) and solution mixture (S) for the variables *Ci* ($p<0.01$), *WUE* ($p<0.01$), *iWUE* ($p<0.05$) and *EiC* ($p<0.05$). For the isolated factor T, its influence was observed only on variable *A* ($p<0.01$). For the single factor S, the variables *A*, *WUE and EiC* were significantly influenced ($p<0.01$). The variables *gs* and *E* were not influenced by any of the factors studied (Table 2).

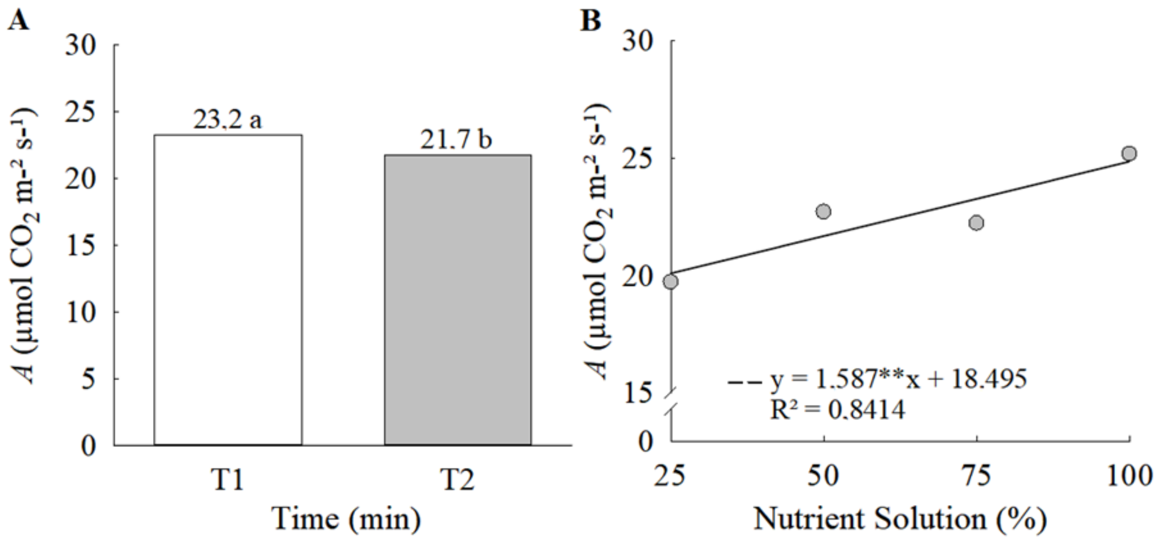
Table 2. Summary of variance analyzes referring to photosynthesis data (*A*), stomatal conductance (g_s), transpiration (*E*), substomatal CO_2 concentration (C_i), water use efficiency (*WUE*), intrinsic water use efficiency water (*iWUE*) and instantaneous carboxylation efficiency (*EiC*) of hydroponic arugula plants, subjected to recirculation of the nutrient solution mixed with fish farming effluent.

Sources of variation	GL	Medium Square						
		Cycle I						
		A	g_s	*E*	C_i	*WUE*	*iWUE*	*EiC*
Block	3	111.23	0.64	17.56	769.80	0.26	427.41	0.15
Time (T)	1	45.34	0.01	1.88	390.41	0.001	76.19	0.045
Waste	3	78.60	0.36	15.80	1899.94	1.52	811.67	0.079
Solution (S)	3	32.64	0.21	1.59	708.67	0.61	223.31	0.058
T x S	3	84.13	0.20	1.33	345.02	0.29	84.35	0.083
Residue (b)	18	92.74	0.20	2.28	1039.48	1.00	285.76	0.13
Total	31							
CV - T (%)	-	45.86	24.80	55.83	14.56	44.72	62.10	42.47
CV - S (%)	-	49.81	93.70	21.22	10.77	37.64	36.85	56.08
Sources of variation	GL	Cycle II						
		A	g_s	*E*	C_i	*WUE*	*iWUE*	*EiC*
Block	3	29.85**	0.14	1.17	41.79	0.87	46.21	0.00012
Time (T)	1	18.74**	0.22	0.05	36.12	0.42	7.60	0.00048
Waste	3	0.41	0.27	1.92	25.45	0.63	114.22	0.0001
Solution (S)	3	39.94**	0,04	0,05	566,70	0,91**	87,76	0,0007**
T x S	3	12,21	0,34	0,89	1590,87**	1,30**	65,11*	0,0002*
Resíduo (b)	18	11,27	0,12	0,67	224,40	0,21	43,50	0,0001
Total	31							
CV - T (%)	-	2,86	46,21	22,95	1,73	21.14	47.19	10.84
CV - S (%)	-	14.95	31.01	13.57	5.14	12.25	29.12	10.60

and * indicate significance at 1 and 5% probability, respectively, according to the F test. **Source: Authors (2023)

The response variable *A* differed significantly in relation to the recirculation time factor, in which T1 was more favorable than T2 was (Figure 1A). It is possible that a duration longer than 15 minutes without activation to recirculate the nutrient solution could cause water deficit in the arugula crop, which could have affected the photosynthetic response. For factor S, the response variable presented an adjustment of linear growth with an increase of 1.587 µmol CO2 m^{-2} s^{-1} for each unit increase in SN (Figure 1B). The T1 factor represents a longer duration time of the nutrient solution; consequently, greater ion–root contact occurred. In addition, increasing the percentage of nutrient solution improved photosynthesis, as both factors allowed the plants to absorb more nutrients from the SN, consequently allowing them to absorb more nutrients such as nitrogen (N). Second, Có *et al*. (2023) This element is the main component of the photosynthetic pigment chlorophyll; therefore, greater absorption of this macronutrient increases the photosynthetic potential of the plant.

Figure 1. The Tukey test (A) and regression analysis (B) for the photosynthesis response variable (*A*) for the Arugula culture depending on the recirculation times of the nutrient solution and water from fish farming.

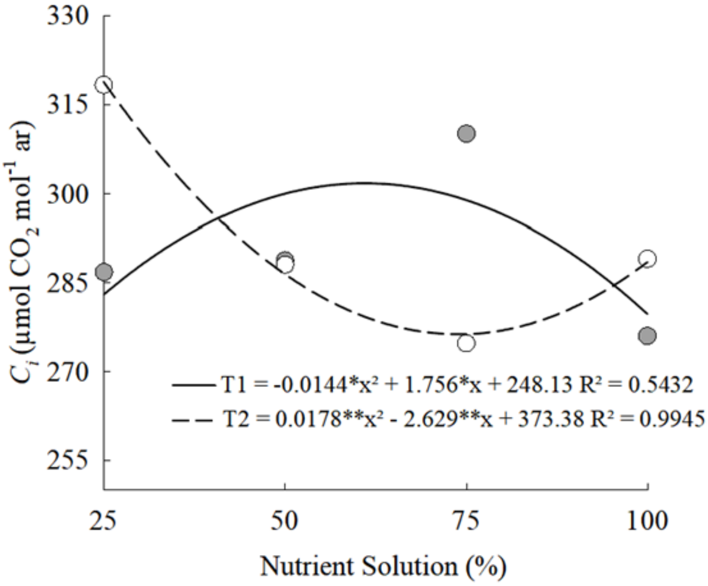


Source: Authors (2023)

Santos *et al*. (2022), in studies with hydroponic arugula in an NFT system, shorter intervals for SN recirculation increased the N content in the leaves, which may have corroborated the increase in *A* in the present research. On the other hand, Souza, CDS *et al*. (2020) did not observe any influence of SN recirculation in hydroponic chive (*Allium schoenoprasum*) culture with reused water on the N content. Souza, CA *et al* . (2020), in studies with hydroponic watercress (*Nasturtium officinale)* and reuse water in an NFT system, observed that increasing the concentration of salts in the SN can increase the *A* response in plants, in which the recirculation of the SN at intervals of 15 minutes showed greater benefit up to tolerable levels of electrical conductivity of the water used. These results were also observed by Oliveira *et al*. (2023) for the SPAD index in watercress culture produced with reused water from fish farming effluent.

Figure 2 shows the regression analysis for the internal concentration of CO2 (*Ci*). The best fit was quadratic for both recirculation times from the SN. For the T1 point, a maximum of 301.7 µmol CO_2 mol $^{-1}$ air was obtained with an SN of 60.97%, while for T2, a minimum of 276.31 µmol CO_2 mol $^{-1}$ air was observed at an SN of 73.85%. With greater availability of SN for T1, there was an increase in *Ci*, which contacts root ions and possibly favors nutrient absorption, as K is N and, consequently, greater physiological activity, considering that both elements help in the physiology of plants, such as osmotic adjustment, transpiration and the production of photoassimilates (Lima *et al*., 2021; Silva *et al*., 2013).

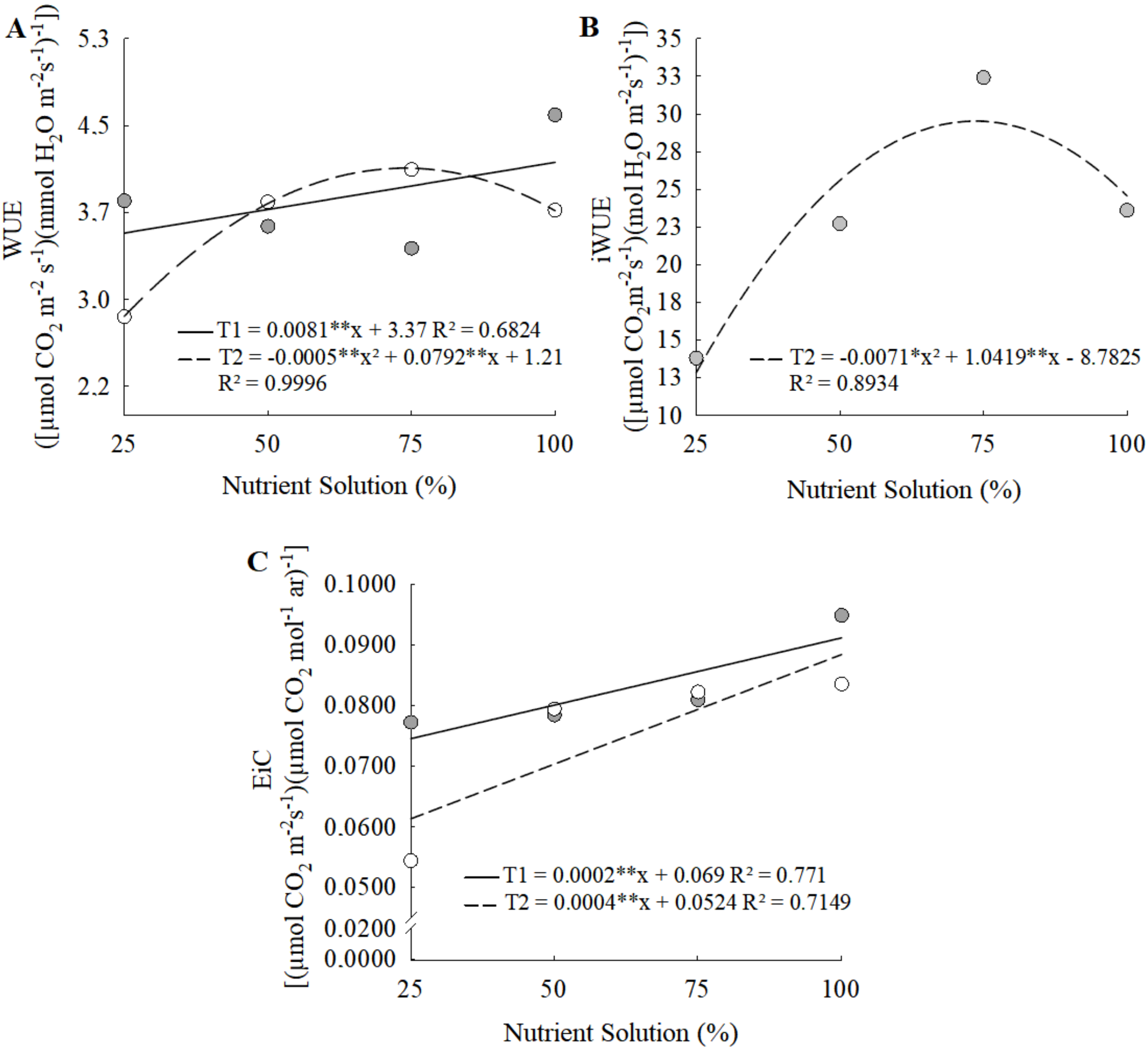
Figure 2. Regression analysis of the response variable internal concentration of CO2 in the culture from Arugula according to the circulation time of the nutrient solution and water from fish farming.



Source: Authors (2023)

Figure 3 shows the regression analysis for the response variables water use efficiency (*WUE*), intrinsic water use efficiency (*iWUE*) and instantaneous carboxylation efficiency (*EiC*). For *WUE* (Figure 3A), the two recirculation times were within an adjustment polynomial quadratic function. T1 linearly increased, with an estimated value of 4.18 ([µmol CO_2 m^{-2} s^{-1}) (mmol H_2O m^{-2} s^{-1}) $^{-1}$]) and an SN of 100%, while for T2, the adjustment was quadratic, with a maximum estimated value of 4.35 ([µmol CO_2 m^{-2} s^{-1}) (mmol H_2O m $^{-2}$ s^{-1}) $^{-1}$]) for 79.2% of the SN. The *WUE* increased to a certain point in T2, decreasing later, possibly due to the increase in the concentration of salts in the SN, with an increase in electrical conductivity, in which the free energy decreased and, consequently, the water potential gradient increased, resulting in a decrease in WUE (Taiz *et al*., 2017). T1 also showed a small decrease in *WUE*, which can be explained by the fact that this variable is directly linked to the internal concentration of CO2 and thus has interdependence, with greater assimilation of CO2 and less water loss during the process (Guimarães *et al*., 2019), which may have influenced the reduction in *WUE* and increase in *Ci* at T1. For the *iWUE* variable (Figure 3B), a quadratic adjustment was observed with the highest estimated value (29.44 µmol CO_2 m^{-2} s^{-1} [mol H_2O m^{-2} s^{-1}] $^{-1}$) to 73.37% of SN; therefore, the use of approximately 26.63% of EP would not possibly affect the development of plants, even reducing fertilizer costs. For the variable *EiC* (Figure 3C), a linear adjustment was observed with an increase of 0.0002 µmol CO_2 m^{-2} s^{-1} [µmol H_2O mol^{-1} air] $^{-1}$ (T1) and 0.0004 µmol CO_2 m^{-2} s^{-1} [µmol H_2O mol^{-1} air] $^{-1}$ (T2) for each unit increment of SN. Values similar to those observed in the present study for *iWUE* were obtained by Guimarães *et al*. (2022), in studies with arugula cultivated in intercropping with nirá, they observed values between 28.63 and 34.80 µmol CO_2 m^{-2} s^{-1} [mol H_2O m^{-2} s^{-1}] $^{-1}$ for *EiC*.

Figure 3. Analysis of the regressions for the response variables water use efficiency (A), intrinsic water use efficiency (B) and instantaneous carboxylation efficiency (C) for the arugula culture depending on the recirculation times of the nutrient solution and water from fish farming.



Source: Authors (2023)

5 CONCLUSIONS

The use of water from fish farming has potential for use in arugula production without major interference in the gas exchange of this crop.

Photosynthesis presented the best response at 15-minute intervals for recirculation of the nutrient solution.

Reducing the nutrient solution by 30% with supplementation of water from fish farming can be an option for use in hydroponic arugula production, especially in situations of water scarcity.

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7 REFERENCES

HAVE, E. G.; SOUSA, G. G. de; GOMES, S. P.; FREIRE, M. HC; SILVA, F. D. B. Strategies involving irrigation with saline water are applied to plants fertilized with nitrogen in the culture of millet. **Magazine Caatinga** , Mossoró, v. 36, no. 2, p. 424-431, 2023.

CORREA, ES; MONTE, CN; NASCIMENTO, TSR Environmental impact assessment caused by effluents from the Santa Rosa fish farming station, Santarém/Pará. **Ibero-American Journal of Environmental Sciences** , Aquiaba, v. 11, no. 1, p. 260-273, 2020.

DANTAS, RML; SILVA. AND. FF; SILVA, AO; MEDEIROS, PRF; SILVA, GF; SOARES, HR Watercress and chinese cabbage in a hydroponic system using groundwater. **Caatinga Magazine** , Mossoró, v. 32, no. 4, p. 1038-1047, 2019.

FAO. **Sustainable irrigated agriculture in Brazil** : Identification of priority areas. Brasília, DF: FAO, 2017. 243 p.

FURLANI, PR **Instructions for growing leafy vegetables using the hydroponic technique – NFT** . Campinas: Instituto Agrônomico, 1998. 30 p. (IAC Documents, 168).

GUIMARÃES, MA; LEMOS NETO, HS; LIMA NETO, BP; HENDGES, ARAA; VIANA, CS; RABELO, JS; OLIVEIRA, FRA Physiological responses of arugula/nirá intercropping under different arrangements and growing seasons. **Brazilian Horticulture** , Brasília, DF, v. 40, p. 255-260, 2022. DOI: http://dx.doi.org/10.1590/s0102-0536-20220302. Available at: https://www.scielo.br/j/hb/a/S4LKQssZZMNxxzxPWGLy57b/?lang=pt. Accessed on: 22 Dec. 2023.

GUIMARÃES, A. F. B.; MAIA JÚNIOR, S. D. O.; BIRTH, R. do; MELO, D. F. of; BRANCHES, J. G.; ANDRADE, J. R. de. Exchanges gaseous in cultivars in lettuce curly in hydroponic cultivation with water saline. **Magazine Brazilian in Agriculture Irrigada** , Fortaleza, v. 13, n. 4, P. 3599-3609, 2019.

JOHN, V. C.; VERMA, A. K.; KRISHNANI, K. K.; CHANDRAKANT, M. H.; BHARTI, V. S.; VARGHESE, T. Optimization of potassium (K^+) supplementation for growth enhancement of *Spinacia oleracea* L. and *Pangasianodon hypophthalmus* (Sauvage, 1878) in an aquaponic system. **Agricultural Water Management**, Amsterdam, v. 261, p. 107339, 2022.

LESSA, C. I. N.; LACERDA, C. F.; CAJAZEIRAS, C. C. A.; NEVES, A. L. R.; LOPES, F. B.; SILVA, A. O.; SOUSA, H. C.; GHEYI, H. R.; NOGUEIRA, R. S.; LIMA, S. C. R. V.; COSTA, R. N. T.; SOUSA, G. G. Potential of brackish groundwater for different biosaline agriculture systems in the brazilian semiarid region. **Agriculture**, Bassel, v. 13 n. 3, p. 1-22, 2023.

LIME, A. F. D. S.; SANTOS, M. F. D.; OLIVEIRA, M. L.; SOUSA, G. G. D.; MENDES FILHO, PF; LUZ, LND Physiological responses of inoculated and uninoculated peanuts under saline stress. **Magazine Environment & Water** , Taubaté , v. 16, no. 1, p. 1-10, 2021.

OLIVEIRA, DR; OLIVEIRA, WC; SILVA, AO; BEZERRA, BGMC; SOUSA, GG; LACERDA, CF Hydroponic watercress production through fish farming water reuse and varied nutrient solution recirculation times. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 27, no. 12, p. 919-926, 2023.

SANTOS, JSG; SILVA, AO; LACERDA, CF; COSTA, RNT; SILVA, GF; PUTTI, FF Frequencies of application and dilution of nutrient solution in hydroponic cultivation of arugula. **Irriga** , Botucatu, v. 27, no. 3, p. 639-652, 2022.

SILVA, AO; KLAR, AE; SILVA. Ê .FF; TANAKA, AA; SILVA JUNIOR, JF Water relations in beet cultivars at different levels of soil salinity. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 17, no. 10, p. 1143-1151, 2013.

SILVA, AO; SOARES, TM; SILVA. AND. FF; SAINTS. AN; KLAR, AE Water consumption of arugula in NFT hydroponic cultivation using desalination waste in Ibimirim-PE. **Irriga** , Botucatu, v. 17, no. 1, p. 114-125, 2012.

SILVA, M. G.; SOARES, TM; GHEYI, H. R.; OLIVEIRA, I. S.; SILVA SON, J. A. Growth and production of hydroponic coriander under different seeding densities and diameters of cultivation channels. **Irriga** , Botucatu, v. 21, no. 2, p. 312-326, 2016.

SOUZA, CA; SILVA, AO; LACERDA, CF; SILVA. AND. FF; BEZERRA, MA Physiological responses of watercress with brackish water and different circulation times of the nutrient solution. **Semina** : Agricultural Sciences, Londrina, v. 41, no. 6, p. 2555-2569, 2020.

SOUZA, CDS; SILVA, GF; MENEZES, SM; SANTOS JUNIOR, JA; MORAIS, JEF; SILVA, AO Nutrient and inorganic solute (Na^+ Cl^-) content in green onion plants under hydroponic cultivation using brackish waters. **Science and Agrotechnology** , Lavras, v. 44, no. e013320, p. 1-12, 2020.

TAIZ, L.; ZEIGER, AND.; MOLLER, I. M.; MURPHY, A. **Physiology It is development vegetable** . 6. ed. Porto Alegre: Artmed, 2017. 888 p.