VISUAL SYMPTOMS OF NUTRIENT DEFICIENCIES IN *Physalis peruviana* L.

SINTOMAS VISUAIS DE DEFICIÊNCIAS NUTRICIONAIS EM FISALIS, Physalis peruviana L.

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ABSTRACT: The physalis production has caused interest of producers, consumers and traders due to its easy growing, high nutritional value and economic value added. The objective of this study was to evaluate the growth and characterize the symptoms of macro and micronutrient deficiencies in physalis seedlings (*Physalis peruviana* L.). The seedlings were grown in complete nutrient solution and also in solutions with individual omissions of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn, using the missing element technique. Visual symptoms of nutrient deficiency and the dry matter production of shoot and root, respectively taken at 68 and 150 days after treatment application were evaluated. Omissions of macro and micronutrients caused visual symptoms of nutrient deficiencies common to other species. Nutrient deficiencies limited the total dry matter production in the following order: N > S> P> K > Ca > Mg for macronutrients and Fe > B > Zn > Mn > Cu for micronutrients, respectively.

KEYWORDS: *Physalis peruviana* L. Visual diagnosis. Missing element. Nutrient solution.

INTRODUCTION

Over these past few years, the production of small fruits in Brazil, which encompasses a number of species such as blackberry, raspberry, blueberry, strawberry and physalis has aroused, the attention of consumers, fruit processors, trading agents, small producers that compose family farming, as well as producers of medium and large size (FACHINELLO et al., 2011).

The *Physalis peruviana* L. (physalis) is a herbaceous plant of perennial habit, that belongs to the Solanaceae family, which is characterized by producing fruits of beautiful visual appearance, sugary and with good content of vitamin A, C, iron and phosphorus, besides presenting numerous medicinal properties (FISCHER et al., 2014).

Although it has perennial habit, physalis is grown as an annual crop when production is done in commercial scale. Physalis production has become an excellent alternative for small and medium Brazilian producer who has an interest in production and trade of fruits, due to this culture is a rustic plant, easy growing, and with great adaptability in different regions of the country. It is a species of great nutritional and economic value with a promising future, which is being developed in the small fruit plantations, and its fruit is enjoyed by high-income consumers (FISCHER et al., 2014). Origin center of physalis is not known, but most studies indicated the Andes region (GONZÁLEZ et al., 2008).

Although it is a rustic plant, physalis is demanding in nutrients, and in Brazil, studies on its nutritional requirement are still incipient. There are a few parameters for fertilizer recommendation and nutritional requirement of this culture, and usually, these recommendations are made using as base search results from other regions, or using fertilizer recommendation for the tomato crop (IANCKIEVICZL et al., 2013).

Then, the developing of programs for fertilizing agricultural crops has a huge importance, and they should be preceded by studies able to evaluate the consequences of mineral deficiencies on the growing and developing of plants. The knowledge of visual symptoms of nutrient deficiencies is also useful for decision making about the need to conduct fertilization (SILVA et al., 2009). Thus, it is very important to know the nutritional aspects of this plant, as soil and climatic variations between different regions of Brazil, which can influence the fertilization and cultural practices to be adopted for each region. Since, the adoption of the same agricultural practice for different regions can reduce the culture developing, not expressing the full productive potential of culture.

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The objective of this study was to evaluate the growing and to characterize the symptoms of nutrient deficiencies in physalis seedlings.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse of the Agronomy Department at Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), Diamantina, Minas Gerais State, Brazil (18° 12' S, 43° 34' W, altitude of 1,350 m). The experimental was designed in randomized blocks with three replications and twelve treatments: complete solution and the individual omissions of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn, totaling 36 experimental plots with a plant in each pot.

Physalis seeds were collected manually from plants grown in the horticulture sector of UFVJM, Diamantina, MG, Brazil. After a week, the seeds were sown in trays of 128 cells, using a commercial substrate, Bioplant®. The seedlings were grown in a greenhouse and irrigation was made by micro sprinklers twice a day.

A month after seedling emergence, it was performed the roots wash to remove the substrate bonded, and it was made the transfer of seedlings for hydroponic pots of black color with 3.0 L capacity, with addition fo 2.5 L of nutrient solution prepared in accordance to Clark (1975).

Solutions with ionic strengths of 25, 50, 75 and 100 % were used. The seedlings were kept in each concentration for one week, using a continuous artificial aeration system. During this adaptation period, in the first and second week, it was supplied nutrient solution contained only macronutrients. And, in the third and fourth week, it was supplied nutrient solution with 50 and, 75% of macronutrients, respectively, and 10 % of the ionic strength of micronutrients. In the fifth week, 100 % of the ionic strength of all nutrients was supplied by the nutrient solution. The treatments with complete solution and with absence of nutrients studied were supplied in the sixth week. The solutions with different treatments were changed weekly, during the 150 days of the experiment conduction.

The solutions were prepared with analytical reagents, and the complete nutrient solution was prepared in accordance to Clark (1975) as following: 114.2 mg N ($N\text{-}NO_3^-$: $N\text{-}NH_4^+$ ratio 8:1); 2.2 mg P; 70.2 mg K; 104.4 mg Ca; 14.4 mg Mg; 16 mg S; 209 µg B; 32 µg Cu; 2128 µg Fe; 385 µg and 131 µg Zn Mn per liter of solution. For the other treatments, the nutrients concentrations were identical to those of the complete solution, except for the omitted nutrient.

Symptoms of nutrient omission were described and photographed 68 days after the treatments application. After 150 days, the plants were harvested, being made the shoot and roots separation. The collected material was washed in distilled water, packed in drilled paper bags and placed for drying in an oven with forced air circulation at a temperature of 65 °C until constant weight. After drying, the harvested plant material was weighed.

Data from dry mass of shoots and roots were subjected to analysis of variance, and the averages of the treatments were compared by the Scott & Knott test at 5 % of probability.

RESULTS AND DISCUSSION

All treatments with disabilities had dry matter production of shoots, roots and total below the complete treatment (Table 1). Macronutrients that most affected the production of total dry matter were N, S, P, K, Ca and Mg, down 67, 63, 54, 45, 43 and 33 % respectively in relation to the complete treatment. The order of limitation was N > S > P > K > Ca > Mg for macronutrients.

Macronutrients, N, S, P, K and Ca did not statistically differ among themselves for the shoot and total dry matter production, both with production below complete treatment, that the N and P omission were the least limited the root dry matter production of physalis plants (Table 1). Batista et al. (2003) found lower shoot and total dry matter production in soursop in the omission of N, the first limiting nutrient, followed by Ca and P. In the present study, among the macronutrients, the N was also the most limiting element with the N, P and Ca being the first, third and fifth macronutrient, respectively, most limiting for total dry matter production. Alves et al. (2008) in sugar beet plants and, Lavres Junior et al. (2009) in castor bean plants also observed reduction in root, shoot and total dry matter production when in the N absence.

The S was the second macronutrient most limiting dry matter production, mainly the roots of physalis (Table 1). This fact showed that it is importance of considering the supply of this macronutrient, and that the use of fertilizers such as superphosphate simple and potassium sulphate at planting would be feasible to contain this nutrient. Conversely, Barroso et al. (2005) with work done with teak (*Tectona grandis*), Alves et al. (2008) with sugar beet plants, Silva et al. (2009) with physic nut, they found their works that S had the lowest reductions in total dry matter production. However, for N, K, P and Ca it was found higher decrease in total dry matter production of sugar beet plants (ALVES et al., 2008).

Table 1. Shoot dry matter, roots dry matter, and total dry matter production of physalis seedlings grown in complete nutrient solution and omissions of nutrients, at 150 days after treatment application

Treatment[(1)]	Dry matter production		
	Shoot (g)	Root (g)	Total (g)
Complete	20,18 a	4,64 a	24,82 a
Omission N	5,06 c	3,16 b	8,21 c
Omission P	6,91 c	4,57 a	11,48 c
Omission K	11,24 c	2,42 c	13,66 c
Omission Ca	11,23 c	2,84 c	14,07 c
Omission Mg	13,95 b	2,71 c	16,66 b
Omission S	7,44 d	1,83 d	9,26 c
Omission B	12,25 b	2,71 c	14,96 c
Omission Cu	17,17 a	2,37 c	19,54 b
Omission Fe	9,59 c	2,21 c	11,80 c
Omission Mn	14,37 b	2,33 c	16,69 b
Omission Zn	12,94 b	3,25 b	16,19 b
CV (%)	15,23	17,11	14,73

[(1)]Averages followed by the same letter in the columns do not differ by the Scott & Knott test at 5% probability.

The P and K were the third and fourth macronutrients, respectively, that caused major reductions in dry matter production when in deficiency, except for the P omission in roots dry matter production of physalis (Table 1). Alves et al. (2008) in sugar beet also observed drastic reductions in the roots, shoot and total dry matter production when K was absent. Silva et al. (2009) observed smaller reductions (32 %) in the absence of P in total dry matter of physic nut seedlings.

The Ca was the fifth macronutrient most limiting of total dry matter production in physalis, and significant difference was found between this element and Mg (Table 1), which in turn was less limiting to the production of total dry matter, statistically differentiating itself from the other macronutrients (N, S, P, K and complete). These reductions in total dry matter production caused by the omission of Ca and Mg, indicated the need for liming with calcitic limestone, and generally, dolomitic and magnesium limestone are more recommended than the calcite. Silva et al. (2009) found in a study of physic nut that Ca, Mg and K are the macronutrients most limiting for total dry matter production.

Comparing the full treatment with the treatments without some of micronutrients studied (Table 1), it was observed that there were major limitations when Fe and B were absent, being the limit order was Fe > B > Zn > Mn > Cu, with decrease of 52, 40, 35, 33 and 21 % respectively. Lange et al. (2005) also found severe reductions in total dry matter production in castor bean caused by the omission of Fe and B. In physic nut, Silva et al. (2009) also observed a drastic reduction in the total dry matter production in the absence of Fe, and unlike the present study, the absence of B showed higher total dry matter production, which was justified by the overgrowth caused by the absence of this micronutrient.

In relation to complete treatment, the Zn, Mn and Cu caused a reduction in total dry matter production significantly lower, than the reductions observed for Fe and B absences (Table 1). Contrary results in relation to Mn were found by Lange et al. (2005) in castor bean, in this study, the Mn deficiency caused the higher reductions in total dry matter production. Silva et al. (2009) found a drastic reduction in shoots, roots and total dry matter production physic nut in Cu omission.

Deficiency symptoms of all nutrients were completely visible to 68 days after the treatment application (Figure 1). The complete treatment did not show any foliar symptoms during the experiment conduction. The plant physalis with complete fertilization showed vigorous with showy green leaves and flowering at 84 days after treatment application.

Only at the experiment end, 150 days after treatment application, a reduced internerval chlorosis was observed on the leaves (Figure 1), possibly, this was due to the grown plant demanding a higher concentration of nutrients for this stage development of plant physalis.

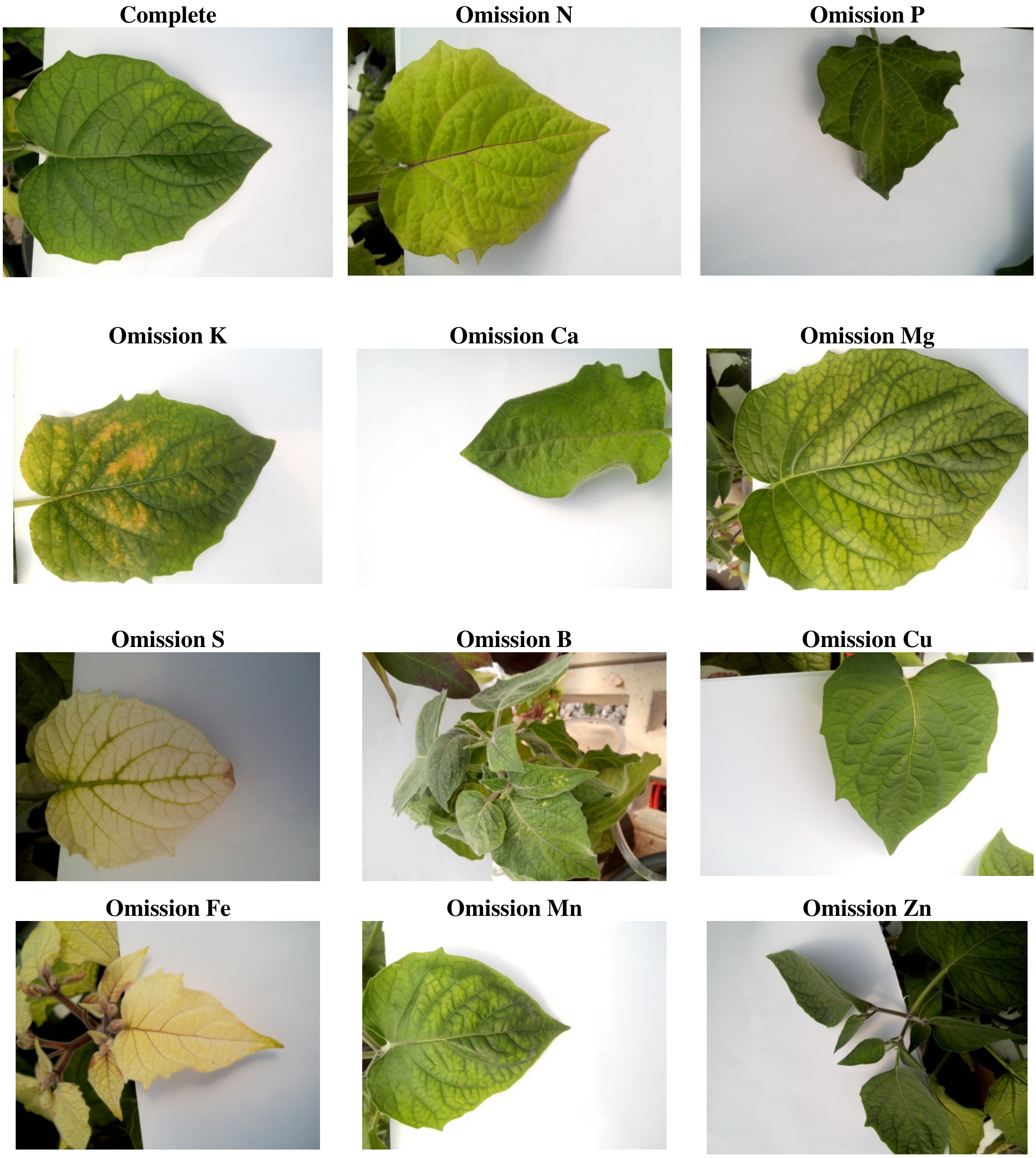

Figure 1. Nutritional deficiency symptoms on physalis plant leaves subjected to treatments on complete nutrient solution and with the nutrients omission, 68 days after treatment application.

The N omission caused a drastic reduction in the plants growth when compared to plants cultivated in complete nutrient solution (Table 1). At 68 days, after treatment application, a light green color was observed on all leaves of plants cultivated without N supply (Figure 1), and flower buds emission occurred at 70 days. After 84 days, the oldest leaves presented a yellowish color evenly, and the new leaves remained with a light green color. With the advance of symptoms, to 103 days all leaves were yellow, being that the oldest leaves presented this symptom with higher intensity, causing necrosis and leaf senescence. The symptoms due to N omission were also observed by Martínez et al. (2009) in physalis plants in an experiment conducted in Colombia, wherein the plants with deficiency of N and K, presented symptoms more severe in relation to plants submitted to other macronutrients deficiencies. In study with passion fruit, Freitas et al. (2011) also found N deficiency symptoms using the missing element technique, and the N deficiency symptoms were the first to manifest in the leaves. Other authors had also described similar symptoms in teak plants (BARROSO et al., 2005) and sugar beet (ALVES et al., 2008), respectively.

At 68 days, in treatments with the P omission was observed an intense green color on all leaves with ripples being formed on the younger leaves edges (Figure 1). The flower buds emission occurred at 84 days after treatment application. After 103 days, the plants presented their new leaves wrinkled up and, with ripples on the edge, already the oldest leaves presented a dull green color, with bright strong green spots and with waxy appearance. The oldest leaves presented thick and brittle texture. The P deficiency dramatically affected the plants growth when compared to the complete treatment (Table 1). Martínez et al. (2009) observed similar features in the culture of physalis. Other authors also observed similar characteristics in soursop (BATISTA et al., 2003) and sugar beet (ALVES et al., 2008) by the missing element technique in nutrient solution.

Due to K omission a chlorosis was observed in the center of oldest leaves, at 68 days after treatment application (Figure 1). Unlike the symptoms observed in leaves of other crops with deficiency of this nutrient, wherein the chlorotic effect commonly appear in the oldest leaves apex until to the limbus base (SILVA et al., 2009). The flower buds emission occurred at 84 days after treatment application. In oldest leaves, it was observed intense and bright green spots with waxy aspect and irregular small marks light-colored with wet aspect, which may be related to the collapse of chloroplasts (MARTÍNEZ et al., 2009). At 103 days, these symptoms advanced and the marks were united to other chlorotic spots, acquiring an orange tonality, after this, there was necrosis and leaf senescence. Martínez et al. (2009) also observed similar symptoms of K deficiency in physalis plants when grown in nutrient solution.

Plants deficient in Ca showed symptoms at 57 days after treatment application, and these were clearly visible after 68 days, when new leaves crinkled and shriveled, and over time the oldest leaves also presented these symptoms. After 103 days, we could observe the developing yellowish color and necrosis of young leaves edges, after this there was necrosis of the plant apex. Similar symptoms were observed in studies performed with sugar beet plants (ALVES et al., 2008) and passion fruit (FREITAS et al., 2011) in absence of Ca.

Although, the omission of all macronutrients had caused significant decreases in the growth of physalis in relation to the complete treatment (Table 1). The Mg was macronutrients that less affected the plant growth. In Mg absence, it was observed flower buds emission at 84 days. At 68 days, on oldest leaves, the symptoms started with a slight yellowing, advancing for a more intense internerval chlorosis with a thick reticulated aspect (Figure 1). With passing of the days, the symptoms progressed more rapidly, causing necrosis of these leaves. After this, the younger leaves also presented internerval chlorosis. Freitas et al. (2011) observed similar symptoms in sweet passion fruit and Barroso et al. (2005) on teak plants with symptoms of chlorosis internerval in old leaves with a narrow strip of green tissue along the veins, and the progression deficiency leaves became yellow, with margins of the necrotic and intense falling leaves.

In turn, the S omission caused severe symptoms in the plysalis plant, as large reduction in growth (Table 1). At 68 days after treatment application, it was observed a light green color throughout the plant. With the symptoms advance there was a general chlorosis in new leaves, and then, the chlorosis had become widespread throughout the plant. These symptoms were more intense on younger leaves, which acquired a yellow color, with green veins and white contours (Figure 1). At 109 days it could be perceived the all the leaves whitening, and, on youngest leaves were observed the necrosis of apex and of the edges. Silva et al. (2009) observed similar symptoms in leaves of physic nut plants cultivated in S omission; however, these authors obtained the highest total dry matter between the macronutrients omissions in relation to complete treatment contrary to this work.

The omission of all micronutrients caused reductions in physalis plant growth (Table 1), except for Cu. In the treatment with the B omission, the symptoms were observed at 68 days after treatment application (Figure 1), with overbudding at the plant top and small chlorotic spots on young leaves. The plants bloomed at 70 days after treatment application. At 84 days, anomalies were observed in the developing leaves, which were issued with various distortions, and also, it was observed the crinkling of new leaves which presented bright and intense green color with waxy appearance. From 103 to 109 days after treatment application, the overbudding at the plant top was more intense, changing its architecture. Martínez et al. (2009)

observed similar symptom related to the plant architecture in physalis plants with cultivation in nutrient solution, due to malformation of all its structures and disorganization of meristems, providing the death of the apical meristem and lateral shoots. Lange et al. (2005) reported other features of symptoms in young leaves of castor bean with wrinkled and thick with winding down with deformation in the tissue at the junction region of the leaf blade lobes that migrated towards the central rib, giving the blade one rounded shape. At the end of development, B deficiency in castor bean caused loss of dominance due to the death of the apical bud, similar to this work. For Oliveira et al. (2009), in study performed with tomato cultivation, the B was bit limiting in the initial phase of development, possibly by the low need of the nutrient that stage where the amount provided in the adaptation phase supplied the need for culture in this period, unlike the present study there was low B supply in the adaptation phase of physalis seedlings.

The total dry matter production under the Cu omission was statistically identical to the complete treatment (Table 1). The flowering occurred at 84 days after treatment application, as it occurred for complete treatment. Due to the small amount of Cu demanded by the plant, possibly the amount provided in the adaptation phase had been enough so that plant had a good development and vigor during the initial stage (Figure 1). Oliveira et al. (2009) in a group of tomato salad observed no symptoms caused by Cu deficiency due to low demand for variety and possible that the quantity of nutrients provided in the adaptation phase has been enough to supply the need of culture.

The Fe omission caused the most dramatic reduction in physalis plant growth when compared to effect due to omission of the other micronutrients studied (Table 1). The symptoms due to Fe omission manifested during the stage of seedlings adaptation in the nutrient solution, on the first and second week, due to nutrient solution had supplied only macronutrients, with ionic strengths of 25 %. However, there was a plant recovery when this element on the 3rd, 4th and 5th week, with ionic strengths of 10, 10 and 100 %, respectively. At 63 days after starting the treatments, Fe deficiency symptoms were the first to appear, and initially, chlorosis resembling a mosaic was observed on the leaves developing present in the plant apex, and it was observed a chlorosis that started in the limbo base of expanded new leaves, which evolved towards the leaf center. After 68 days, the chlorosis manifested itself throughout the limbo of new leaves, and only a leaf part presented a little green color (Figure 1). With the advancement of these symptoms, newly expanded leaves became totally chlorotic, and later there was a whitening of these leaves. At 103 days after treatment application, it was observed necrosis that evolved from inside to outside of the leaves. The Fe omission led to a chlorosis generalized leaf entire, evolving for the whitening of leaves, and culminating in death of the plant apex. Oliveira et al. (2009) observed identical symptoms on tomato crops of the salad group with the first expression of Fe deficiency symptoms, about 3 to 4 days after Fe omission in the nutrient solution with new leaves presenting chlorosis which started at the base of the petiole and walking toward the tip of the leaves with increasing time deficiency; chlorosis achieved old leaves, so that whole plants became chlorotic and end of the cycle, the leaves had is totally whitened.

With the omission of Mn, at 68 days after application of treatments, it was observed an internerval chlorosis with thick crosslinked aspects on young leaves (Figure 1). And, with the evolving of symptoms, the old leaves had presented the characteristics. The flower buds emission occurred at 84 days**.** These symptoms were similar to those described in castor bean by Lange et al. (2005) in which younger leaves Mn omission presented chlorosis internerval that looks thick crosslinked, i.e. the ribs and adjacent areas became dark green, while the rest of the leaf surface had become yellowish.

In plants deficient in Zn, stretch marks perpendiculars to veins of the new leaves were observed at 68 days after starting treatments (Figure 1). Flowering occurred at 70 days after treatment application. At 95 days, it was observed a large number of smaller sized leaves, thinner stem, a greater number of branches in relation to the complete treatment, and subsequently, there was chlorosis on old leaves. In castor bean, Zn omission caused no symptoms, this fact was due to the plant had been cultivated on complete solution during the adaptation phase (LANGE et al., 2005). In tomato, Zn omission caused symptoms that initially manifested in the young leaves, which showed slight chlorosis, with the intensification deficiency, the entire plant was struck, showing chlorotic leaves, coerces and wrinkled, shortening the ribs and thickening of the petiole (OLIVEIRA et al., 2009).

CONCLUSIONS

The limiting order for total dry matter production of physalis plant was N > S > P > K >

Ca > Mg for macronutrients, and Fe > B > Zn > Mn > Cu for micronutrients.

The nutrients omissions to the physalis plants caused visual symptoms of nutrient deficiency, common to other species.

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RESUMO: A produção de fisalis tem despertado interesse de produtores, consumidores e comercializadores devido seu fácil cultivo, grande valor nutricional e econômico agregado. O objetivo deste trabalho foi avaliar o crescimento e caracterizar os sintomas de deficiências de macro e micronutrientes em mudas de fisalis (*Physalis peruviana L.*). As mudas foram cultivadas em solução nutritiva completa e, também em soluções com omissões individuais de N, P, K, Ca, Mg, S, B, Cu, Fe, Mn e Zn, pelo uso da técnica do elemento faltante. Foram avaliados os sintomas visuais de deficiência de nutrientes, e a produção de matéria seca da parte aérea e das raízes aos 68 e 150 dias após a aplicação dos tratamentos, respectivamente. As omissões de macro e micronutrientes provocaram sintomas visuais de deficiências nutricionais comuns a outras espécies. As deficiências limitaram a produção de matéria seca total na seguinte ordem: N > S > P > K > Ca > Mg para macronutrientes e Fe > B > Zn > Mn > Cu, para micronutrientes, respectivamente.

PALAVRA-CHAVE: *Physalis peruviana* L. Diagnose visual elemento faltante. Solução nutritiva.

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