



ORIGINAL ARTICLE

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PALAVRAS-CHAVE

*Coriandrum sativum* L.  
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## Production of coriander in substrate fertigated with increasing nutrient concentrations

### *Produção de coentro em substrato fertirrigado com crescentes concentrações de soluções nutritivas*

**ABSTRACT:** Coriander is one of the most popular vegetables in the cuisine of the northeastern region of Brazil and its leaves are used in the composition and decoration of various regional dishes. However, its cultivation has been little studied, especially in hydroponic systems. This study aimed to evaluate the effect of increasing nutrient concentrations in the nutritive solution applied to coriander plants grown on fertigated substrate. A completely randomized design with five treatments and six replications was used. Each experimental unit was represented by a PVC channel (1.0 x 0.1 x 0.1 m). Treatments represented five nutrient concentrations in the nutritive solution (25, 50, 75, 100 and 125% of the standard solution recommended for lettuce cultivation). Plants were harvested 35 days after sowing. The evaluated variables were plant height, number of leaves, fresh and dry matter (root, shoot and whole plant), and N, P and K content. All variables were affected by the increased nutrient concentration in the nutritive solution used for fertigation. The ionic concentration of 75% of the nutrients contained in the standard formulation recommended for hydroponic production of lettuce can be used for coriander crop.

**RESUMO:** O coentro é uma das hortaliças mais populares na culinária da região nordeste do Brasil, cujas folhas são utilizadas na composição e decoração de diversos pratos regionais. No entanto, ainda é uma cultura pouco estudada, principalmente em cultivo hidropônico. Este trabalho foi realizado com o objetivo de avaliar o efeito de crescentes concentrações de nutrientes da solução nutritiva sobre o coentro cultivado em substrato. O delineamento experimental utilizado foi o inteiramente casualizado, com cinco tratamentos e seis repetições, sendo cada unidade experimental representada por uma canaleta de PVC (1,0 x 0,1 x 0,1 m). Os tratamentos foram constituídos por cinco concentrações de nutrientes na solução nutritiva (25%, 50%, 75%, 100% e 125% da solução padrão recomendada para a cultura da alface). A colheita foi realizada aos 35 dias após a semeadura, avaliando as seguintes variáveis: altura de plantas, número de folhas, massa fresca e massa seca de raiz, parte aérea e total, além dos teores de N, P e K. Todas as características da planta foram afetadas pelo aumento da concentração de nutrientes da solução nutritiva, e a concentração iônica de 75% de nutrientes contidos na formulação recomendada para a produção hidropônica da alface pode ser utilizada no cultivo de coentro em substrato.

## 1 Introduction

Coriander (*Coriandrum sativum* L.), an annual herb of the family Apiaceae, is an aromatic leafy vegetable. It is cultivated mainly by small producers, not only due to its green mass, but also its fruits, which are used in food and cosmetic industries (Filgueira, 2008).

Coriander cultivation in protected environments is a practice currently adopted in some parts of Brazil, mainly using the hydroponic nutrient film technique (NFT) (Donegá et al., 2013; Luz et al., 2012; Vasconcelos et al., 2014). In addition to cultivation in NFT system, the production of vegetables in chemically inert substrates has attracted the attention of producers. The responses of plants grown in such substrates can be influenced by several factors, particularly the composition of the nutrient solution used. Thus, the nutritional requirements of the crop must be taken into account in the preparation of this solution (Andriolo et al., 2009).

There is no specific nutrient solutions recommended for each vegetable crop. Thus, the solution recommended for lettuce, for example, is used in the cultivation of other leafy vegetables, such as chicory and endive (Luz et al., 2009), arugula (Silva et al., 2011), parsley (Luz et al., 2012), chinese cabbage (Lira et al., 2015), and others. However, some authors have demonstrated that the cultivation of some leafy vegetables could be accomplished with lower nutrient concentrations than the nutrient solution proposed by Furlani et al. (1999). This would result in nutrient economy without significantly reducing plant yield (Luz et al., 2009, 2012).

Given the above, this study aimed to evaluate coriander production in substrate fertigated using different nutrient concentrations in the fertigation solution.

## 2 Materials and Methods

The experiment was carried out under greenhouse conditions in June and July 2012, at the Department of Environmental Sciences and Technology, Universidade Federal Rural do Semi-Arid Region–UFERSA, Mossoró – RN – Brazil (5°11' S; 37°20' W; 18 m of altitude).

A digital thermo-hygrometer (Mod. 30.5000.02, TFA Technology HK Ltd., Hong Kong/China) was placed in a central point of the greenhouse at 1.5 m height to monitor the air temperature (current, maximum and minimum) and relative humidity (current, maximum and minimum). Readings were performed every day at 3:00 pm and the daily means were calculated by the expressions: Air temperature ( $T_m$ ) =  $(T_{max} + T_{min})/2$  and Relative humidity ( $RH_m$ ) =  $(RH_{max} + RH_{min})/2$ . Mean values of these variables were recorded for the whole period of the experiment:  $T_{min}$  = 21.4 to 25.1 °C;  $T_m$  = 30.1 to 33.6;  $T_{max}$  = 30.3 to 43.1 °C;  $RH_{min}$  = 15 to 47%;  $RH_m$  = 45 to 62%;  $RH_{max}$  = 72 to 92%.

The greenhouse was made of galvanized steel, with its front and side walls made with 50% shading black mesh, and its coverage a bow-type tunnel measuring 7.0 m wide x 18.0 m long, was made of a low density, transparent polyethylene film, 0.15 mm thick.

The experiment was carried out in a structure consisting in 30 PVC channels (1.00 x 0.10 x 0.10 m), 0.10 m apart from each other and arranged on wood trestles (0.65 m in height).

The substrate was a mix (1:1:1) of coconut fiber, fine sand, and non-carbonized rice husks. Seeds of cv. Verdão were sown directly along a sole row in the center of the PVC channel. Thinning was performed eight days after sowing, in order to keep 50 plants per linear meter.

A completely randomized design with five treatments and six replications was used. Experimental units were represented by a one meter long channel. Treatments consisted of five nutrient concentrations in the nutrient solution (S1-25%, S2-50%, S3-75%, S4-100% and S5-125%), using as reference the standard nutrient solution recommended by Furlani et al. (1999) for lettuce crop.

The nutrient solution at 100% concentration had the following fertilizer composition ( $mg\ L^{-1}$ ): 750 calcium nitrate, 500 potassium nitrate, 150 mono ammonium phosphate, 400 magnesium sulfate, 0.15 copper sulfate, 0.50 zinc sulfate, 1.5 manganese sulfate, 1.5 boric acid, 0.15 sodium molybdate and 60 Fe EDDHA-6%. The pH of the solution was adjusted to a level between 6.0 and 6.5 using solutions containing 0.1 Mol  $L^{-1}$  KOH or HCl.

The electrical conductivities of the prepared solutions, determined by a bench conductivimeter with temperature automatic adjustment, were 1.05, 1.51, 1.68, 2.15 and 2.65 dS  $m^{-1}$  to the S1, S2, S3, S4 and S5, solutions, respectively.

Irrigations were performed daily to supply a sufficient volume of the nutrient solution in order to compensate the evapotranspiration of the crop, using a 1000 mL capacity beaker. The process of irrigation was halted as soon as drainage signs appeared.

The experiment was harvested 35 days after sowing. Twenty plants were collected from each experimental unit, considering only the central 0.50 m portion of the row as the inside border in order to reduce the possibility of mixing solutions due to capillarity and assure that a maximum number of roots had been sampled.

After harvesting, plants were packed in plastic bags and transported to the Irrigation and Salinity Laboratory of the UFERSA, to be analyzed with respect to the following variables: plant height, number of leaves, and fresh and dry matter weights of shoot, roots, and whole plant.

Data were analyzed through ANOVA (F test). Variables with significant values in the treatments were also submitted to regression analysis.

## 3 Results and Discussion

Increasing nutrient concentration in the nutrient solution resulted in a significant increase in plant height. Positive responses were observed up to the concentration of 87.2% of the standard solution, with a maximum height of 28.98 cm, corresponding to an increase of approximately 25.13% compared to the concentration of 25% of the standard solution. Plant growth was lessened in concentrations above 87.2%, up to the highest value (125%), where the average plant height of 23.2 cm was obtained. However, plant height exceeded 23 cm at all concentrations, which means that the plants reached the commercial size in all treatments (Figure 1).

Similar results were obtained by Luz et al. (2012) in hydroponically-grown coriander cv. Verdão, which attained

greater plant height (27.9 cm) when submitted to a nutrient solution concentration corresponding to 95% of the standard solution (Furlani et al., 1999).

The number of leaves responded linearly and positively to nutrient concentration. There was an increase of 0.012 leaves for each increased unit in the concentration of the nutrient solution. In average, there were 5.3 and 4.1 leaves per plant under the nutrient solution concentrations of 125% and 25%. According to the regression equation, the number of leaves increased 29.3% between the highest and the lowest concentrations (Figure 1).

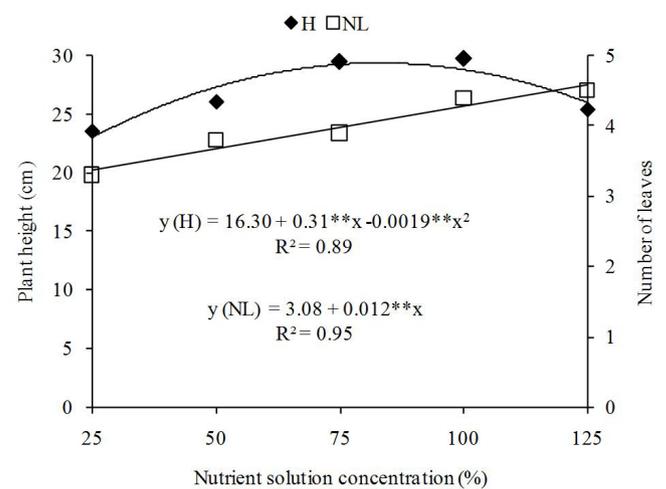
These results are different, in part, from those reported by Luz et al. (2012) for the same cultivar grown in an NFT hydroponic system using different ionic concentrations in the nutrient solutions; these authors obtained a greater number of leaves with a concentration of 91.4% of the standard nutrient solution. From values above this concentration, inverse responses were observed, with the increasing concentration of nutrients negatively affecting the plant metabolism. Part of these divergent results of the present study may have been due to the type of cultivation used. Part of the salts are probably adsorbed by the substrate particles in the case of cultivation on substrate, while in NFT system cultivation, all nutrients remain available in the solution (Santos, 2010).

When the effect of nutritional solutions on plant height and number of leaves was concomitantly analyzed, it was noticed that both variables had increasing values up to a concentration of 75% of the standard nutrient solution, followed by decreasing values in plant height and increasing number of leaves up to the highest concentration. Such responses may be attributed to the adjustment of plants to accumulation of salts in the substrate, so that plants may have compensated the reduction in stem size by increasing the number of ramifications, thus increasing photosynthetic efficiency (Kasele et al., 1995).

Regarding biomass accumulation, shoot, root and whole plant fresh weight behaved similarly, with a second-degree polynomial model best fitting the regression analysis. The highest fresh weight values were obtained with the nutrient solution concentrations of 92% (whole plant – 3.60 g), 94% (shoot – 3.13 g) and 92% (root – 0.56 g). Adjusted regression equations showed gains of about 67%, 71% and 61% to whole plant, shoot and root fresh weights, respectively, comparing the lowest to the other nutrient concentrations (Figure 2).

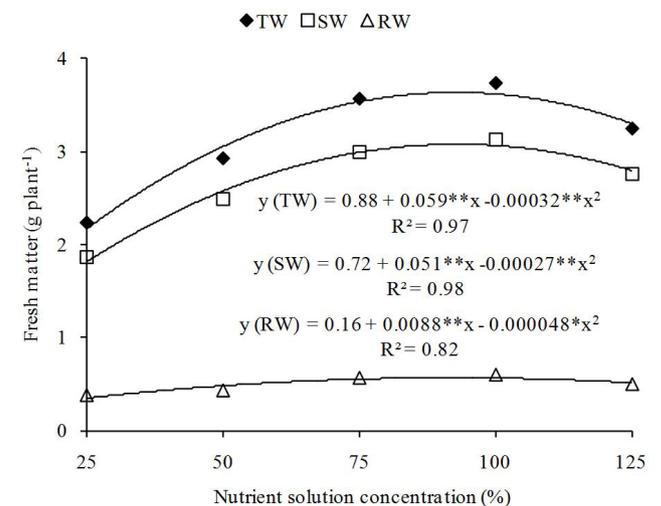
The lowest plant growth rates were found in the lowest nutrient concentrations and this was probably caused by insufficient nutrient levels, mainly nitrogen. This nutrient plays an important role as an osmotically active solute in the cell elongation process which, in turn, influences the formation of vascular tissues and, consequently, the accumulation of biomass (Helbel Junior et al., 2008).

On the other hand, decreases in fresh weights were seen in the highest nutrient concentration (125%) as a result of the higher electrical conductivity (2.65 dS m<sup>-1</sup>). These results corroborate the findings of Vasconcelos et al. (2014) for the same cultivar grown on substrate supplied a nutrient solution with electrical conductivity of 1.63 dS m<sup>-1</sup>, which is close to that of the 75% nutrient solution used in the present study (1.68 dS m<sup>-1</sup>). Furthermore, according to these authors, the electrical conductivity of the original nutrient solution recommended by Furlani et al. (1999) is 1.84 dS m<sup>-1</sup>, which



**Figure 1.** Plant height (H) and number of leaves per plant (NL) in coriander grown on substrate fertigated with different concentrations of nutrient solution.

**Figura 1.** Altura de plantas e número de folhas por plantas em coentro cultivado em substrato e fertirrigado com diferentes concentrações de solução nutritiva.



**Figure 2.** Fresh matter production in coriander plants grown on substrate fertigated with different nutrient solution concentrations: TW = total weight; SW = shoot weight; RW = root weight.

**Figura 2.** Produção de massa fresca em plantas de coentro cultivado em substrato e fertirrigado com diferentes concentrações de solução nutritiva.

is, in fact, high for the maximum yield of coriander, and thus is in accordance with the results obtained in the present study.

The reduction in fresh weight at the highest concentrations of the nutrient solution happened probably due to osmotic stress caused by reduction of the external water potential and the resulting effect of the accumulation of ions in plant tissues (Munns & Tester, 2008).

These results highlight the need for more studies on cultivation of coriander in hydroponic systems, especially with respect to the nutritional needs of plants, since many researchers and producers grow coriander and other leafy vegetables in

hydroponic system using the nutrient solution recommended for lettuce crops (Genuncio et al., 2011; Luz et al., 2009, 2012; Silva et al., 2011). Yet, these authors found that the optimal cultivation of leafy vegetables can be obtained with diluted nutrient solutions in relation to that recommended for lettuce. This can reduce production costs without affecting crop yields.

Shoot and whole plant dry weights showed a quadratic response to the concentrations of the nutrient solution, with the highest accumulations (0.23 and 0.28 g plant<sup>-1</sup>) obtained respectively in the nutrient solution concentrations of 103% and 94%. Although the highest shoot and total dry weights were obtained at nutrient concentrations near the concentration of 100% of the solution recommended for lettuce, there was little gain when compared to the concentration of 75%, that is, 0.22 and 0.27 g plant<sup>-1</sup>, respectively (Figure 3).

Root dry matter weight had linear and positive response, reaching 0.044 g plant<sup>-1</sup> at the highest nutrient concentration, which represents an excess of about 46% as compared to the mean dry weight (0.031 g plant<sup>-1</sup>) obtained in the lowest nutrient solution concentration (Figure 3).

In addition to the possible minor nutritional requirement of coriander compared to lettuce, another factor that may have influenced the response of the crop is likely related to the sensitivity of coriander to increasing salt concentrations in the nutrient solution, since some studies have shown that coriander plants reduce growth as the salinity level of the medium increases (Neffati & Marzouk, 2010; Rebouças et al., 2013; Sales et al., 2015; Silva et al., 2015).

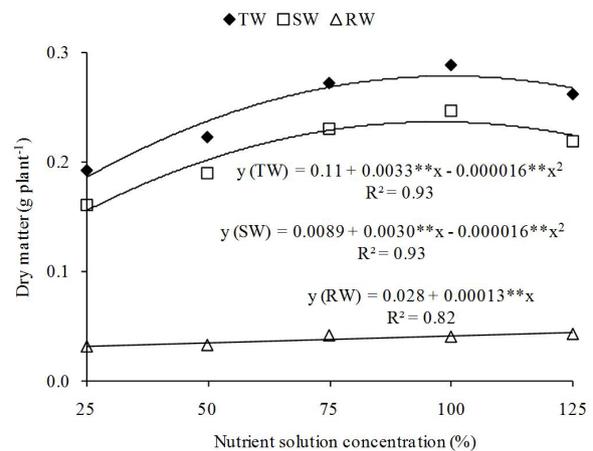
The response of coriander plants in terms of macronutrient contents in the leaves is shown in Figure 4. Phosphorus absorption was not affected by the treatments and its average content was 2.85 g kg<sup>-1</sup>. Among the macronutrients analyzed in this study, phosphorus was the less absorbed by the plants, a fact also observed in other studies (Donegá et al., 2013; Grangeiro et al., 2011). However, despite the fact that coriander plants require low amounts of phosphorus, an adequate supply of this nutrient is fundamental for plant growth, because this component takes part in the constitution of molecular structures, mainly as a constituent of proteins and nucleic acids, acts in energy transference processes, and plays a regulatory role in many metabolic reactions (Malavolta et al., 1997).

Nitrogen content increased linearly with increasing nutrient solution concentrations up to a maximum of 26.7 g kg<sup>-1</sup> at the concentration of 125%, which corresponds to an excess of 53.4% compared to the content (17.4 g kg<sup>-1</sup>) obtained with the less concentrated nutrient solution (25%) (Figure 4).

Many studies have already demonstrated that nitrogen is the second most absorbed nutrient in the coriander crop, either grown on soil (Grangeiro et al., 2011) or under hydroponic conditions (Daflon et al., 2014; Donegá et al., 2013).

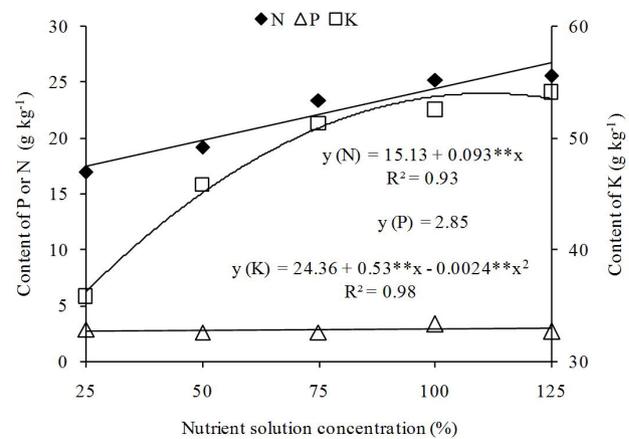
Daflon et al. (2014) reported that P and N are the most limiting macronutrients with regard to biomass production. Biomass production is reduced in plants with deficiency of these elements in the order of up to 50 and 49.6% of P and N, respectively, secondly only to calcium.

Potassium content increased with increasing ionic concentrations of the nutrient solution up to a maximum (53.6 g kg<sup>-1</sup>) at the concentration of 110%, tending to decrease in the highest nutrient solution concentration (Figure 4). This maximum



**Figure 3.** Dry matter production in coriander grown on substrate fertigated with different nutrient solution concentrations: TW = total weight; SW = shoot weight; RW = root weight.

**Figura 3.** Produção de massa seca em plantas de coentro cultivado em substrato e fertirrigado com diferentes concentrações de solução nutritiva.



**Figure 4.** Contents of N, P and K in coriander plants grown on substrate fertigated with different nutrient solution concentrations.

**Figura 4.** Concentração de N, P e K em plantas de coentro cultivado em substrato e fertirrigado com diferentes concentrações de solução nutritiva.

K content represents an excess of 48.5% compared to the content obtained at the nutrient solution concentration of 25% (36.1 g kg<sup>-1</sup>). Also, low K absorption rate took place above the nutrient solution concentration of 75%.

Potassium is the nutrient better absorbed by the coriander crop (Daflon et al., 2014; Donegá et al., 2013; Grangeiro et al., 2011; Vasconcelos et al., 2014). This higher demand of potassium, observed also in several other vegetable crops, occurs because this element, besides being an enzyme activator, regulates the mechanism of stomatal opening and closing, so that low concentrations of this nutrient supplied to the crop can hamper photosynthesis and consequently limit plant growth (Meurer, 2006).

## 4 Conclusions

Coriander can be cultivated in substrate using a nutrient solution with 75% of the concentration of nutrients recommended by Furlani et al. (1999) for lettuce crop.

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