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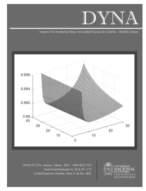

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Continuous and pulse fertigation on dry matter production and nutrient accumulation in coriander

Sirleide Maria de Menezes [a], Gerônimo Ferreira da Silva [a], Manassés Mesquita da Silva [a], José Edson Florentino de Morais [a], José Amilton Santos Júnior [a], Dimas Menezes [b] & Mário Monteiro Rolim [a]

[a] *Departamento de Engenharia Agrícola, Universidade Federal Rural de Pernambuco, Recife, Brasil. sirleidemeneses@hotmail.com, geronimo.silva@ufrpe.br, manasses.ufrpe@gmail.com, joseedson50@hotmail.com, joseamilton.santosjunior@ufrpe.br, mariorolim10@uol.com.br*
[b] *Departamento de Agronomia, Universidade Federal Rural de Pernambuco, Recife, Brasil. dimasmenezes@superip.com.br*

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Abstract
This study aimed to evaluate the dry matter production and nutrient accumulation of coriander (*Coriandrum sativum* L.) under pulse and continuous fertigation depths. The experiment was conducted in randomized blocks in 2 x 5 factorial arrangement, with three replicates. Treatments consisted of two types of fertigation application (pulse and continuous) and five fertigation depths (40, 60, 80, 100 and 120% of crop evapotranspiration – ETc). Highest accumulations of dry matter, N, P, K, Fe, Mn, Cu and Zn were obtained with pulse fertigation. Pulse fertigation combined with depths lower than 100% ETc led to highest accumulations of K, Mn, Cu and Zn. The accumulation of nutrients decreased in the following order: K > N > Ca > P > Mg > S > Fe > Mn > Zn > Cu.

Keywords: *Coriandrum sativum* L.; pulse drip irrigation; mineral nutrition.

Fertirrigación continua y pulsada sobre la producción de masa seca y acumulación de nutrientes en cilantro

Resumen
El objetivo de la investigación fue evaluar la producción de masa seca y la acumulación de nutrientes del cilantro (*Coriandrum sativum* L.) bajo láminas de fertirrigación pulsada y continua. El experimento fue conducido en bloques al azar en esquema factorial 2 x 5, con tres repeticiones. Los tratamientos fueron compuestos por dos tipos de aplicación de fertirrigación (pulsada y continua) y cinco láminas de reposición de la fertirrigación (40, 60, 80, 100 y 120% de la evapotranspiración del cultivo-ETc). Los mayores acumuladores de masa seca, N, P, K, Fe, Mn, Cu y Zn, fueron obtenidos con la utilización de la fertirrigación pulsada. La aplicación de la fertirrigación pulsada combinada con láminas inferiores al 100% de la ETc proporcionaron las mayores acumulaciones de K, Mn, Cu y Zn. La acumulación de nutrientes disminuyó en el siguiente orden: K> N> Ca> P> Mg> S> Fe> Mn> Zn> Cu.

Palabras clave: *Coriandrum sativum* L.; goteo por pulsos; nutrición mineral.

1. Introduction

Coriander (*Coriandrum sativum* L.) is a worldwide used leafy vegetable due to its versatility and use in cooking, pharmaceutical industries, food industries and application as an aromatic plant [6]. It is highly consumed in Brazil, especially in the Northeastern region, which makes it a popular crop of socioeconomic importance in this region [22].

In general, vegetables have relatively short cycles, in which production quantity and quality are directly related to the nutritional supply performed according to the actual requirement of each species, considering the cultivation system employed [9].

In modern agriculture, a common technique to meet the nutritional requirements of plants is fertigation, where

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nutrients are solubilized and applied via irrigation water. Nonetheless, the success of this practice is related, among other factors, to the irrigation management adopted, knowledge on soil chemical conditions, crop nutritional requirements, application frequency, concentration of the solution to be injected and time of application [25].

Irrigation management is based on the rational use of water resources, as well as on the reduction of unnecessary expenses with agricultural inputs and energy, promoting sustainable development of irrigated agriculture. Pulse irrigation is a technique with recent studies, developed to support irrigation management. It consists in the application of a daily irrigation depth split into cycles composed of one short period of irrigation, followed by a rest phase, and another short period of irrigation, which are thus repeated until all the water volume is completely applied in a series of on-off cycles [1,20].

The irrigation depth corresponds to the water volume to be applied in a crop and is obtained considering climatic characteristics of the region, as well as characteristics of the crop, soil and irrigation system used. When all daily irrigation is performed using a nutrient solution, it can be considered as an application of fertigation depths.

Research on the effect of pulse drip fertigation on coriander and on its relationship with nutrient accumulation is still incipient in the literature. Thus, this study aimed to evaluate the accumulation of dry matter and nutrients in coriander as affected by continuous and pulse drip fertigation depths.

2. Material and methods

The experiment was carried out in the period from August to September 2017 in a protected environment, at the Agronomy Department – DEPA of the Federal Rural University of Pernambuco – UFRPE, Dois Irmãos Campus, in Recife, PE, Brazil. The geographic coordinates are: 08° 01’ 6.50” S; 34° 56’ 46” W and altitude of 6.5 m. According to Köppen’s classification, the climate of the region is As’ (hot and humid), with rains from March to August [2].

The experimental plots comprised 30 masonry beds with dimensions of 1.0 m^2 area (5.0 x 0.20 m) and 0.20 m depth, set up in a gable greenhouse with 162 m^2. Each bed had an independent drainage system and walls covered by a plastic film for waterproofing purposes. Along the experiment, the average maximum and minimum temperatures inside the greenhouse were 34.35 and 25.66 ºC, respectively, and the average maximum and minimum values of relative air humidity were 92.22 and 55.90%, respectively.

The soil used to fill the beds was sandy, with sand, silt and clay contents of 90.4, 3.2 and 6.4%, respectively. Bulk density and particle density were 1.5 and 2.5 kg dm^{-3}, respectively. Soil water storage limits were 0.10 m^3 m^{-3} (field capacity) and 0.09 m^3 m^{-3} (permanent wilting point). Soil chemical analysis, carried out before the beds were filled, showed the following results: pH (water 1:2.5) = 5.1; Ca^{2+} = 0.30 $cmol_c$ dm^{-3}; Mg^{2+} = 0.22 $cmol_c$ dm^{-3}; Al^{3+} = 0.2 $cmol_c$ dm^{-3}; Na^+ = 0.01 $cmol_c$ dm^{-3}; K^+ = 0.01 $cmol_c$ dm^{-3}; P = 2.0 mg dm^{-3}; OM = 9.69 g kg^{-1}; ($H^+ + Al^+$) = 4.68 $cmol_c$ dm^{-3}.

The experiment was set up in randomized blocks in a 2 x 5 factorial arrangement, in which the first factor was represented by two types of fertigation application (pulse and continuous) and the second was represented by five fertigation depths (40, 60, 80, 100 and 120% of crop evapotranspiration – ETc), with three replicates, forming 10 treatments and totaling 30 experimental plots.

The term ‘fertigation depths’ was attributed to the application of nutrient solution via irrigation water, so that all irrigation was characterized as a fertigation applied daily according to each treatment.

For the fertigation applied in pulses, six pulses were defined with 60-min interval between two irrigation events. ETc was directly obtained based on the average water balance of four drainage lysimeters with capacity for 5 L, cultivated with coriander and installed inside the greenhouse.

A drip irrigation system composed of drip tapes (DN 16 mm), with emitters spaced by 0.30 m and nominal flow rate of 0.60 L h^{-1}, supplied the experimental plots individually. The irrigation system was equipped with common valves, solenoid valves, pressure regulator (regulated at 10.0 m.w.c.), microcontroller, disc filter and an electric pump (0.5 hp).

Irrigation time in each treatment was obtained based on the gross irrigation depth, determined by the relationship between ETc and the nominal application efficiency (95%) of the irrigation system. Treatments began to be applied at 13 days after sowing (DAS). An Arduino electronic circuit was responsible for automatically controlling the splitting of the gross irrigation depth as well as calculating the times of application of each pulse, according to each treatment, starting every day at 09:00 a.m.

Liming was performed to correct soil acidity and neutralize exchangeable Al, using calcitic limestone, according to the methodology of [7]. In each bed, 20 seeds of coriander cv. ‘Verdão’ were directly planted in each hole, spaced by 0.10 x 0.15 m. At 13 DAS, thinning was carried out, leaving six plants per hole.

Fertilization was applied via irrigation water according to the nutrient solution proposed by [13], prepared using water from the public supply system, except for phosphorus, which was conventionally applied at planting (120 kg ha^{-1} of P_2O_5) based on soil chemical analysis according to [7]. The average values of electrical conductivity and pH of the nutrient solution, recorded along the experiment, were 2.10 dS m^{-1} and 6.23, respectively.

The experiment lasted 34 days, which was the period required for plants to reach the fresh consumption point, represented by full vegetative development and first signs of beginning of reproductive stage. Until 12 DAS, which corresponded to the stage of germination and crop establishment, irrigation was applied in all plots, replacing 100% of ETc.

At the end of the experiment, 48 plants were randomly collected in each experimental plot and dried in a forced air circulation oven (65 °C) until constant weight. After drying, the samples were weighed to determine dry matter production (DM) and the results were expressed in g $hole^{-1}$.

Subsequently, the samples were ground in Wiley-type mill with 2-mm-sieve and then subjected to the extraction of macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Cu, Fe, Mn and Zn). Nutrients were extracted by wet digestion of dry matter, adopting sulfuric digestion with digester block for N and nitric digestion using a microwave digester for the other nutrients, according to the methodology recommended by [23].

Total N concentration was determined using the steam drag method (Kjeldahl); K through flame photometry; P by molybdate-vanadate colorimetric method; S by the barium sulfate turbidimetric method; and Ca, Mg, Fe, Cu, Mn and Zn were determined by atomic absorption spectrophotometry, according to the methodological procedures suggested by [5].

To quantify the accumulation of nutrients by coriander plants, their concentrations were multiplied by the dry matter. Accumulation was expressed in g hole^{-1} for macronutrients and in mg hole^{-1} for micronutrients.

The results were subjected to analysis of variance by F test ($p<0.05$). When there was significant effect, polynomial regression analysis was carried out for the quantitative factor and Scott-Knott test was applied to the qualitative factor, both at 0.05 probability level, using the statistical program SISVAR [11].

3. Results and discussion

The analysis of variance indicated significant and independent effects ($p<0.01$) of the types of application and depths of fertigation on dry matter production (DM). For nutrient accumulation, the interaction between factors had significant effect ($p<0.01$ and $p<0.05$) on manganese (Mn), copper (Cu) and zinc (Zn). The accumulations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S) and iron (Fe) were influenced ($p<0.01$ and $p<0.05$) by the factors independently, whereas magnesium (Mg) accumulation was influenced ($p<0.01$) only by the fertigation depths.

The effect of fertigation depths and types of application on coriander dry matter production can be seen in Fig. 1. A quadratic model was fitted to coriander DM data as a function of the fertigation depths, and the one corresponding to ETc replacement of 96.7% led to maximum DM production (2.29 g hole^{-1}).

These results are similar to those found by [17], who evaluated the coriander crop under different levels of soil moisture and observed higher values of shoot dry matter with moisture content of 100% pot capacity, demonstrating the importance of maintaining the soil close to pot capacity for the increase in this growth variable.

[4] observed that, as water availability to arugula plants increased, their dry matter accumulation increased linearly, with maximum value at the largest water volume applied (120% field capacity).

These results are consistent, because water stress directly affects plants, causing reduction in cell turgor, with negative influence particularly at the initial stage of cell expansion, in which the presence of water is a limiting factor for the occurrence of numerous physiological processes that lead to the formation of tissues [24] and, consequently, to increased dry matter.

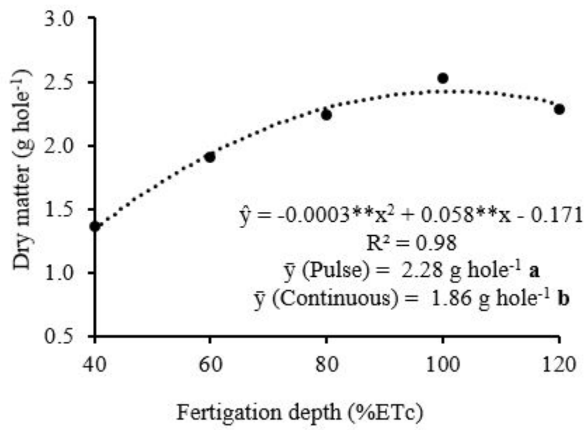

Figure 1. Effect of the depth and types of fertigation application on the accumulation of dry matter in the culture of coriander cv. Verdão. Different letters indicate significant differences between the types of fertigation application (pulse and continuous) by the Scott-Knott test ($p < 0.05$).
Source: The Authors.

Regarding the effect of the types of application, pulse fertigation was the method which caused highest DM accumulation by the crop (2.28 g hole^{-1}), with 22.6% increment compared to the continuous fertigation (1.86 g hole^{-1}). These results agree with those obtained by [3], who studied the effect of pulse and continuous irrigation on bell pepper and observed that the highest dry matter accumulation was obtained with pulse irrigation.

Fig. 2 shows the effect of fertigation depths and types of application on nitrogen (2A), phosphorus (2B) and potassium (2C) accumulations.

According to the regression analysis, a quadratic model fitted to N accumulation data as a function of fertigation depths (Fig. 2A). Maximum N accumulation (0.077 g hole^{-1}) was estimated with a water depth corresponding to 100% ETc, revealing an 87.8% increment compared to the lowest water depth (40% ETc).

[14], evaluating the mineral nutrition of coriander in a conventional fertilization system, obtained values of 0.062 g hole^{-1}, which are lower than those found here. Such higher N accumulation by the crop can be attributed to the use of fertigation, instead of conventional fertilization.

In relation to the effects of the types of fertigation application, N accumulation was higher when plants were under pulse fertigation, reaching 0.079 g hole^{-1}, a 31.7% increment compared to the continuous application. [3] observed that, in the bell pepper crop, pulse irrigation also favored N accumulation in old leaves.

For phosphorus (P) accumulation as a function of the fertigation depths, it can be observed in Fig. 2B that a quadratic model fitted to the data. Maximum P accumulation (0.015 g hole^{-1}) was estimated with the application of a water depth corresponding to 100% ETc, revealing a 87.5% increment compared to the water depth of 40% ETc.

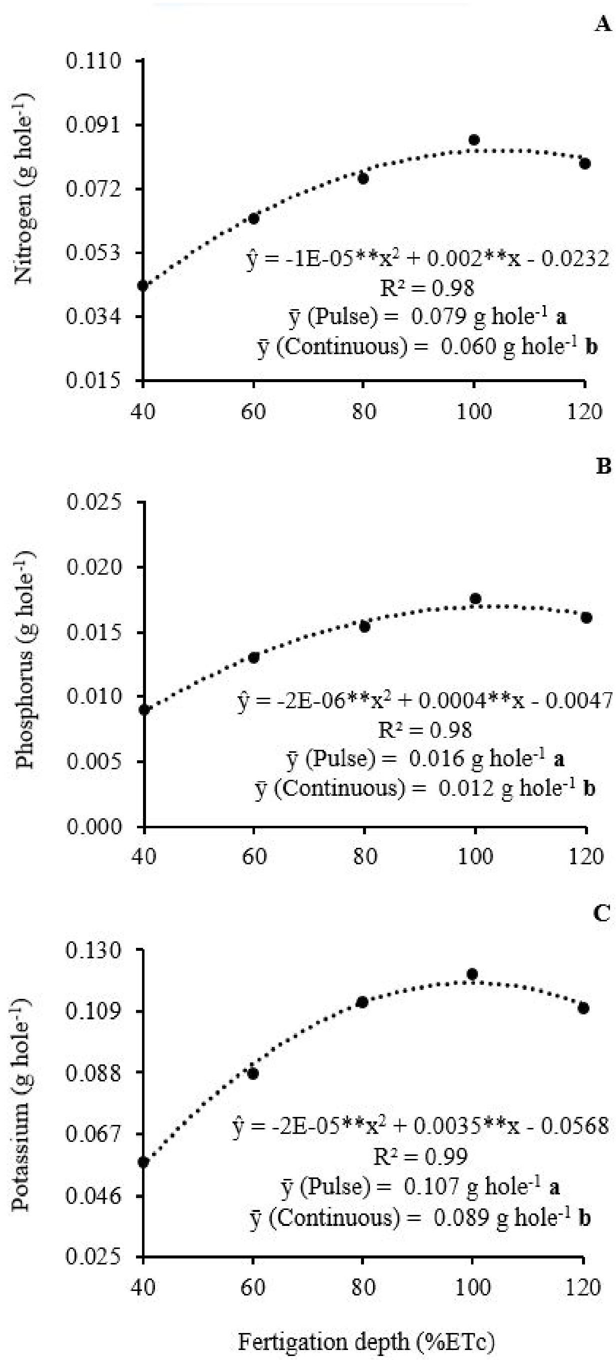

Figure 2. Analysis of the effect of fertigation depth and the types of application of these depth on the accumulation of nitrogen (A), phosphorus (B) and potassium (C), in the culture of coriander cv. Verdão. Different letters indicate significant differences between the types of fertigation application (pulse and continuous) by the Scott-Knott test ($p < 0.05$).
Source: The Authors.

Studying the effect of irrigation on P accumulation in coffee, [10] found that 100% ETc replacement led to the highest accumulations of P in the leaves.

Highest P accumulation (0.016 g hole^{-1}) by coriander was obtained with the application of pulse fertigation; with continuous fertigation the value was 0.012 g hole^{-1}, which represents a 33.3% increment in the accumulation of this nutrient. [14] found P accumulation of 0.021 g hole^{-1} in coriander leaves, differing from the results found in the present study. P is a nutrient with low mobility and solubility in soil, positively correlated with water application; however, this nutrient may be leached when water is applied in excess. According to [3], P availability and absorption are favored by high frequency of irrigation.

For potassium (K) accumulation as a function of fertigation depths, a quadratic model was fitted (Fig. 2C), with maximum accumulation of 0.096 g hole^{-1}, estimated at the water depth corresponding to 87.5% ETc, an 88.2% increment compared to the depth of 40% ETc. In a study with the arugula crop, [4] observed that irrigation depths greater than 100% field capacity reduce K accumulation.

Pulse fertigation led to highest K accumulation by the crop (0.107 g hole^{-1}), revealing a 20.2% increment compared to the continuous fertigation. [3] observed that pulse irrigation did not influence K accumulation in the bell pepper crop. [14] observed that K was the nutrient absorbed in largest amounts by coriander cv. 'Verdão', with maximum accumulation of 0.153 g hole^{-1}. Also according to these authors, although K does not participate in any organic compound, it participates in fundamental processes for plants, such as photosynthesis, also performing important functions such as enzymatic activation, synthesis of proteins, transport of carbohydrates, among others. Thus, it is essential for plant growth, development and production.

Fig. 3 presents the analysis of the effect of fertigation depths and types of application on the accumulation of nutrients: calcium (3A), magnesium (3B) and sulfur (3C).

In relation to calcium (Ca) accumulation in coriander as a function of fertigation depths, a quadratic model fitted to the data (Fig. 3A). The maximum estimated Ca accumulation was 0.068 g hole^{-1}, obtained with water depth of 85% ETc, a 41.7% increment compared to the water depth of 40% ETc.

[4] observed that the arugula crop under water stress accumulated higher Ca contents with the water depth corresponding to 120% field capacity, in a sandy soil, differing from the results obtained in the present study. Possibly, the lower Ca accumulations found in this study with the application of higher water depths of ETc replacement are due to the dilution effect of this nutrient. This effect occurs when the relative growth rate of dry matter is greater than the relative absorption rate of the nutrient.

According to [12], knowledge on the factors capable of influencing the concentration of nutrients in plants is very important, because all methods of interpretation of leaf analysis results use the concentration of the nutrient as a reference.

Thus, all factors which caused different changes in the rates of growth and absorption of nutrients lead to different concentrations of these nutrients in plant tissues. If the growth rate is null, i.e., if plant growth is stopped and the nutrient continues to be absorbed, there will be a concentration of this nutrient. However, if the opposite occurs, i.e., fast plant growth and the nutrient is absorbed at lower rate, there will be a dilution [18].

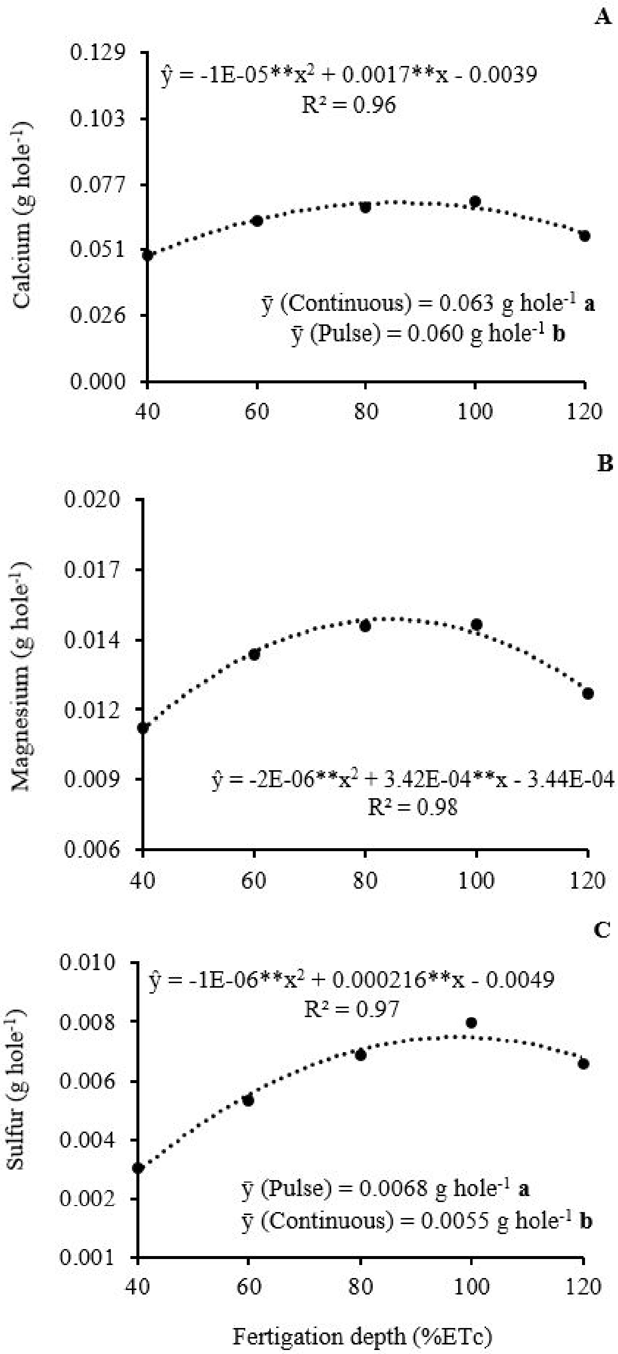

Figure 3. Analysis of the effect of the fertigation depth and the types of application of these depth on the accumulation of calcium (A), magnesium (B) and sulfur (C) in the culture of coriander cv. Verdão. Different letters indicate significant differences between the types of fertigation application (pulse and continuous) by the Scott-Knott test ($p < 0.05$).
Source: The Authors.

Regarding the effect of the types of fertigation application, the highest Ca accumulation was found under continuous fertigation, 0.063 g hole^{-1}. Pulse fertigation caused accumulation of 0.060 g hole^{-1}, revealing a 5% increment for continuous fertigation compared to pulse fertigation.

[3] evaluated Ca accumulation in bell pepper and obtained a different result from that of the present study. These authors observed no significant difference between pulse and continuous irrigation on Ca accumulation in bell pepper leaves. A result higher than the one obtained here was found by [14], who studied nutrient accumulation in coriander under conventional fertilization and found maximum Ca accumulation of 0.122 g hole^{-1}.

For the effect of fertigation depths on magnesium (Mg) accumulation, a quadratic model was fitted (Fig. 3B), in which the maximum estimated accumulation was equal to 0.0143 g hole^{-1}, found at the water depth of 85.5% ETc, a 41.6% increment compared to the water depth of 40% ETc. These results demonstrate that the high mobility of Mg in soil may have contributed to greater leaching of this nutrient and, consequently, led to reduction in its accumulation with the application of water depths greater than 86% ETc.

On this aspect, [4] observed in arugula cultivation that the higher the water depth applied, the lower the Mg content accumulated by the crop. [14], studying nutrient accumulation in coriander under conventional fertilization, obtained higher value than that of the present study, with maximum Ca accumulation of 0.0612 g hole^{-1}.

A quadratic model fitted to the data of sulfur (S) accumulation as a function of the effect of fertigation depths (Fig. 3C). Maximum S accumulation of 0.0068 g hole^{-1} was estimated with the application of a water depth corresponding to 108% ETc, a 1.5% increment compared to the water depth of 100% ETc. As in the present study, [4] observed that the replacement of 100% field capacity in a sandy soil favored S accumulation in arugula plants.

Regarding the effect of the types of fertigation application on S accumulation, it was observed that pulse fertigation led to highest S accumulation in coriander (0.0068 g hole^{-1}), revealing a 23.6% increment compared to the continuous fertigation. Lower result was reported by [19], who found S accumulation of 0.0001 g hole^{-1} in coriander cv. 'Verdão' in the emergence test.

The accumulation of macronutrients at the end of the experiment (34 DAS) by the coriander crop, under both pulse and continuous fertigation, decreased in the following order: K>N>Ca>P>Mg>S. [14] found the following decreasing order of macronutrients for the coriander crop: K<Ca<N<Mg<P. [8, 15, 21] observed the following decreasing order of extraction of macronutrients by lettuce: K>N>Ca>P>Mg>S.

According to Fig. 4, the interaction between fertigation depths and types of application had significant effect on the accumulations of manganese (A) and copper (B). Based on the simple-effect analysis of fertigation depths considering each type of application, significant difference was observed for both types of application in the accumulation of both Mn and Cu.

For pulse fertigation, a quadratic model was fitted to the data, and the fertigation depth which led to maximum Mn accumulation by coriander plants (0.417 mg hole^{-1}) was 91.25% ETc (Fig. 4A), revealing a 101.5% increment compared to the lowest water depth (40% ETc).

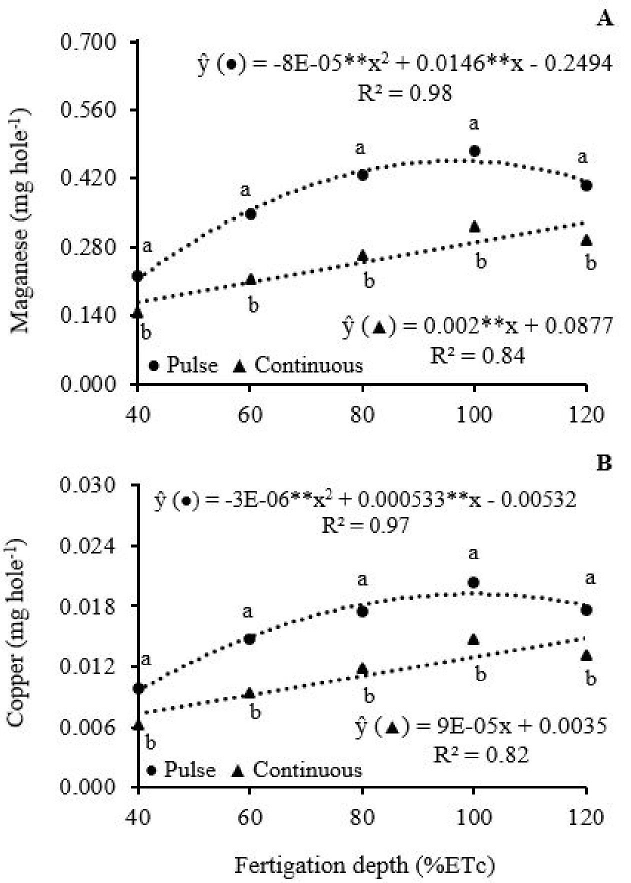

Figure 4. Unfolding the interaction between the factors for the accumulation of manganese (A) and copper (B) in the culture of coriander cv. Verdão subjected to fertigation depth and the types of application of these depth. Different letters indicate significant differences between the types of fertigation application (pulse and continuous) by the Scott-Knott Test ($p < 0.05$).
Source: The Authors.

An increasing linear model was fitted to the data of continuous fertigation, and maximum Mn accumulation (0.328 mg hole^{-1}) was obtained with water depth of 120% ETc, a 0.002% increment per unit increase in the fertigation depths. Likewise, for the arugula crop, [4] found that Mn accumulation was higher when an irrigation depth equivalent to 90% field capacity was applied in a sandy soil.

Further analysis of types of application considering each fertigation depth revealed that there was significant difference between pulse and continuous irrigation for all water depths evaluated, with increments of 23.2, 62.9, 64.1, 42.7 and 7% in Mn accumulation for the irrigation depths of 40, 60, 80, 100 and 120% ETc, respectively, under pulse fertigation.

A quadratic model (Fig. 4B) was fitted to the data of copper (Cu) accumulation as a function of irrigation depths under pulse fertigation. Maximum Cu accumulation (0.0184 mg hole^{-1}) was obtained with water depth equivalent to 88.8% ETc, representing a 64.3% increment compared to 40% ETc.

For continuous fertigation, an increasing linear model was fitted to the Cu accumulation data, with maximum of 0.0143 mg hole^{-1} at the water depth corresponding to 120% ETc, a percentage increment of 9.10^{-5} per unit increase in the fertigation depth.

[4] observed no significant difference between the water volumes applied in arugula plants for Cu accumulation. [16], evaluating the nutritional impacts of water deficit on bell pepper, observed that Cu accumulation in fruits increased as the water availability to plants decreased, a result different from that obtained in the present study.

Simple-effect analysis of types of application considering each fertigation depth revealed a significant difference between pulse and continuous irrigation at all ETc replacement water depths. Under pulse fertigation, Cu accumulation increased by 57.7, 78.7, 69.2, 44 and 7.7% for the water depths of 40, 60, 80, 100 and 120% ETc, respectively.

Effect of the interaction between factors on Zn accumulation and independent effect of fertigation depths on Fe accumulation can be observed in Figs. 5A and 5B, respectively. Further analysis of fertigation depths considering each type of application showed significant difference in Mn accumulation by coriander under both types of fertigation.

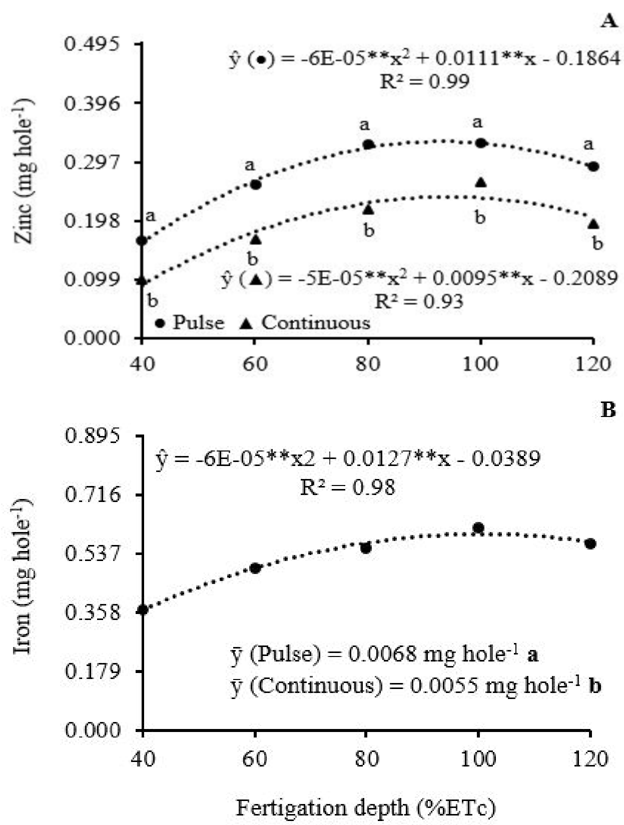

Figure 5. Analysis of the unfolding of the interaction between the fertigation depth and the types of application of these depth on the accumulation of zinc (A), and the isolated effect of these factors on the accumulation of iron (B), in the culture of coriander cv. Verdão. Different letters indicate significant differences between the types of fertigation application (pulse and continuous) by the Scott-Knott Test ($p < 0.05$).
Source: The Authors.

A quadratic model was fitted to the data of Zn accumulation in coriander plants under pulse fertigation (Fig. 5A), in which a maximum value of 0.327 mg $hole^{-1}$ was obtained with water depth corresponding to 92.5% ETc, a 101.9% increment compared to the water depth of 40% ETc.

Under continuous fertigation, maximum Zn accumulation (0.243 mg $hole^{-1}$) was obtained with water depth of 95% ETc, showing a 167% increment compared to the water depth of 40% ETc. [4] observed that the highest amounts of Zn accumulated in arugula shoots occurred under moisture content equivalent to 60 and 100% soil water retention capacity, and higher water depths reduced the accumulation of this nutrient.

Further analysis of types of fertigation application considering each irrigation depth revealed significant difference between pulse and continuous irrigation for all water depths evaluated. Under pulse irrigation Zn accumulation increased by 45.9, 37.7, 34.4 and 33.6% for water depths corresponding to 40, 60, 80, 100 and 120% ETc, respectively.

According to Fig. 5B, an increasing quadratic model was fitted to the data of Fe accumulation in coriander as a function of the fertigation depths applied. Maximum Fe accumulation (0.633 mg $hole^{-1}$) was obtained with water depth corresponding to 105.8% ETc, a 0.32% increment compared to the water depth of 100% ETc.

In arugula cultivation, [4] observed that for water depths above 100% field capacity in a sandy soil, the amount of Fe accumulated was higher and significantly different from those obtained at the other water depths, which were lower.

In relation to the effect of types of fertigation application, highest Fe accumulation (0.560 mg $hole^{-1}$) was obtained with pulse fertigation, showing a 26.7% increment compared to the accumulation found with continuous fertigation (0.442 mg $hole^{-1}$). Unlike the present study, [3] studied the bell pepper crop and found no influence of pulse irrigation on Fe accumulation in both young and old leaves.

The decreasing order of accumulation of micronutrients by the coriander crop, for both types of fertigation application, was: Fe>Mn>Zn>Cu. For lettuce, this same order of accumulation of micronutrients was obtained by [13,15].

4. Conclusions

The fertigation depths caused increments in the accumulation of dry matter and of all nutrients evaluated.

Pulse fertigation led to higher production of dry matter and accumulation of N, P, K, Fe, Mn, Cu and Zn, and reduced Ca accumulation.

Highest accumulations of K, Mn, Cu and Zn were obtained with pulse fertigation combined with water depths lower than 100% ETc.

Nutrient accumulation by coriander under both types of fertigation decreased in the following order: K>N>Ca>P>Mg>S>Fe>Mn>Zn>Cu.

References

[1] Almeida, W.F., Lima, L.A. and Pereira, G.M., Drip pulses and soil mulching effect on american crisphead lettuce yield. Engenharia Agrícola, 35(6), pp. 1009-1018, 2015. DOI: 10.1590/1809-4430-Eng.Agric.v35n6p1009-1018/2015

[2] Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves J.L.M. and Sparovek, G., Köppen's climate classification map for Brazil. Meteorologische Zeitschrift. Stuttgart, 22(2), pp. 711-728, 2014. DOI: 10.1127/0941-2948/2013/0507

[3] Assouline, S., Moller, M., Cohen, S., Ben-Hur, M., Grava, A., Narkis, K. and Silber, A., Soil–plant system response to pulsed drip irrigation and salinity: Bell pepper - Case study. Soil Science Society of America Journal, Madison, 70(5), pp. 1556-1568, 2006. DOI: 10.2136/sssaj2005.0365

[4] Becari, G.R.G., Eficiência do uso da água e parâmetros nutricionais na cultura da rúcula submetida a diferentes condições de estresse hídrico, Tese Doutorado em Agronomia, Universidade Estadual Paulista, Faculdade de Ciências Agronômicas, Botucatu, São Paulo, 2015.

[5] Bezerra Neto, E. e Barreto, L.P., Análises químicas e bioquímicas em plantas. 1ra ed. Recife: UFRPE, Editora Universitária da UFRPE, Brasil, 2011.

[6] Bhat, S., Kaushal, P., Kaur, M. and Sharma, H.K., Coriander (*Coriandrum sativum L.*): processing, nutritional and functional aspects. African Journal of Plant Science, Nairobi, 8(1), pp. 25-33, 2014. DOI: 10.5897/AJPS2013.1118

[7] Cavalcanti, F.L.A., Santos, J.C.P., Pereira, J.R., Leite, J.P., Silva, M.C.L., Freire, F.J., Silva, D.J., Sousa, A.R., Messias, A.S., Faria, C.M.B., Burgos, N., Lima Júnior, M.A., Gomes, R.V., Cavalcanti, A.C. e Lima, J.F.V.F., Recomendações de adubação para o estado de Pernambuco. 2a aproximação. 3ra ed. Recife: Instituto Agronômico de Pernambuco-IPA, Brasil, 2008.

[8] Costa, C.G., Uso de composto de resíduos da unidade de alimentação e nutrição do IFMG – Campus São João Evangelista na cultura da alface (*Lactuca sativa* L.). 2017. Monografia Graduação em Agronomia, Instituto Federal de Minas Gerais, São João Evangelista, Minas Gerais, Brasil, 2017.

[9] Daflon, D.S.G., Freitas, M.S.M., Carvalho, A.J.C., Monnerat, P.H. e Prins, C.L., Sintomas visuais de deficiência de macronutrientes e boro em coentro. Horticultura Brasileira, Brasília, 32(1), pp. 28-34, 2014. DOI: 10.1590/S0102-05362014000100005

[10] Dominghetti, A.W., Scalco, M.S., Guimarães, R.J., Silva, D.R.G., Carvalho, J.P.S. e Pereira, V.A., Doses de fósforo e irrigação na nutrição foliar do cafeeiro. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, 18(12), pp. 1235-1240, 2014. DOI: 10.1590/1807-1929/agriambi.v18n12p1235-1240

[11] Ferreira, D.F., Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, Lavras, 35(6), pp. 1039-1042, 2011.

[12] Fontes, P.C.R., Diagnóstico do estado nutricional das plantas. 1ra ed. Viçosa: UFV, 2001.

[13] Furlani, P.R., Instruções para o cultivo de hortaliças de folhas pela técnica de Hidroponia NFT. Boletim Técnico IAC, 168. 1ra ed. Instituto Agronômico, Campinas, Brasil, 1998.

[14] Grangeiro, L.C., Freitas, F.C.L., Negreiros, M.Z., Marrocos, S.T.P., Lucena, R.R.M. e Oliveira, R.A., Crescimento e acúmulo de nutrientes em coentro e rúcula. Revista Brasileira de Ciências Agrárias, Recife, 6(1), pp. 11-16, 2011. DOI: 10.5039/agraria.v6i1a634

[15] Kano, C., Cardoso, A.I.N. e Villas Bôas, R.L., Acúmulo de nutrientes e resposta da alface à adubação fosfatada. Revista Biotemas, Santa Catarina, 25(3), pp. 39-47, 2012. DOI: 10.5007/2175-7925.2012v25n3p39

[16] Lima, G.S., Broetto, F., Sousa, A.P., Correia, J.S. e Silva, A.O., Impactos nutricionais e produção de pimentão submetido à deficiência hídrica. Irriga, Botucatu, 21(4), pp. 724-735, 2016. DOI: 10.15809/irriga.2016v21n4p724-735

[17] Lira, R.M., Santos, A.N., Silva, E.F.F., Silva, J.S., Barros, M.S. e Gordin, L.C., Cultivo de coentro em diferentes níveis de salinidade e umidade do solo. Revista Geama Environmental Sciences, Recife, 1(3), pp. 293-303, 2015.

[18] Maia, C.E., Morais, E.R.C., Porto Filho, F.Q., Gueyi, H.R. e Medeiros, J.F., Teores foliares de nutrientes em meloeiro irrigado com águas de diferentes salinidades. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, 9, pp. 292-295, 2005.

[19] Pereira, M.F.S., Linhares, P.C.F., Macarajá, P.B., Lima, G.K.L. e Madeiros, G.S., Composição nutricional de cultivares de coentro por ocasião do teste de emergência de plântulas. Revista Verde, 7(5), pp. 01-05, 2012.

[20] Prats, A. and Picó, S., Adaptation of pressurized irrigation networks to new strategies of irrigation management: energy implications of low discharge and pulsed irrigation. Agricultural Water Management, Amsterdam, 169(1), pp. 52-60, 2016. DOI: 10.1016/j.agwat.2016.02.023

[21] Raij, B. van, Cantarella, H., Quaggio, J.H. e Furlani, A.M.C., Recomendações de adubação e calagem para o Estado de São Paulo. Boletim Técnico 100, 2da ed., Instituto Agronômico e Fundação IAC, Campinas, Brasil, 1996.

[22] Silva, M.A.D., Coelho Júnior, L.F. e Santos, A.P., Vigor de sementes de coentro (*Coriandrum sativum* L.) provenientes de sistemas orgânico e convencional. Revista Brasileira de Plantas Medicinais, Botucatu, 14, pp. 192-196, 2012. DOI: 10.1590/S1516-05722012000500012

[23] Silva, F.C., Manual de análises químicas de solos, plantas e fertilizantes. Embrapa Informação Tecnológica, 2da ed., Brasília, Brasil, 2009.

[24] Soares, L.A.A., Lima, G.S., Brito, M.E.B., Sá, F.V.V.S. e Araújo, T.T., Crescimento do tomateiro e qualidade física dos frutos sob estresse hídrico em ambiente protegido. Revista Verde, Pombal, 6(3), pp. 203-212, 2011.

[25] Souza, H.A., Hernandes, A., Romualdo, L.M., Rozane, D.E., Natale, W. e Barbosa, J.C., Folha diagnóstica para avaliação do estado nutricional do feijoeiro. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, 15(12), pp. 1243-1250, 2011. DOI: 10.1590/S1415-43662011001200005.

S.M. de Menezes, is BSc. an Agricultural Engineer in 2016, from the Federal University of Alagoas (UFAL), Brazil. MSc in 2018, and PhD student in Agricultural Engineering by the Federal Rural University of Pernambuco (UFRPE), Brazil. Research line: plant mineral nutrition; irrigation management; integrated water and soil management.
ORCID: 0000-0003-1225-5572

G.F. da Silva, is BSc. in Agronomist in 2004, and MSc in Soil and Water Management in 2008, from the Federal University of Paraíba (UFPB), Brazil. PhD in Phytotechnology from the Federal Rural Semi-Arid University (UFERSA), Brazil. Post-Doctor in Agricultural Engineering from the Federal Rural University of Pernambuco (UFRPE), Brazil. He is currently an adjunct professor at the Federal Rural University of Pernambuco (UFRPE), Brazil.
ORCID: 0000-0002-3348-7252

M.M. da Silva, is BSc. an Agricultural Engineer in 2001, MSc in 2005, and PhD in 2010 in Agricultural Engineering, all of them from the Federal University of Campina Grande (UFCG), Brazil. He is currently an adjunct professor at the Federal Rural University of Pernambuco (UFRPE), Brazil.
ORCID: 0000-0002-3316-8024

J.E.F. de Morais, is BSc. an Agronomist in 2013, MSc. in Plant Production in 2015, and PhD student in Agricultural Engineering from the Federal Rural University of Pernambuco (UFRPE), Brazil.
ORCID: 0000-0002-3641-2221

J.A.S. Junior, is BSc. an Agricultural Engineer in 2009, MSc, in 2010, and PhD in 2013 in Agricultural Engineering from the Federal University of Campina Grande (UFCG), Brazil. He is currently an adjunct professor at the Federal Rural University of Pernambuco (UFRPE), Brazil.
ORCID: 0000-0002-6204-352X

D. Menezes, is BSC. an Agronomist in 1976, MSc. in Agronomy in 1980, by University of São Paulo (USP), Brazil. And PhD in 1998, in Botany from the Federal Rural University of Pernambuco (UFRPE), Brazil. Currently associate professor IV of the Federal Rural University of Pernambuco (UFRPE), Brazil.
ORCID: 0000-0003-2139-4259

M.M. Rolim, is a BSc. in Civil Engineer in 1984, from the Catholic University of Pernambuco (UCPE) and Cartographic Engineer, in 1987, from the Federal University of Pernambuco (UFPE), Brazil. MSc (1996) and PhD in Agricultural Engineering in 1999, from the State University of Campinas (UNICAMP), Brazil. He is currently a lecturer at the Federal Rural University of Pernambuco (UFRPE), Brazil.
ORCID: 0000-0003-2111-3875

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