Solos nos Biomas Brasileiros 2

Alan Mario Zuffo
Jorge González Aguilera
(Organizadores)

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APRESENTAÇÃO

A obra "*Solos nos Biomas Brasileiro*" aborda uma série de livros de publicação da Atena Editora, em seu volume II, apresenta, em seus 17 capítulos, conhecimentos tecnológicos para Ciências do solo na área de Agronomia.

O uso adequado do solo é importante para a agricultura sustentável. Portanto, com a crescente demanda por alimentos aliada à necessidade de preservação e reaproveitamento de recursos naturais, esse campo de conhecimento está entre os mais importantes no âmbito das pesquisas científicas atuais, gerando uma crescente demanda por profissionais atuantes nessas áreas.

As descobertas agrícolas têm promovido o incremento da produção e a produtividade nos diversos cultivos de lavoura. Nesse sentido, as tecnologias nas Ciências do solo estão sempre sendo atualizadas e, em constantes mudanças para permitir os avanços na Ciências Agrárias. A evolução tecnológica, pode garantir a demanda crescente por alimentos em conjunto com a sustentabilidade socioambiental.

Este volume dedicado à Ciência do solo traz artigos alinhados com a produção agrícola sustentável, ao tratar de temas como o uso de práticas de manejo de adubação, inoculação de microorganismos simbióticos para a melhoria do crescimento das culturas cultivadas e da qualidade biológica, química e física do solo. Temas contemporâneos de interrelações e responsabilidade socioambientais tem especial apelo, conforme a discussão da sustentabilidade da produção agropecuária e da preservação dos recursos hídricos.

Aos autores dos diversos capítulos, pela dedicação e esforços sem limites, que viabilizaram esta obra que retrata os recentes avanços científicos e tecnológicos nas Ciências do solo, os agradecimentos dos Organizadores e da Atena Editora.

Por fim, esperamos que este livro possa colaborar e instigar mais estudantes e pesquisadores na constante busca de novas tecnologias para a área de Agronomia e, assim, garantir incremento quantitativos e qualitativos na produção de alimentos para as futuras gerações de forma sustentável.

Alan Mario Zuffo

Jorge González Aguilera

SUMÁRIO

CAPÍTULO 16

LEAF INDEX FOR FOLIAR DIAGNOSIS AND CRITICAL LEVELS OF NUTRIENTS FOR *Physalis peruviana*

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ABSTRACT: Physalis (*Physalis peruviana* L.) is a species that produces edible fruits with a sour and sweet taste, characterized as a fleshy berry. Its production has aroused great interest of producers, merchants and consumers, for its easy cultivation, high nutritional value and economic added. Basic information about mineral nutrition of physalis is scarce, especially as regards the determination of the index leaf to evaluate nutritional status. The objective of this study is to establish the index leaf, the type and leaf position in the floral branch and propose critical levels of nutrients for nutritional diagnosis of physalis. The data of nutrient concentrations in leaf limb, petiole and complete leaf and shoot dry weight of physalis collected from an experiment of nutrients omission in greenhouse were used to define leaf type to be sampled. The complete leaf samples were collected in three positions of the branch (apical, median and basal) in the flowering of crop and fruit productivity. These data were obtained in an experimental plot of NPK fertilization in physalis was used to define the position of the complete leaf to be sampled and to propose values of critical nutrient levels for physalis. Critical levels of nutrients were proposed by means of reduced normal distribution criterion with field experiment data. The complete leaf (petiole and leaf limb) in the median position of floral branches is can be indicated as sampling standard for diagnosis of nutritional state of physalis. The critical levels of nutrients proposed are N (34.1 g kg^{-1}), P (2.9 g kg^{-1}), K (17.1 g kg^{-1}), Ca (13.5 g kg^{-1}), Mg (3.9 g kg^{-1}), S (4.2 g kg^{-1}), B (19.3 mg kg^{-1}), Cu (16.9 mg kg^{-1}), Fe Mn (40.9 mg kg^{-1}) and Zn (20.2 mg kg^{-1}) for sampling of complete leaf in the median position of floral branches of physalis.

KEYWORDS: Leaf sampling, nutrients, nutritional status, critical levels.

RESUMO: A fisalis (*Physalis peruviana* L.) é uma espécie produtora de frutos comestíveis com sabor azedo e adocicado, caracterizados como uma baga carnosa. Sua produção vem despertando grande interesse de produtores, comerciantes e consumidores, pelo seu fácil cultivo, alto valor nutricional e econômico agregado. Informações básicas sobre a nutrição mineral do fisalis são escassas, principalmente no que se refere à determinação da parte da planta indicada para avaliar o estado nutricional da cultura. O objetivo deste trabalho foi estabelecer a folha índice quanto ao tipo e a posição da folha no ramo floral e propor o nível crítico de nutrientes para diagnose nutricional de fisalis. Os dados de concentração de nutrientes no limbo foliar, pecíolo e folha completa e de peso seco da parte aérea de fisalis foram coletados de um experimento de omissão de nutrientes em casa de vegetação para definição do tipo de folha a ser amostrada. Amostras de folha completa (pecíolo e limbo foliar) foram coletadas em três posições dos ramos (apical, mediana e basal) no florescimento da cultura e a produtividade de frutos. Os dados foram obtidos de um experimento de adubação NPK em fisalis para definição da posição a ser amostra da folha completa e propor valores de nível crítico de nutrientes para fisalis. A folha completa (pecíolo e limbo foliar) na posição mediana de ramos florais pode ser indicada com amostragem padrão para diagnose do estado nutricional de fisalis. Os níveis críticos de nutrientes propostos são para N (34,1 g kg^{-1}), P (2,9 g kg^{-1}), K (17,1 g kg^{-1}), Ca (13,5 g kg^{-1}), Mg (3,9 g kg^{-1}), S (4,2 g kg^{-1}), B (19,3 mg kg^{-1}), Cu (16,9 mg kg^{-1}), Fe (361,0 mg kg^{-1}), Mn (40,9 mg kg^{-1}) e Zn (20,2 mg kg^{-1}) para amostragem da folha completa na posição mediana de ramos florais de fisalis.
PALAVRAS-CHAVE: Amostragem foliar, nutrientes, estado nutricional, nível crítico.

1 I INTRODUCTION

Physalis peruviana L. is an Andean exotic plant being characterized by being shrub, decumbent habit and very dense branches (RODRÍGUEZ et al., 2013). It belongs to the Solanaceae family and to the genus *Physalis*, which has about twelve species in South America (SOARES et al., 2009), being these species, producing edible fruits of sour and sweet taste being these species, producing edible fruits of sour and sweet taste (VARGAS-PONCE et al., 2016). The fruit is presented by a berry enveloped by the chalice, popularly called boll (RUFATO et al., 2008). It has a high nutritional value and attractive medicinal properties (PUENTE et al., 2011), being rich in vitamins A, C, Fe, P and fibers (MUNIZ et al., 2014).

Soil chemical analysis is the routine form used as criterion to evaluate soil fertility and need of fertilization for different crops (FAGERIA et al., 2009). Normally, nutritional diagnosis of plants is performed by evaluation of results of foliar chemical analysis, among others, constituting a tool that allows planning, evaluating and calibrating fertilization recommendation used in the crops, being complementary to soil analysis (FAGERIA, 2007; PRADO; CAIONE, 2012).

Foliar analysis has been widely used in the diagnosis of plants nutritional status is based on fact that there is a direct correlation between growth or yield and nutrient concentration in their tissues (MARSCHNER, 2012). From this correlation, values are established for nutrient concentrations corresponding to changes in terms of yield. These points represent critical levels and delimit ranges of concentrations related to nutrient deficiencies, appropriate levels or toxicity of nutrients (MOURÃO FILHO, 2004, PRADO; CAIONE, 2012).

Several factors that may determine variations in nutrient concentrations in leaves, such as leaf age and its position in the branch, fruiting performance, cultivar, genotype, soil type and cultural practices (FAGERIA, 2007; FAGERIA et al., 2009, SOUZA et al., 2011; PRADO; CAIONE, 2012). Therefore, there is no information on the leaf indexing for foliar diagnosis for physalis within the premise of a well-defined relationship between growth and crop yield and the nutrient concentration in the tissues. Given the above, the study aimed to establish the index leaf, the type and leaf position in the floral branch and propose critical levels of nutrients for nutritional diagnosis of physalis.

2 I MATERIALS AND METHODS

Two experiments were carried out in Diamantina, state Minas Gerais, Brazil (18°15'S, 43°36'W, 1,250 m altitude) in a greenhouse in a nutrient solution and in field condition. Other in the field condition were carried out in Maria da Fé, state Minas Gerais, Brazil (22º 17'S, 43°23'W, 1,285 m altitude).

The greenhouse data in nutrient solution referred to an experiment that utilized the missing element technique. The experimental was designed in completely randomized with three replications and twelve treatments: complete nutrient 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 was grown from seeds of a population provided by Company of Agricultural Research of Minas Gerais, from the center in the South of the State Minas Gerais, in Maria da Fé (22º 17'S, 43°23'W, 1,285 m altitude), 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. The pH of the nutrient solution was maintained at about 6.0 ± 0.1; applying HCl 0.1 mol L^{-1} or NaOH 1.0 mol L^{-1} with daily control, as needed, using a portable pH meter. At 150 days after the start of the experimental period, seedlings were evaluated shoot dry weight and divided in dry weight of stem, petiole and leaf limb, in the last two parts were used to define index leaf of physalis.

The field data were related to an experiment to study NPK rates in physalis that was cultivated in Quartzarenic Neossol and Yellow Red Argisol (SANTOS et al., 2013). Soil samples were air-dried, sieved (2.0 mm) and characterized according to Teixeira et al. (2017) with the following results: For Quartzarenic Neossol (pH_{water}=5.3; P =10.3; K=0.5 mg dm^{-3} (Mehlich-1); Ca=1.0; Mg=0.3; Al=0.04 (KCl 1 mol L^{-1}); Cation-exchange capacity =3.1 $cmol_c$ dm^{-3}; Bases saturation=42%, Organic carbon=1.7 and Clay=60 g kg^{-1}) and Yellow Red Argisol (pH_{water}=5.3; P=0.4; K=0.1 mg dm^{-3} (Mehlich-1); Ca =1.6; Mg=0.8; Al=0.1; Cation-exchange capacity =4.8 $cmol_c$ dm^{-3}; Bases saturation =25%, Organic carbon=2.9 and Clay=260 g kg^{-1}). The experiments were arranged in a randomized blocks, fractional factorial design $(4 \times 4 \times 4)^{½}$, with 32 treatments, totalizing 32 experimental plots. The following nutrient rates were applied: 0, 40, 80 and 160 kg ha^{-1} N, as urea; 0, 45, 90 and 180 kg ha^{-1} P, as triple superphosphate, and 0, 35, 70 and 140 kg ha^{-1} K, as potassium chloride. The experimental plot consisted of 18 plants, spaced 3 x 1 m (density of 3,333 plants ha^{-1}) being the plot useful to the four central plants. Soil preparation of the experimental area was conducted in conventional manner (plowing and harrowing). The fertilization with micronutrients was 1 kg of B (boric acid) and 4 kg of Zn (zinc sulfate) per ha.

Leaf samples with complete leaf (petiole and leaf limb) were collected in the four useful plants of the experimental plots, in three positions of the plant (apical, median and basal) in the flowering of crop. Each sample consisted of 10 leaves, counted in the apex direction for the base of the plants. Fruits productivity of physalis was evaluated by a useful plot in the year 2015 in Diamantina and in the year 2017 in Maria da Fé, Brazil.

The petiole, leaf limb and complete leaf samples in the experiments were dried in a forced-air oven at 65 C for nutrient determination (SILVA, 2009).

Greenhouse data, totaling 36 shoot dry weight data of physalis with a dependent variable and the concentration of all nutrients in the leaf limb, petiole and complete leaf (petiole and leaf limb) sampled according to Figure 1a, as independent variables were submitted to multiple linear regression study with the purpose of obtaining the index leaf of physalis. Field experiment data of 32 experimental plots of Diamantina were submitted to multiple linear regression study between the concentrations of all nutrients in the three leaf positions of the plant (apical, median and basal), sampled according to Figure 1b, in floral branch as independent variable and fruits productivity of physalis as dependent variable.

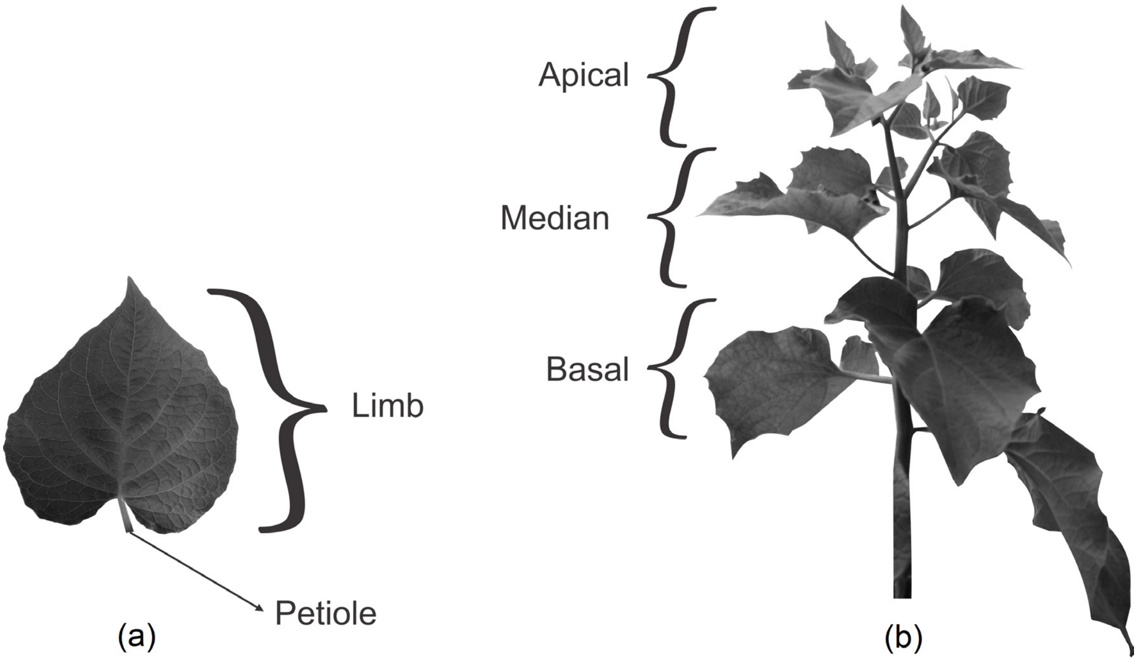

Figure 1. Sampling scheme of leaf type to be sampled (leaf limb, petiole and, complete leaf) (a) and three positions of floral branches (apical, median and basal) (b) physiologically mature leaves in flowering of physalis.

The selection of index leaf in type and position in physalis was considered: significance of the multiple linear regression, the adjustment index (R^2 and R^2 adjusted), the significance of each estimated nutrient parameter of the multiple linear regression with shoot dry weight part and fruits productivity of physalis, study of the graphic distribution of standardized residues (SEBER; LEE, 2003) and simple linear correlation (r) of observed and estimated shoot dry weight and fruits productivity of physalis.

The critical levels of nutrients for the physalis were obtained after the definition of the index leaf, using the criterion of the reduced normal distribution (MAIA; MORAIS; OLIVEIRA, 2001) in two experiments were carried out in Diamantina and Maria da Fé, state Minas Gerais, Brazil. The methodology consists of firstly verifying, if the fruit productivity data have normal distribution, and if negative, can do transformation of the data. When productivity has a normal distribution, the arithmetic mean (X_1) and the standard deviation (s_1) of the productivity are calculated. Next, productivity representing 90% of the maximum is calculated by Equation 1.

$$\text{Productivity}_{90\%} = 1.281552*s_1 + X_1 \quad (1)$$

The next step calculated the variable Y by Equation 2, where n_i is the nutrient concentration that is desired to find the critical level.

$$Y = productivity / n_i \quad (2)$$

Subsequently, the Y values are verified for the normal distribution and the arithmetic mean (X_2) and the standard deviation (s_2) of the created variable are calculated. Then, the value of Y referring to 90 % of the maximum is calculated by Equation 3.

$$Y_{90\%} = 1.281552*s_2 + X_2 \quad (3)$$

Knowing that Y = productivity / n_i and replacing productivity with 90% of maximum (Equation 1), the critical level is calculated by Equation 4, for nutrient n_i.

$$n_i = 1.281552*s_1 + X_1 / 1.281552*s_2 + X_2 \quad (4)$$

The critical levels of nutrients in the physalis leaves were compared with those proposed by Raviv & Lieth (2008) found in plant tissues.

3 I RESULTS AND DISCUSSION

The multiple linear regressions between the nutrient concentrations in leaf limb, petiole and complete leaf and shoot dry weight of physalis were significant by F test with better adjustment index results (R^2 and R^2 adjusted) (Table 1). The complete leaf presented higher value of R^2 adjusted between nutrient concentrations and shoot dry weight of physalis, which occur for the petiole and leaf limb (Table 1). The estimated parameters of the regression (intercept and nutrient concentrations) were all significant at the 1% level by t test for leaf limb, petiole and complete leaf (Table 1) showing the relationship that the nutrients have with the plant growth (FAGERIA et al., 2009, MARSCHNER, 2012, PRADO; CAIONE, 2012).

The statistical study of the standardized residuals was adequate for this type of procedure (SEBER; LEE, 2003), since the points are random and homogeneous around the horizontal axis with value equal to zero, this characterizes a better result for the linear regression between the shoot dry weight of physalis and the nutrient concentrations for leaf limb, petiole and complete leaf (Figure 2). In addition, simple linear correlations (r) were elevated between the estimated and observed shoot dry weight of physalis (Figure 2). In this way, it is possible to use leaf limb, petiole and complete leaf, but as a form of standardization for future evaluation of the nutritional status and recommendation for the farmers of physalis crop would be ideal the complete leaf as index leaf.

The field experiment was used to define the position (apical, median and basal) of the complete leaf in the floral branch of physalis. The multiple linear regressions adjusted between the fruits productivity of physalis and all the nutrient concentrations in the complete leaf in full flowering of the plants can verify that the sampling of the complete leaf in the median position of floral branch was the one that presented significance by F test and the highest adjustment indexes (R^2 and R^2 adjusted) (Table 2).

Independent variable	Leaf limb	Petiole	Complete leaf
	.... Estimated parameter		
Intercept	-29.6367	-12.8086	-42.4426
N	0.5667**	0.2377**	0.7664**
P	-4.3138**	-4.3340**	-4.5955**
K	0.2891**	0.5678**	0.2990**
Ca	0.3240**	3.1969**	0.0922**
Mg	2.5922**	4.2711**	2.3259**
S	-2.6989**	-0.6453**	-2.3746**
B	-0.7218**	-0.9030**	-0.8545**
Cu	1.9169**	0.9373**	1.9498**
Fe	0.0790**	-0.0332**	0.1168**
Mn	0.0228**	-0.0388**	0.0355**
Zn	0.0639**	-0.2845**	0.1538**
F test	409.2980**	75.5770**	5278.2880**
R^2	0.9947	0.9719	0.9996
R^2 adjusted	0.9923	0.9591	0.9994

Table 1. Parameters of multiple linear regression equations between nutrient concentrations in leaf limb, petiole and complete leaf as independent variables and shoot dry weight (g $plot^{-1}$) of physalis as dependent variable.

**Significant at p = 0.01. Concentration values for macronutrients are in g kg^{-1} and micronutrients in mg kg^{-1}.

Independent variable	Sampling position of complete leaf		
	Basal	Median	Apical
	.... Estimated parameter..................................		
Intercept	3014.692	-1.176.438**	391.271
N	-238.371	415.344**	186.379
P	-1176.226*	-1840.399**	-2350.082*
K	-98.507	281.753**	10.087
Ca	-319.599	-136.987**	-104.027
Mg	1716.916**	1227.637**	1690.205*
S	1325.750	501.548**	2568.860
B	5.452*	8.716**	13.493*
Cu	6.738	-1.764**	-4.308
Fe	-0.538	-0.186**	-0.535
Mn	2.749*	10.791**	12.285*
Zn	-5.777*	-7.562**	-11.737*
F test	4.725**	203.231**	6.125**
R^2	0.779	0.999	0.818
R^2 ajustado	0.616	0.989	0.685

Table 2. Parameter of multiple linear regression equations between complete leaf nutrient concentrations in three positions in the plant (basal, median and apical) as independent variable and, fruit productivity (kg ha^{-1}) of physalis as dependent variable.

**Significant at p = 0.01. Concentration values for macronutrients are in g kg^{-1} and micronutrients in mg kg^{-1}.

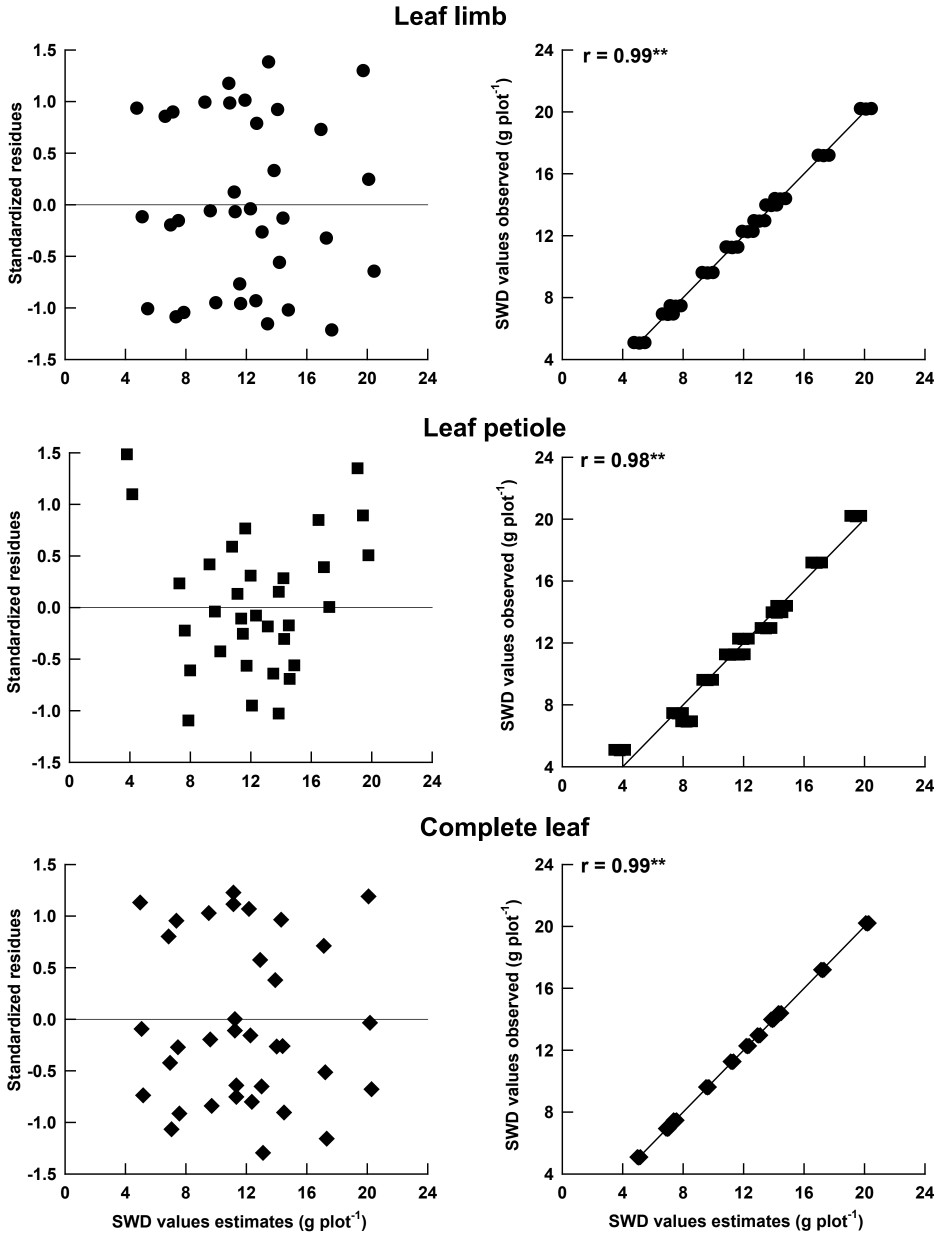

Figure 2. Graphical distribution of the standardized residues for the multiple linear regressions of all nutrients in leaf limb, petiole, and complete leaf with the estimated shoot dry weight (SDW) of physalis and, the simple linear correlation (r) between SDW values observed and estimates.

The estimated parameters of the regression (intercept and nutrient concentrations) were all significant at the 1% level by t test (Table 2) for sampling the complete leaf in the median position in floral branch showing the relation that the nutrient concentrations have with the plant productivity (FAGERIA et al., 2009; MARSCHNER, 2012, PRADO; CAIONE, 2012). The statistical study of the standardized residues shows a better result for the regression when sampling of the complete leaf in the median position in floral branch and, with greater simple linear correlation (r) between the estimated and observed values of fruits productivity of physalis (Figure 3).

The definition of the median sampling position of the complete leaf in a physalis plant follows what is generally observed for several crops such as cucumber, potato (SILVA, 2009) and common bean, which presented closer correlations for the concentration, accumulation and yield variables when sampled in the medium leaf (SOUZA et al., 2011). For the coffee crop, the collection at medium height of the plant of the third pair of leaves from the tip of branch is sufficient to carry out the chemical determinations of macro and micronutrients (CINTRA, 2012).

However, the median sampling position is not a standard. For leaf sampling of rice is indicated the sampling of the total shoot (FAQUIN, 2002). Cultures with characteristics similar to physalis have very specific samplings as in the case of eggplant, which is only sampled the newly developed leaf petiole (SILVA, 2009).

The leaf index for foliar diagnosis of a crop is based on the direct correlation between growth rate or yield and the nutrient concentrations in its tissues (FAGERIA et al., 2009; MARSCHNER, 2012, PRADO; CAIONE, 2012). Therefore, failure to correlate all nutrients with crop growth and yield may provide misleading recommendation of the index leaf to be sampled to diagnose the nutritional status of plants. Without correlating the yield or growth of the plant with the nutrient concentrations, a wide variation was obtained for physalis as a function of the nutrient to be diagnosed.

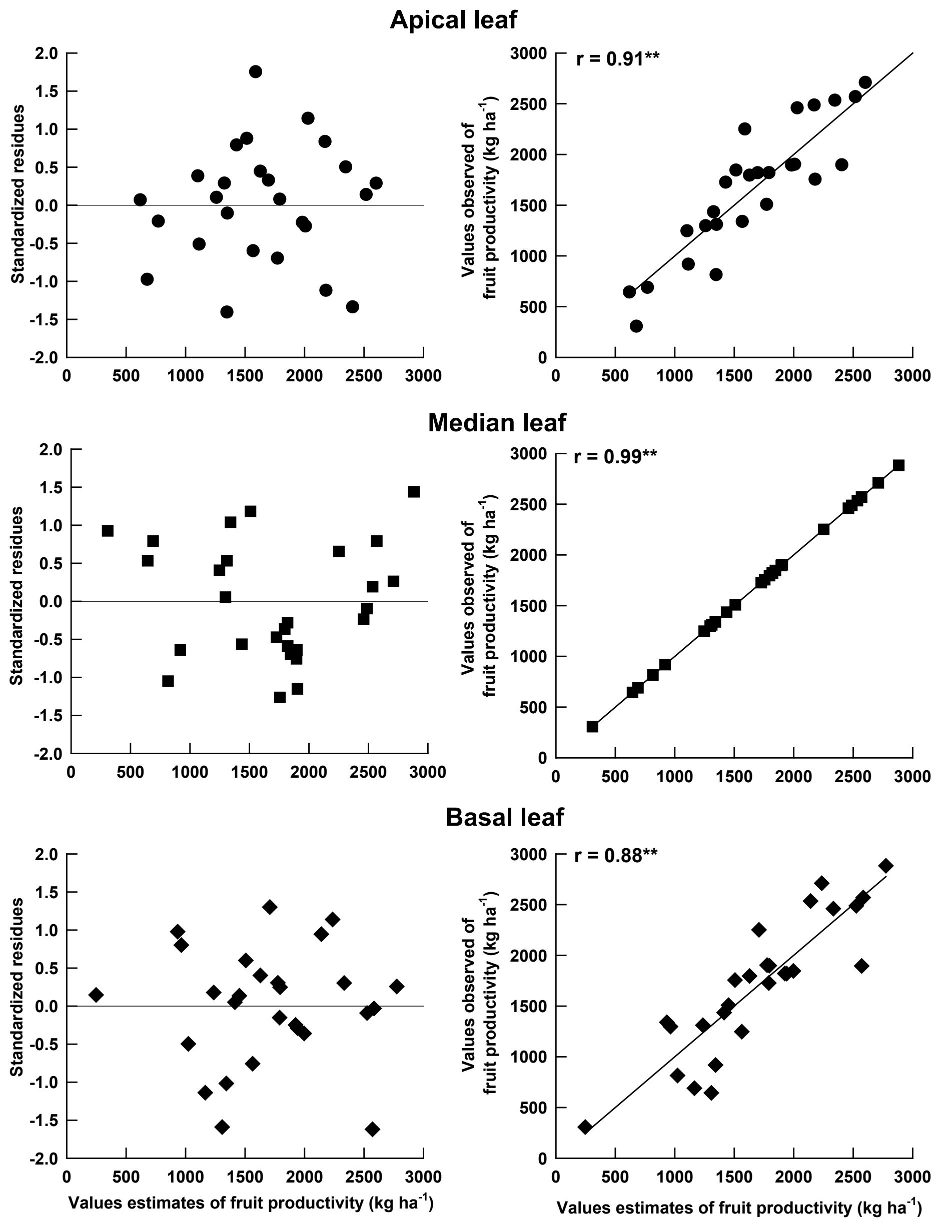

Figure 3. Graphical distribution of the standardized residues for the multiple linear regressions

of all nutrients in three positions in the plant (basal, median and apical) with the estimated fruit productivity of physalis and, simple linear correlation (r) between the fruit productivity values observed and estimates.

Foliar diagnosis is recommended to collect leaves physiologically mature, i.e. with photosynthetic activity at its maximum and fully formed (MARSCHNER, 2012, PRADO; CAIONE, 2012). This leaf should behave as a source of photoassimilates (KOCH, 2004). Young leaves collected at the apex of the branch are physiologically immature, with low photosynthetic activity and at this stage it functions as a drain, with older leaves presenting a reduction of physiological activity with the onset of senescence (KITAJIMA et al., 2002). Thus, it is understandable that the leaves with the highest degree of maturity are ideal samples for leaf diagnosis of the physalis crop.

The data from the field experiments for the recommended complete leaf sample at the median position in the floral branches of the physalis plants were submitted to the methodology of the critical levels of nutrients by the criterion of the reduced normal distribution (MAIA; MORAIS; OLIVEIRA, 2001) for nutrient standards for this crop, which has been characterized as efficient and its use is fully feasible (Table 3). Although the data are obtained from a crop yield cycle, these new data may eventually be used to evaluate the nutritional status of the physalis as a first approximation.

The critical levels of nutrients in physalis leaves for leaf sampling in the median position of floral branches (Table 4), when compared to the established range proposed by Raviv and Lieth (2008), were high for Ca, Mg, B and Cu, adequate for N, P, Fe, Mn and Zn and low for K and S. Thus, it can be observed that there was a change in the classification of critical levels of nutrients in comparison with the authors (RAVIV; LIETH, 2008). The definition of index leaf and critical levels of nutrients for physalis, as this work, may reduce the occurrence of inadequate diagnosis of nutritional deficiencies, excesses or imbalances, which may reduce increases in crop production cost.

Variable	Mean	Standar deviation	Lilliefors test
Fruit productivity	1,425.8	714.8	0.078**
Fruit productivity / N	398.7	224.0	0.075**
Fruit productivity / P	4,333.6	2,936.2	0.154**
Fruit productivity / K	708.5	517.7	0.146**
Fruit productivity / Ca	989.6	577.0	0.158**
Fruit productivity / Mg	2,900.7	2,367.5	0.125**
Fruit productivity / S	3,058.6	1,955.1	0.116**
Fruit productivity / B	52.6	53.7	0.121**
Fruit productivity / Cu	73.6	50.4	0.130**
Fruit productivity / Fe	3.4	2.4	0.135**
Fruit productivity / Mn	31.3	20.3	0.141**
Fruit productivity / Zn	59.6	44.0	0.149**

Table 3. Mean, standard deviation (s) and Lilliefors test for fruit productivity and relation between productivity and nutrient concentration in the complete leaf in the median position of physalis to obtain the critical levels of nutrients by reduced normal distribution criterion.

**Significant at $p = 0.01$. Fruit productivity is in kg ha^{-1}. Concentration values for macronutrients are in g kg^{-1} and micronutrients in mg kg^{-1}.

Nutrient	Nutrient concentration	
	Complete leaf median	Raviv & Lieth (2008)
	.... g kg^{-1}	
N	34.1	10-56
P	2.9	1,2-5.0
K	17.1	14-64
Ca	13.5	2,0-9.4
Mg	3.9	1.4-2.1
S	4.2	2.8-9.8
	.... mg kg^{-1}	
B	19.3	1-35
Cu	16.9	2.3-7.0
Fe	361.0	53-550
Mn	40.9	50-250
Zn	20.2	10-100

Table 4. Critical levels of nutrients in complete leaf in the median position of physalis by reduced normal distribution criterion.

4 I CONCLUSION

Sampling of the complete leaf (petiole and leaf limb) in the median position of floral branches is can be indicated as sampling standard for diagnosis of nutritional state of physalis.

The critical levels of nutrients proposed are N (34.1 g kg^{-1}), P (2.9 g kg^{-1}), K (17.1 g kg^{-1}), Ca (13.5 g kg^{-1}), Mg (3.9 g kg^{-1}), S (4.2 g kg^{-1}), B (19.3 mg kg^{-1}), Cu (16.9 mg kg^{-1}), Fe Mn (40.9 mg kg^{-1}) and Zn (20.2 mg kg^{-1}) for sampling of complete leaf in the median position of floral branches of physalis.

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