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Water use efficiency of coriander produced in a low-cost hydroponic system

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A B S T R A C T

The increase of water use efficiency in crop production is a clear need in areas with restricted access to this resource and, in these cases, the adoption of forms of cultivation contextualized to local conditions are essential. Thus, the implications of the variation in the amount of seeds per cell (0.5, 1.0, 1.5 and 2.0 g) and spacing between cells (7.0, 10.0 and 15.0 cm) on variables related to consumption and water use efficiency for the production of coriander (cv. Tabocas) in a low-cost hydroponic system, an alternative for semiarid regions, were evaluated. A completely randomized experimental design, analysed in 4 x 3 factorial scheme with three replicates, was adopted, and the data were subjected to analysis of variance at 0.05 probability level. It was found that the reduction in the spacing between cells has a better cost-benefit ratio with respect to water consumption, biomass produced and cost of seeds. Therefore, it is recommended the adoption of a spacing of 7.0 cm between cells and the use of 1.0 g seeds per cell; this configuration promoted efficiency of 81.59 g L^{-1} in shoot green mass production and total mass of 62.4 g coriander bunches.

Palavras-chave:
semiárido brasileiro
Coriandrum sativum L.
validação de protótipo

Eficiência do uso da água na produção do coentro em hidroponia de baixo custo

R E S U M O

O incremento da eficiência do uso da água na produção das culturas é uma necessidade evidente em regiões com acesso restrito a este recurso e, nesses casos, a adoção de formas de cultivo contextualizadas à realidade local é imprescindível. Neste contexto, avaliou-se as implicações da variação da quantidade de sementes por célula (0,5; 1,0; 1,5 e 2,0 g) e do espaçamento entre células (7,0; 10,0 e 15,0 cm) sobre variáveis relacionadas ao consumo e eficiência do uso da água na produção de molhos de coentro (cv. Tabocas) em um “módulo hidropônico de baixo custo”, alternativo para regiões semiáridas. Adotou-se um delineamento experimental inteiramente casualizado analisado em esquema fatorial 4 x 3, com três repetições cujos dados foram submetidos à análise de variância em nível de 0,05 de probabilidade. Verificou-se que a redução dos espaços entre células proporcionou melhor relação custo benefício em relação ao consumo de água, massa produzida e custo de sementes. Recomenda-se, portanto, a adoção de 7,0 cm de espaçamento entre células e a utilização de 1,0 g de sementes célula^{-1}; esta configuração proporcionou eficiência de 81,59 g L^{-1} na produção de massa verde da parte aérea e molhos de 62,4 g de massa total.

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Introduction

The viability of vegetable crop production under semiarid conditions, in regions notably characterized by the low availability of surface water resources and high values of potential evapotranspiration, is directly related to the adoption of management practices and cultivation systems that result in high levels of water use efficiency (Ghamarnia et al., 2012).

Among the various ways of rationalizing water use in vegetable production, there are the application of deficit irrigation, use of localized and efficient irrigation systems, use and management of saline waters, etc. However, the results obtained in hydroponic cultivation systems with recirculation of the percolating solution in different crops (Alves et al., 2011; Santos et al., 2012) stand out.

However, issues related to energetic infrastructure, skilled labor or even high implantation costs have made the access of small farmers from the Brazilian semiarid region to hydroponic system unviable. Yet, some authors have already developed researches on the production of vegetable crops, like coriander (*Coriandrum sativum* L.) in semiarid conditions under water or saline stress (Ghamarnia et al., 2013; Silva et al., 2013; Hassan & Ali, 2014), with even conventional hydroponic systems (Luz et al., 2012; Rebouças et al., 2013).

Nevertheless, new adjustments have been made in hydroponic systems in order to adapt this technology to the peculiar conditions of the Brazilian semiarid region, such as the low-cost hydroponic system (Santos Júnior, 2013). Thus, it is necessary to study some ways of rationalizing costs and water use in these hydroponic systems, such as the spacing between cells and the amount of seeds to be used, because these factors directly influence the amount of water used in the enterprise and the produced mass, as well as the necessary costs and even its implantation viability.

Although widely consumed and important for the economy of this region (Rebouças et al., 2013), many municipalities in the Brazilian semiarid region need to import vegetable crops like coriander from producing centers, and the distance and transport conditions increase the price and decrease the shelf life of the product.

Despite being native from the Mediterranean, coriander is currently cultivated and consumed in many countries (Ghamarnia et al. 2013) and, among its different uses, there are aromatic and medicinal applications (Ramadan & Wahdan, 2012) and uses in industries of food (Michalczyk et al., 2012) and pharmaceuticals (Jabeen et al., 2009). In Brazil, it is consumed in all the regions, especially its green mass, which is used in the cookery of many typical dishes, and its dry fruits, used as seasonings and in the manufacture of breads, candies, pickles and fine liquors (Rebouças et al., 2013).

Based on the above, this study aimed to evaluate the impacts of the variation in the amount of seeds and in the spacing between cells on variables related to water consumption and water use efficiency of coriander (cv. Tabocas) in a low-cost hydroponic system, an alternative for semiarid regions.

Material and Methods

The experiment was carried out in a greenhouse from July to August 2013, at the Experimental Station of the National Institute of Semiarid – INSA/MCTI, Campina Grande-PB, Brazil (7º 16' 41" S; 35º 57' 59" W; 470 m).

A low-cost hydroponic system (Santos Júnior, 2013) was used, which consisted of a 6 x 1.40 m wooden support waterproofed with oil paint, projected with supporting capacity for 12 PVC tubes, leveled, with 6 m of length and 100 mm of diameter.

The tubes were perforated with circular "cells" of 60 mm diameter, equidistantly spaced according to each specific treatment, considering the central axis of each cell. Tube elbows with the same diameter were attached to the tubes and taps were installed in order to allow water outflow, as in an overflow pipe system, and maintain a constant water level of 4 cm along the tubes, for uniform distribution of solution to plants. Perforated couplers were attached to the elbows to allow gas exchange with the environment.

Plastic cups of 200 mL, perforated at the bottom and on the lower portion of the sides and filled with coconut fiber, were placed in the cells. It was considered that each cell produced one bunch of coriander.

For the establishment of validation parameters specific for coriander (cv. Tabocas) in this hydroponic system, the treatments consisted of variable amounts of seeds per cell (0.5, 1.0, 1.5 and 2.0 g) and different spacings between cells (7.0, 10.0 and 15.0 cm), in order to evaluate how this variation influences water consumption, water use efficiency and plant-water relations.

The treatments were distributed in a completely randomized design, analyzed in a 4 x 3 factorial scheme, with three replicates in the same tube, so that each replicate corresponded to 1/3 of the total tube length.

The nutrient solution used in the experiment (Furlani et al., 1999) has an original electrical conductivity of 3.4 dS m^{-1}. The produced volume of solution was diluted in water (1:1) from the local supply system of Campina Grande-PB (Table 1), obtaining an initial electrical conductivity of 2.5 dS m^{-1} in the nutrient solution.

Table 1. Characterization of the water used in the preparation of nutrient solution, July/2013*

Parameters	Results
pH	7.06
EC_w (dS m^{-1})	0.85
Ca (mg L^{-1})	29.00
Mg (mg L^{-1})	29.40
Na (mg L^{-1})	274.62
K (mg L^{-1})	7.02
Chloride (mg L^{-1})	273.67
Sulfate (mg L^{-1})	46.66
Bicarbonate (mg L^{-1})	114.68
Carbonate (mg L^{-1})	0.00
Iron (mg L^{-1})	0.15
Dissolved oxygen (mg L^{-1})	3.30
Alkalinity in carbonate – CO_3 (mg L^{-1})	0.00
Alkalinity in bicarbonate – HCO_3 (mg L^{-1})	94.00
Total alkalinity – $CaCO_3$ (mg L^{-1})	94.00
Total hardness - $CaCO_3$ (mg L^{-1})	195.00
Dry residue (mg L^{-1})	545.28
Free ammonia – NH_3^- (mg L^{-1})	Absence
Nitrites – NO_2^- (mg L^{-1})	Presence
Nitrates – NO_3^- (mg L^{-1})	Absence

* Methodology of analysis: EMBRAPA (2009)

Twelve 80-L recipients were used for the management of the nutrient solution, which was performed per tube, i.e., as per specific treatment. In spite of that, although the same solution was used in all treatments, manually added: at 8 h, 20 L of nutrient solution in all the tubes according to the respective treatment and at 16 h, another 20 L were added to the tubes, promoting the homogenization of the solution and nutrient recycling.

The replenishment of the evapotranspired volume was calculated and weekly performed, using water from the local supply system, so that the preparation of the solution with the addition of fertilizers occurred only once, at the beginning of the experiment. CE and pH were monitored every 7 days after seeding (DAS).

The temperature in the greenhouse was daily monitored and, during the experiment, the mean maximum temperature was 34.6 ºC and the mean minimum was 18.1 ºC. No symptom of diseases or the occurrence of pests was observed during the experiment, even without the application of any type of insecticide.

At 28 DAS, based on the sum of the weekly replenishments of the nutrient solution metabolized by plants, the water consumption necessary for the production of one bunch of coriander (shoots + roots) was calculated, and total fresh phytomass (TFP) and shoot fresh and dry phytomasses (SFP and SDP) of all the experimental units were determined. Then, water use efficiency was estimated for each one of them (E-SFP and E-SDP)

The values of fresh matter were determined on a precision scale (0.001 g), immediately after plant harvest and the results of dry matter were obtained after drying in a forced-air oven at 60 ºC, until constant weight. The values of water use efficiency were obtained by the relationship between the mass (g) produced in each cell and the volume (L) consumed.

In addition, the following variables were determined: mean water content in the entire plant (WCP), in the shoots (WCS) and in the roots (WCR) and the index of shoot biomass production (ISBP), according to Benincasa (2003), and the root/shoot ratio (R/S), according to Magalhães (1979).

The data were analysed using a statistical program (Ferreira, 2011). Follow-up analysis was used when the interaction between the amount of seeds and the spacing between cells was significant. When isolated factors were significant, regression analysis was applied for the factor amount of seeds and Tukey test was applied for the spacing between cells. A significance level of 0.05 was adopted in all the analyses.

Results and Discussion

The management of the nutrient solution with replenishment of the weekly-consumed water volume promoted slight variations in CE and pH of the nutrient solution (Table 2). The importance of these results is reflected in the comments of Silva et al. (2012), who mention that the increase in EC reduces the osmotic potential of the solution, thus requiring more energy for the absorption of water and nutrients by plants. McBride & Blasiak (1979) add that pH influences the solubility, concentration in solution and ionic form of nutrients and, consequently, their absorption and use by plants.

Table 2. Variation in EC and pH of the nutrient solution in different periods of the growth of coriander (cv. Tabocas), cultivated in a low-cost hydroponic system

Treatments		DAS							
		7		14		21		28	
Amnt. (g)	Spc. (cm)	EC_{ns}^{*}	pH_{ns}	EC_{ns}^{*}	pH_{ns}	EC_{ns}^{*}	pH_{ns}	EC_{ns}^{*}	pH_{ns}
0.5	7.0	2.15	6.75	2.17	6.32	2.17	6.64	2.23	7.13
1.0	7.0	2.39	7.08	2.47	6.39	2.39	6.37	2.37	6.86
1.5	7.0	2.49	6.63	2.48	6.29	2.42	6.54	2.60	6.77
2.0	7.0	2.15	6.71	2.12	6.37	2.17	6.59	2.10	7.17
0.5	10.0	2.30	6.40	2.36	6.46	2.39	6.45	2.58	6.69
1.0	10.0	2.39	6.81	2.36	6.24	2.39	6.51	2.43	7.07
1.5	10.0	2.48	7.06	2.45	6.48	2.25	6.84	2.48	7.17
2.0	10.0	2.42	6.81	2.40	6.49	2.38	6.46	2.32	6.89
0.5	15.0	2.30	6.71	2.44	6.34	2.33	6.81	2.48	7.05
1.0	15.0	2.15	6.31	2.20	6.25	2.08	7.17	2.38	7.14
1.5	15.0	2.60	6.60	2.54	6.41	2.33	6.44	2.52	6.95
2.0	15.0	2.10	6.64	2.30	6.34	2.17	6.41	2.34	6.76

DAS – Days after seeding; $^{*}EC_{ns}$ – electrical conductivity of the nutrient solution (dS m^{-1}); pH_{ns} – pH of the nutrient solution; Amnt. – Amount of seeds per cell; Spc. – Spacing between cells

Water consumption showed variation of 14% in plants cultivated in cells spaced by 7.0 cm, with mean values of 1.060 L $cell^{-1}$ for the use of 0.5 g of seeds (bunches of 56 g) and 1.232 L $cell^{-1}$ for the use of 1.5 g of seeds (bunches of 70 g) (Figure 1).

For the spacing of 10.0 cm, the mean water consumption $cell^{-1}$ was 1.18 L, with variation of up to 13% as a function of the different amounts of seeds per cell. In addition, when cells were spaced by 15.0 cm, there was a mean increase of up to 35% in mean water consumption as a function of the different amounts of seeds per cell.

Considering the entire hydroponic system with spacing of 15.0 cm between cells, 480 coriander bunches were produced, with which metabolized 757.44 L of water with mean value of 1.578 L $bunch^{-1}$. For the spacing of 7.0 cm between cells, the production was 1008 bunches and the total water demand was 1,131.7 L, with mean value of 1.122 L $bunch^{-1}$, i.e., using the spacing of 7.0 cm instead of 15.0 cm, there was a reduction of 28.98% in the water demand per bunch.

As to the variation in the amount of seeds, there was an estimated increment of 3.7 kg in SFP for the use of 1.0 or 1.5 g of seeds $cell^{-1}$ (considering the entire hydroponic system) and, in contrast, there was an investment of more than 0.5 kg of seeds and 57.0 L of water. In general, these results evidence that water consumption did not increase in the same proportion of

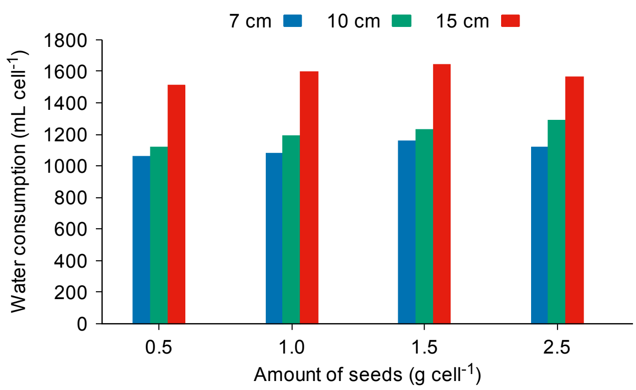

Figure 1. Mean water consumption per bunch of coriander (cv. Tabocas) at 28 days after seeding, as a function of the amount of seeds and spacing between cells

plant density, as also observed by Santos Júnior et al. (2013) for sunflower.

The variation in the amount of seeds did not influence significantly ($p > 0.05$) E-SFP, but TFP, SFP and SDP, as well as E-SDP, showed significant results ($p < 0.05$) and fitted to a linear regression model. In addition, there was significant effect ($p < 0.05$) of the spacing between cells on TFP, SFP, E-SDP and SDP; on the other hand, the interaction between factors caused significant differences ($p < 0.05$) on SDP and E-SDP. It should be pointed out that the uniformity of data observed in the experiment through the coefficient of variation (Table 3).

The variation in the amount of seeds promoted significant effect ($p < 0.05$) on TFP and, based on the regression equation, there was an estimated increment of 5.345 g with each increment of 0.5 g of seeds added to the cell. It should be pointed out that this estimated difference reached 16.035 g in the comparison between TFP values of bunches produced using 0.5 and 2.0 g of seeds cell^{-1} (Figure 2A).

Since the mean price of coriander seeds is relevant in the production costs, these results gain greater proportion in the total production of the low-cost hydroponic system and the logic of the spacing between cells are considered, because there was no significant difference ($p > 0.05$) in TFP per bunch for spacings of 7.0 and 10.0 cm (Figure 2B). However, for the total production of the system, this mean difference reached 22%, with 59 kg of TFP for a spacing of 7.0 cm between cells and 46 kg for 10.0 cm, i.e., seed costs can be optimized by adopting smaller spacings between cells. Janick (1986) agrees and claims that, as the spacing decreases and population density increases, the production per unit area increases, leading to greater profitability for the farmer.

Disregarding the roots and considering only the green mass, which is the part of the bunch generally consumed in Brazil, SFP increased at the rate of 3.70 g cell^{-1} per 0.5 g of seeds added (Figure 2C), i.e., an increase 30.69% lower than that observed for TFP, for the same increment in the amount of seeds.

It should be pointed out that there was no significant difference ($p > 0.05$) for the spacings of 7.0 and 10.0 cm and, in general, the maximum variation observed for SFP as a function of the spacings between cells was 15.93% (Figure 2D). Rebouças et al. (2013), studying the cultivation of coriander (cv. Verdão) in NFT hydroponic system under EC_{ns} of 2.5 dS m^{-1}, observed mean SFP

Table 3. Summary of the ANOVA for total fresh phytomass (TFP), shoot fresh and dry phytomass (SFP and SDP) and water use efficiency (E-SFP and E-SDP) of bunches of coriander (cv. Tabocas) cultivated in a low-cost hydroponic system under different amounts of seeds per cell and spacing between cells along the tube

Source of variation	DF	Mean square				
		TFP[1]	SFP[1]	E-SFP[1]	SDP[1]	E-SDP
Amount of seeds (A)	3	1.823**	1.086**	0.708^{ns}	0.203**	0.146**
Linear regression	1	5.062**	3.094**	510.713^{ns}	0.586**	0.433**
Quadratic regression	1	0.348^{ns}	0.071^{ns}	0.024^{ns}	0.002^{ns}	0.001^{ns}
Spacing (S)	2	2.293**	1.163**	3.225**	0.541**	0.048^{ns}
Interaction A x S	6	0.201^{ns}	0.142^{ns}	0.296^{ns}	0.045**	0.047**
Residue	24	0.196	0.157	0.227	0.106	0.014
CV	(%)	5.49	5.55	5.51	4.39	4.36

*,**Significant at 0.05 and 0.01 probability levels, respectively; ^{ns}Not significant by F test. DF: Degrees of freedom; CV – Coefficient of variation; [1]Values transformed by the equation $(X + 0.5)^{0.5}$

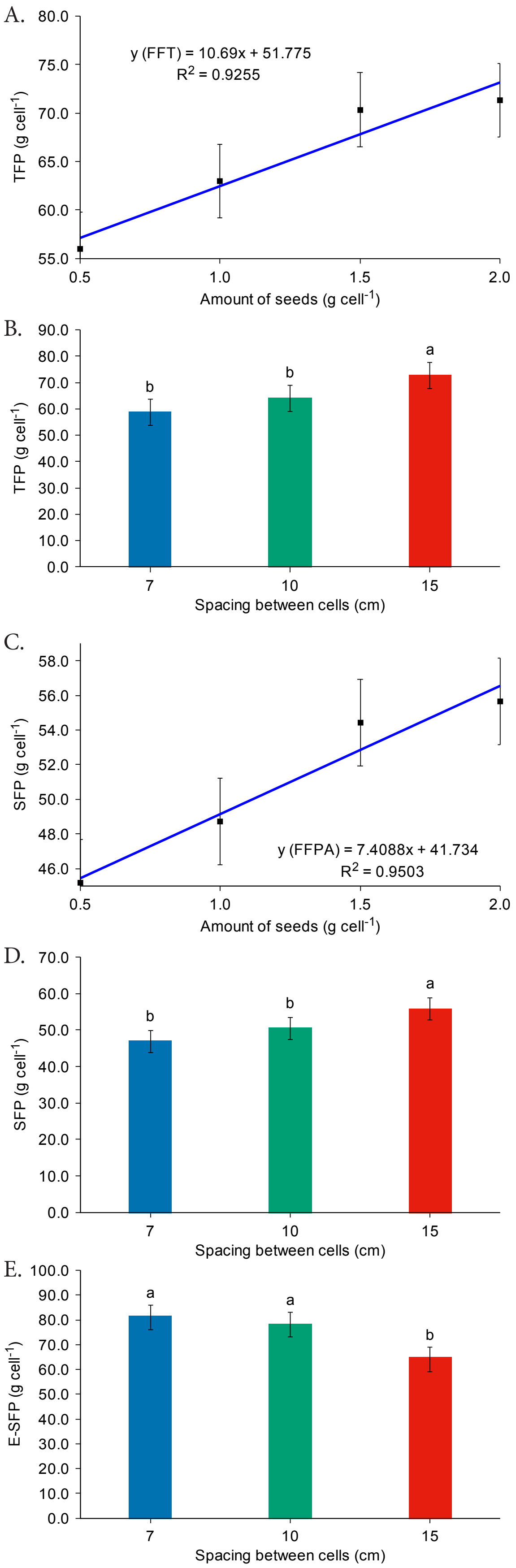

Figure 2. Total fresh phytomass – TFP (A and B), shoot fresh phytomass – SFP (C and D) and water use efficiency in the production of shoot fresh phytomass – E-SFP (E) of bunches of coriander (cv. Tabocas) cultivated in a low-cost hydroponic system under different amounts of seeds per cell and spacing between cells along the tube

of 2 kg m^{-2}, while the present study obtained 5.9 kg m^{-2} using 1.0 g of seeds cell^{-1} (cv. Tabocas) and spacing of 7.0 cm, with the same nutrient solution (Furlani et al., 1999) and the same mean EC_{ns}.

E-SFP was not significantly influenced ($p > 0.05$) by the variation in the amount of seeds; nevertheless, with the increase in the spacing between cells from 5.0 to 7.0 cm, E-SFP was reduced by 20.39%, and no significant difference in E-SFP was observed for spacings of 7.0 and 10.0 cm. Thus, the spacing of 7.0 cm is recommended (Figure 2E).

In the follow-up analysis of the interaction between treatments for SDP, the different amounts of seeds did not promote significant differences ($p > 0.05$) on SDP production for the spacings of 7.0 and 10.0 cm, which showed estimated mean values of 4.12 and 5.0 g cell^{-1}, respectively. As to the variation in the amount of seeds for the spacing of 15.0 cm, there was an increment of 0.90 g in SDP for each 0.5 g of seeds added to the cell, with estimation of up to 7.5 g of SDP cell^{-1} in the treatment with 2.0 g of seeds (Figure 3A).

In the follow-up analysis of the factor spacing between cells as a function of the factor amount of seeds per cell, there was no significant effect on SDP ($p > 0.05$) for spacings of 7.0 and 10.0 cm, regardless of the amount of seeds per cell. For the spacing of 15.0 cm, SDP did not vary significantly ($p > 0.05$) for 1.0, 1.5 or 2.0 g of seeds cell^{-1}; however, the difference in SDP reached 39.4% between the treatments 0.5 and 2.0 g of seeds cell^{-1} (Figure 3B).

As to E-SDP and the effects of the interaction between treatments on this variable, there was no significant effect ($p > 0.05$) on E-SDP for spacings of 7.0 and 10.0 cm, regardless of the amount of seeds per cell (Figure 3C). The adoption of larger spacings between cells, 15.0 cm, promoted increase in water use efficiency, estimated in 0.97 g L^{-1} for each 0.5 g of seeds added to the cell, which is consistent with the observations of Farahani et al. (2008). These authors comment that coriander optimizes water use in the production of dry matter, increasing its efficiency, especially under water stress conditions.

In the follow-up analysis of the factor spacing between cells as a function of the factor amount of seeds for E-SDP, there was no influence of the amount of seeds on coriander bunches cultivated at spacings of 7.0 and 10.0 cm, with efficiency of up to 8.6 g L^{-1} for spacing of 15.0 cm and, at this spacing, a significant difference ($p < 0.05$) of up to 33.35% was observed in E-SDP between 0.5 and 2.0 g of seeds cell^{-1} (Figure 3D).

The different amounts of seeds per cell and the spacing between cells, as well as the interaction between these factors, caused significant effect ($p < 0.05$) on WCP and WCS. In addition, the variables ISBP and R/S, as a function of the variation in the amount of seeds per cell, fitted to a linear regression model. None of the tested treatments influenced WCR (Table 4).

Table 4. Summary of the ANOVA for mean water contents in the entire plant (WCP), in the shoots (WCS) and in the roots (WCR), index of shoot biomass production (ISBP) and root/shoot ratio (R/S) of bunches of coriander (cv. Tabocas) cultivated in a low-cost hydroponic system under different amounts of seeds per cell and spacing between cells along the tube

Source of variation	DF	Mean square				
		WCP	WCS	WCR	ISBP	R/S[1]
Amount of seeds (A)	3	3.502^{**}	3.404^{**}	3.600^{ns}	0.0009^{ns}	0.0007^{ns}
Linear regression	1	4.179^{**}	5.088^{**}	3.596^{ns}	0.0022^{**}	0.0016^{**}
Quadratic regression	1	0.524^{ns}	0.021^{ns}	4.197^{ns}	0.00008^{ns}	0.00006^{ns}
Spacing (S)	2	9.514^{**}	15.157^{**}	1.222^{ns}	0.00003^{ns}	0.00002^{ns}
Interaction A x S	6	2.732^{**}	3.554^{**}	2.791^{ns}	0.0006	0.0005^{ns}
Residue	24	0.725	0.730	1.103	0.0003	0.0002
CV	(%)	0.94	0.95	1.14	2.24	1.93

*,**Significant at 0.05 and 0.01 probability levels, respectively; ^{ns}Not significant F test; DF – Degrees of freedom; CV – Coefficient of variation; [1]Values transformed by the equation $(X + 0.5)^{0.5}$

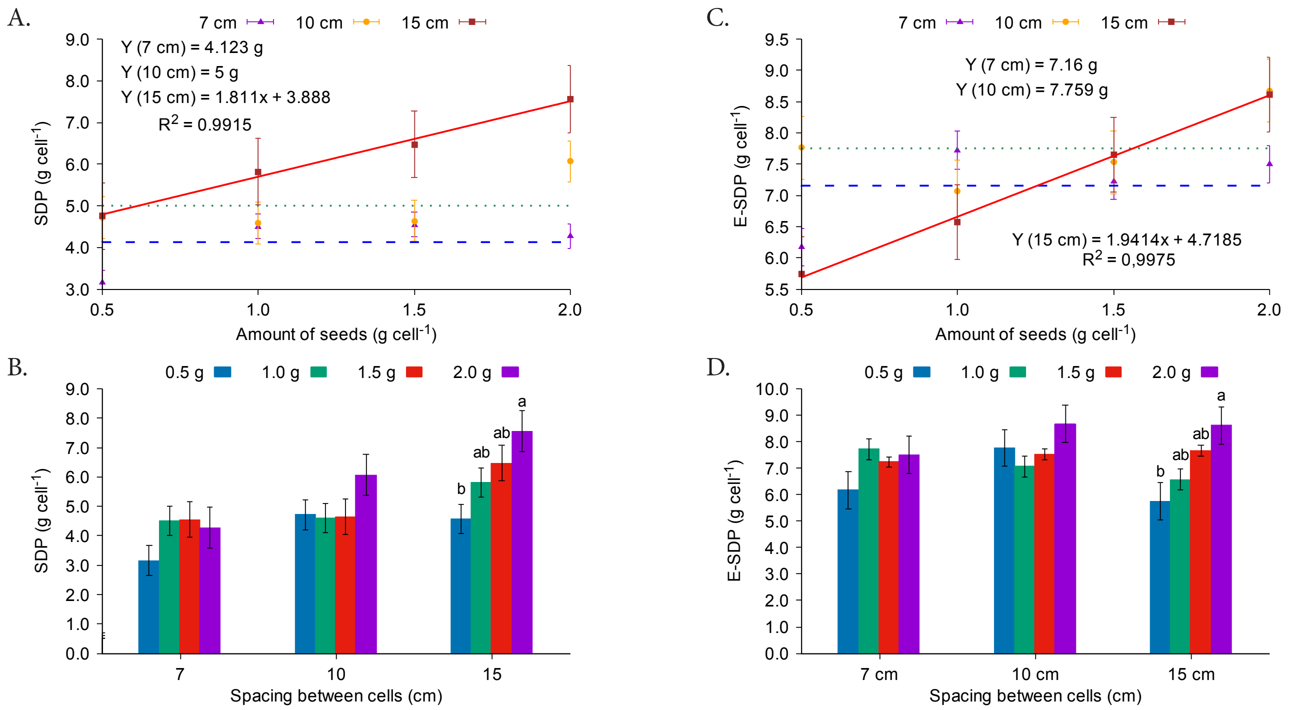

Figure 3. Follow-up analysis of the interaction between the amount of seeds per cell and the spacing between cells for shoot dry phytomass – SDP (A and B) and water use efficiency in the production of shoot dry phytomass – E-SDP (C and D) of bunches of coriander (cv. Tabocas) cultivated in a low-cost hydroponic system

The mean water content in the bunch (shoots + roots) did not vary with the amount of seeds per cell for the spacings of 7.0 and 10.0 cm, which showed mean water contents of 91.48% and 90.56% in the bunch, respectively. However, for the spacing of 15.0 cm, the mean water content in the bunch decreased by 1.08% for each 0.5 g of seeds added per cell, i.e., with the increase in the amount of seeds up to 2.0 g cell^{-1}, the reduction in the water content was equal to 3.26% (Figure 4A).

Still according to the follow-up analysis for the interaction between treatments, there was significant effect of the amount of seeds only for the spacing of 15.0 cm and, in this case, mean WCP values of 91.24, 89.1, 90.44 and 88.06% were observed for the use of 0.5, 1.0, 1.5 and 2.0 g of seeds cell^{-1}, respectively (Figure 4B).

The mean water content in the shoots of bunch of coriander was also influenced by the interaction between the studied factors. As observed for TFP, regardless of the amount of seeds per cell, there was no significant difference ($p > 0.05$) in WCS for plants cultivated at spacings of 7.0 or 10.0 cm. However, at the spacing of 15.0 cm, this variation was equal to 1.131% for each 0.5 g of seeds added to the cell (Figure 4C).

According to the follow-up analysis of the interaction between the treatments (Figure 4D), there was no significant differences ($p > 0.05$) for the spacings of 7.0 and 10.0 cm between cells, as a function of the variation in the amount of seeds. However, when the spacing of 15.0 cm was used, as a reference, the WCS for the use of 0.5 g of seeds cell^{-1} was 3.7% higher in comparison to the use of 2.0 g of seeds cell^{-1}.

The index of shoot biomass production (ISBP) decreased linearly at a rate of 0.0071 for each 0.5 g of seeds added to the cells (Figure 4E) and the root/shoot ratio (Figure 4F) increased at a rate of 0.010 with the same increment in the amount of seeds. These results confirm the information that the green mass of coriander shoots, which is the effectively consumed part, decreases with the increment in the amount of seeds to the detriment of the increase in the mass of roots, which are obviously discarded.

In a general analysis, the competition between plants inside the cell, caused by the increased amount of seeds used, became relevant for variables like TFP, SFP, E-SFP, SDP, E-SDP, WCP and WCS only in the spacing between cells of 15.0 cm, i.e., the increase in spacing made these variables dependent on the

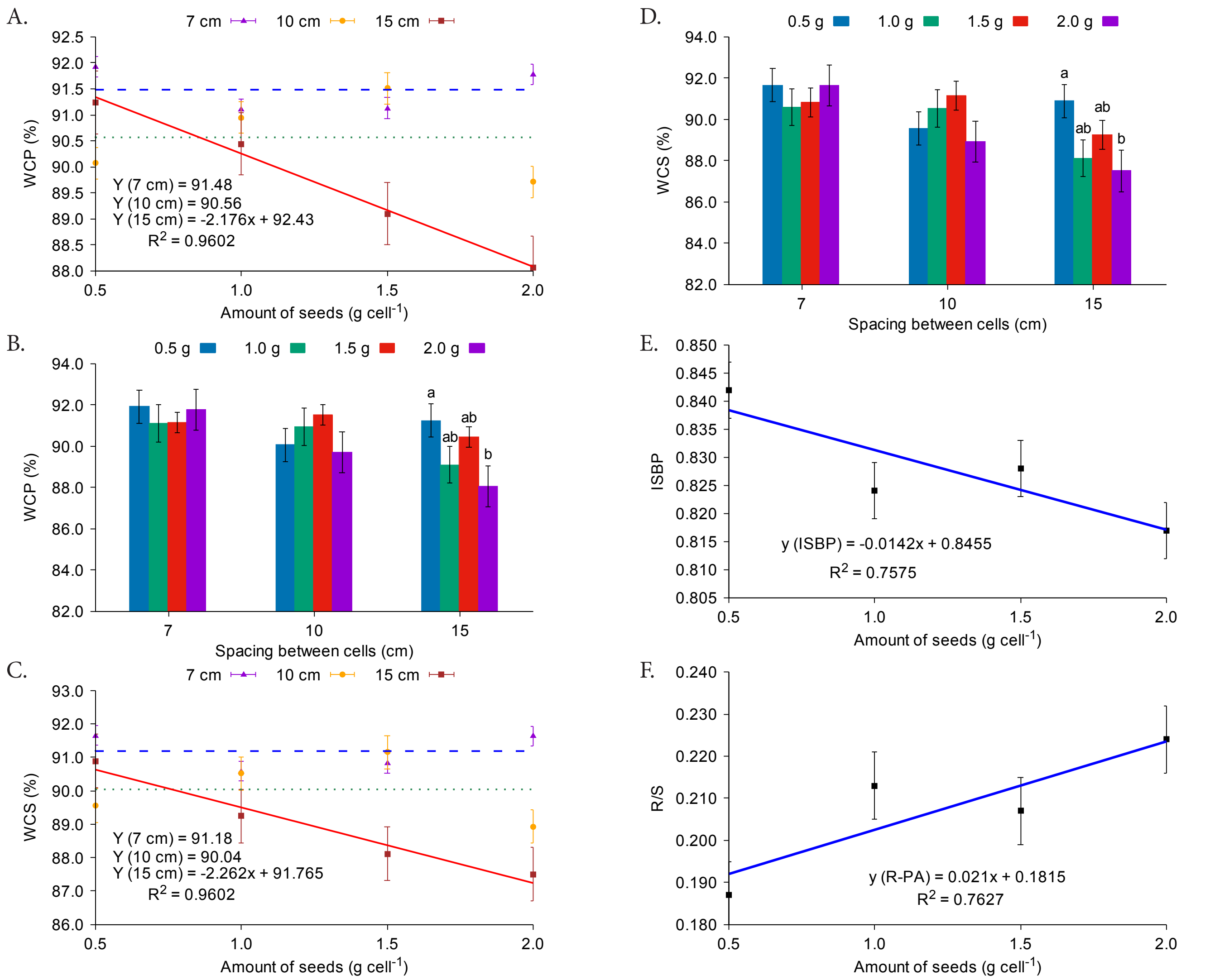

Figure 4. Follow-up analysis of the interaction between the amount of seeds per cell and the spacing between cells for water content in the entire plant – WCP (A and B), water content in the shoots – WCS (C and D). Effect of the amount of seeds on the index of shoot biomass production – ISBP (E) and root/shoot ratio – R/S (F) of bunches of coriander (cv. Tabocas) cultivated in a low-cost hydroponic system

amount of seeds per cell. For instance, as the amount of seeds increased, WCP decreased and SDP increased. From another perspective, the lower the spacing between cells, specifically 7.0 or 10.0 cm, the lower the influence of the variation in the amount of seeds on biomass production, water use efficiency and water content of coriander plants.

Conclusions

1. The increment in the amount of seeds did not increase shoot dry phytomass in the same proportion of the increase in total fresh phytomass of coriander plants.

2. The reduction in the spacings between cells promoted better cost/benefit ratio with respect to water consumption, produced mass and cost of seeds.

3. The use of a spacing of 7.0 cm between cells and 1.0 g of seeds per cell is recommended. This configuration promoted efficiency of 81.59 g L^{-1} in the production of green mass in the shoots and bunches with total mass of 62.4 g.

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