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YELLOW PASSION FRUIT PLANT NUTRITIONAL DIAGNOSIS AT DIFFERENT PHENOLOGICAL STAGES BY THE DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM METHOD

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YELLOW PASSION FRUIT PLANT NUTRITIONAL DIAGNOSIS AT DIFFERENT PHENOLOGICAL STAGES BY THE DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM METHOD

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□ *This work was performed in the Rio de Janeiro State, Brazil, with the objective to evaluate the nutritional status of yellow passion fruit plants along different phenological stages, using the DRIS method. Fifty-four passion fruit cultivated areas with an annual yield productivity ranging from 6.95 to 33.8 t ha^{-1} $year^{-1}$ and average productivity of 16.9 t ha^{-1} $year^{-1}$ were selected in the region. The contents of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), chlorine (Cl), iron (Fe), zinc (Zn), manganese (Mn), and boron (B) were evaluated. The reference standards were established (mean and variation coefficient) for the values of the nutrient concentration ratios, two by two, on samples from high yield productivity plantations and analyzed by the DRIS index of nutrients for the medium and low yield productivity areas. The established standards differed according with the phenological stage of the culture. In a general way, the mean content of the evaluated nutrients did not differed between the two productivity levels into each phonological stage. There was a difference for the Nutritional Limitation Order between different phenological stages of yellow passion fruit plants. The most negative DRIS indexes and the highest absolute values for the Average Nutritional Balance on yellow passion fruit plants in the region, were found for potassium in May, phosphorus in October and iron in January.*

Keywords: *Passiflora edulis*, passion fruit, leaf nutrient, phenology

INTRODUCTION

In order to improve economical profit of yellow passion fruit cultivation in the Northern region of Rio de Janeiro State in Brazil, the development of technologies to increase yield productivity, especially those concerning to the mineral nutrition and irrigation-fertilization, is an essential necessity.

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Information about the nutritional status of a plant is a basic prerequisite for its adequate nutrition and crucial to achieve high yield productivity.

According with Bataglia (2004), one of the intrinsic characteristics of diagnosis and recommendation integrated system (DRIS), which differentiates it from other interpretation criteria of the nutritional status of plants, is the establishment of the reference standards known as 'norms', obtained from cultivated areas considered of high productivity. While on the definition of the critical point and sufficiency range, conventional experimental data is required, nutritional standards in DRIS are established rather with plants from commercial producing areas.

The DRIS index of a nutrient, is no other than the mean value of the standard deviation from quotients (ratios) containing a given nutrient ratio to its own optimal values (Bailey et al., 1997). Each ratio of nutrients content into the high productivity population represents a DRIS standard and has its own mean and variation coefficient (Reis Júnior and Monnerat, 2002).

DRIS is being tested as an evaluation method to access the nutritional status of a plant in cultures such as soybean (Beverly et al., 1986), sugarcane (Zambello Júnior et al., 1981; Reis Júnior and Monnerat, 2002), green dwarf coconut (Santos et al., 2004), pineapple (Angeles et al., 1990), coffee (Partelli et al., 2007), papaw (Costa, 1995), citrus (Cerda et al., 1995), and grapes (Costa, 1998). Until the present day, all available results were still contradictory, particularly by the absence of information about nutrient levels in cultures considered standard and due to the difficulty in validation of the previously defined norms.

The nutritional diagnosis trough DRIS index also provides the nutritional equilibrium index (IEN), which allows the confirmation of the nutritional equilibrium of diverse crops, demonstrating that the lower is its value, the lower would be the nutritional disequilibrium of the sampled crop.

Evaluating the nutritional status of Italia cv. grapevines in three developmental stages using DRIS method, Costa (1998) verified that it reflected the nutritional local status and the grapevines showed variability regarding to the order and degree of nutrient limitation in productivity. Reis Júnior and Monnerat (2003), evaluating the establishment of DRIS standard for sugar-cane, observed that the different nutritional balances between groups of low and high productivity constitute an evidence for the confidence of the developed norms.

Moreno et al. (1996) support that DRIS standards universality is unquestionable. Payne et al. (1990) affirmed that after development of the DRIS standards for any species, those reference parameters may be used independently of the variety or the local conditions. According with Sanches et al. (1991), the associations between nutrients used in DRIS occasionally are less sensitive to the differences caused by the effects of leaf location in the plant branch, crop and soil or climatic conditions, than to the sufficiency technique. However, there are some scientific divergences regarding to the universality of DRIS standards, once differences have being found between standards obtained from different populations and locations, demonstrating that these are not entirely independent from local conditions or sampling period.

It is well known that concentrations of labile elements from leaves decrease with plant age, while concentrations of non-labile elements increase. Thus, the ratio between one labile and one non-labile nutrient would not be constant during a period of time, diverging from the DRIS premise that states this method can be used for sampling at any time. Thus, this universality attributed to the DRIS standards may be responsible for the diagnosis errors found with this method (Reis Júnior and Monnerat, 2002).

The objective of this work was to evaluate the nutritional status of yellow passion fruit plants in the Northern region of the Rio de Janeiro State in Brazil, in different phenological stages using DRIS method.

MATERIALS AND METHODS

This work was performed in the Northern region of the Rio de Janeiro State in Brazil, to establish the diagnosis and recommendation integrated system standards. Fifty-four regional representative cultivated areas were selected, with a yield productivity varying from 6.95 to 33.8 t ha^{-1} $year^{-1}$ and average productivity of 16.9 t ha^{-1} $year^{-1}$. The mineral content analysis of plants was made on leaf samples collected in three different phenological stages: 1) fruit development, slow vegetative growth and blooming (May 2003); 2) intense vegetative growth, high blooming and fruit development (October 2003) and 3) fruit development and harvest (January 2004).

New matured leaves, without petiole, containing a floral bud next to its anthesis were collected for the analysis. These were generally the fourth or fifth pair of leaves from the branch apex. After collecting, samples were conditioned in paper bags and transported to a laboratory where they were cleaned. Then, leaves were dried in a hot air oven at 70°C, during 48 hours. After dehydrated, samples were pulverized on a mill (Wiley-like mill) with a 20 mesh sieve and then stored in hermetical closed glass vials.

The concentration of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), chlorine (Cl), iron (Fe), zinc (Zn), manganese (Mn), and boron (B) was analyzed in the samples. The analyses were performed according with Malavolta et al. (1997).

The establishment of the reference standards (mean and variation coefficient), from the values of nutrient concentration associations, were made two-by-two, in samples from high productivity crops. Establishment of the standards is required for the DRIS indexes calculation.

Among the 54 crop areas selected in the region, crop productivities comparable with Carvalho (1998) results, considered as a standard, were

TABLE 1 Nutrient concentration ranges observed in yellow passion fruit leaves by different research teams in field experiments

Nutrient	Menzel et al. (1993)	Carvalho et al. (2001)	Carvalho et al. (2002)	Alves (2003)
N (g kg^{-1})	42–52	34.7–49.8	34.7–58.0	44.3–53.5
P (g kg^{-1})	1.5–2.5	2.31–3.43	2.31–3.85	2.46–3.25
K (g kg^{-1})	20–30	23.5–35.5	24.1–38.0	18.4–29.3
Ca (g kg^{-1})	17–27	10.6–15.1	6.13–14.4	9.6–13.8
Mg (g kg^{-1})	3–4	2.13–3.62	2.13–4.28	2.68–3.92
S (g kg^{-1})	—	3.19–4.33	3.11–4.64	2.91–4.82
Cl (g kg^{-1})	<20	16.9–28.9	13.1–32.4	14.2–23.2
Fe (mg kg^{-1})	100–200	77–135	77–246	72–162
Mn (mg kg^{-1})	100–500	50.1–91.4	44.4–94.5	74–221
Zn (mg kg^{-1})	50–80	26.1–37.6	21.1–31.8	30.4–39.5
Cu (mg kg^{-1})	5–20	4.53–95.4	4.41–8.47	3.33–4.85
B (mg kg^{-1})	40–60	22.8–54.5	34.1–48.9	22.5–40.7

not observed. This low productivity was probably, among others, due to inadequate management of fertilization, diseases and pollination, in addition to the high precipitation registered during the blooming stage. Due to these observed low productivities, previous results from research with yellow passion fruit in the region and studied in the same phenological stages (Carvalho, 1998) as the 54 crops evaluated in this work, were used to establish the DRIS standards,

Areas considered as standard, according data originated from Carvalho (1998), had always productivity above 33 t ha^{-1} $year^{-1}$ (18 areas with productivity ranging from 33.4 to 46.9 t ha^{-1} $year^{-1}$).

Crops were separated in two classes, according to the productivity: 1) areas with productivity above 20 t ha^{-1} $year^{-1}$ (varying from 20.5 to 33.8 t ha^{-1} $year^{-1}$), and 2) areas with productivity under 10 t ha^{-1} $year^{-1}$ (varying from 6.95 to 9.47 t ha^{-1} $year^{-1}$).

The nutrient concentrations obtained were compared with data from different authors (Table 1) and with the mean concentration values for high productivity used to generate DRIS standards. The concentration and standard deviation of macro and micro-nutrients were determined for three different phenological stages and two productivity levels.

Starting from the concentrations in data bank from Carvalho (1998), DRIS indexes were calculated and the frequency in which DRIS index of each nutrient showed higher positive and negative absolute values, when compared to IENM (index of mean nutritional equilibrium), was determined. The frequency in which the DRIS index, for each nutrient, was more positive or negative into each evaluated plantation was also determined.

DRIS was calculated using the following formula:

$$\text{Index X} = \frac{\{[f(X/Y_1) \pm f(X/Y_2) \pm \cdots \pm [f(Z_1/X) \pm f(Z_2/X) \pm \cdots \pm f(Z_m/X)]\}}{n + m}$$

$$f(X/Y_n) = \left(\frac{X/Y_n}{x/y_n} - 1\right)\frac{100\,k}{CV_{(x/y_n)}} se X/Y_n > x/y_n$$

$$f(Z_m/X) = \left(\frac{Z_m/X}{Z_{zm/}x} - 1\right)\frac{100\,k}{CV_{(x/y_n)}} se Z_m/X > z_m/x$$

$$f(X/Y_n) = \left(1 - \frac{x/y_n}{X/Y_n}\right)\frac{100\,k}{CV_{(x/y_n)}} se X/Yn < x/y_n$$

$$f(Z_m/X) = \left(1 - \frac{z_m/x}{Z_{m/}X}\right)\frac{100\,k}{CV_{(x/y_n)}} se Z_m/X < z_m/x$$

where:

X is the specific nutrient for which the index is calculated;
$Y_1, \ldots, Y_n$ are the nutrients on the denominator of the associations with nutrient X;
$Z_1, \ldots, Z_m$ are the nutrients on the numerator of the associations with nutrient X;
m is the number of functions where the nutrient X appears in the denominator;
n is the number of functions where the nutrient X appears in the numerator; furnish
Zm/X is the ratio between concentration of nutrient Z and X from sample submitted to DRIS;
X/Yn is the ratio between concentration of nutrient X and Y from sample submitted to DRIS;
z_m/x is the mean ratio between concentration of nutrient Z and X, supplied by DRIS standards;
x/y_n is the mean ratio between concentration of nutrient X and Y, supplied by DRIS standards;
$CV_{(z/x)}$ is the variation coefficient of the ratio between z and x, supplied by the DRIS standards;
$CV_{(x/y)}$ is the variation coefficient of the ratio between x and y, supplied by the DRIS standards;
k is the constant of arbitrary value sensibility, defined in this case as a value of 10.

RESULTS AND DISCUSSION

Nutrient concentrations and its respectively standard deviations, sampled in three different phenological stages from standard crops (>33 t ha^{-1} year^{-1}) (Table 2), may represent an adequate range for yellow passion fruit

TABLE 2 Mean content and standard deviation of nutrients in the foliar dry matter from yellow passion fruit crops considered of high productivity, in different phenological stages cultivated in the Northern region of Rio de Janeiro, Brazil

	Sampling period		
Nutrient	Slow fruit and blooming development (May)	Plant growth, intense development blooming and of fruits (October)	Fruit development and harvest (January)
N ($g\ kg^{-1}$)	48.1 ± 1.4	48.9 ± 1.4	39.5 ± 2.5
P ($g\ kg^{-1}$)	3.17 ± 0.23	3.31 ± 0.14	2.81 ± 0.16
K ($g\ kg^{-1}$)	26.3 ± 1.0	24.9 ± 3.1	26.5 ± 2.7
Ca ($g\ kg^{-1}$)	10.2 ± 1.6	8.41 ± 1.5	11.5 ± 1.9
Mg ($g\ kg^{-1}$)	2.31 ± 0.13	2.42 ± 0.24	3.06 ± 0.24
S ($g\ kg^{-1}$)	3.41 ± 0.17	3.56 ± 0.19	3.22 ± 0.31
Cl ($g\ kg^{-1}$)	19.6 ± 3.6	15.2 ± 1.4	23.6 ± 2.3
B ($mg\ kg^{-1}$)	26.9 ± 2.3	20.7 ± 2.7	51.5 ± 8.8
Fe ($mg\ kg^{-1}$)	109 ± 12	87 ± 5	136 ± 14
Mn ($mg\ kg^{-1}$)	66.1 ± 15	51 ± 8	47 ± 10
Zn ($mg\ kg^{-1}$)	26.3 ± 3.1	27.8 ± 1.7	17.6 ± 2.3
Productivity ($t\ ha^{-1}\ year^{-1}$)		36.6 ± 3.5	

Modified from Carvalho (1998).

plants into these stages and were obtained from data collected by Carvalho (1998).

In Table 3 are standards DRIS (mean of ratio and its respective variation coefficient) obtained from a population considered of high productivity, to be used as a reference for nutritional diagnosis of yellow passion fruit in northern Rio de Janeiro, Brazil, in three phenological stages: 1- fruit development and slow blooming and vegetative growth (May—Autumn in Brazil); 2- intense growth, blooming and fruit development (October—Spring in Brazil); and 3- fruit development and harvest (January—Summer in Brazil).

These standards were established as results of research obtained by Carvalho (1998), in field experiments with yellow passion fruit, under similar phenological fluxes to the crops analyzed in present work in May, October and January. According with Bataglia (2004), such a procedure may be used only if the available data is of confidence and originated from experiments in field conditions.

Differences were verified, occurring in two-by-two nutrient ratios, between the different phenological fluxes (Table 3). According with Jones (1993) and Bailey et al. (1997), DRIS was developed to provide a valid diagnosis independently of plant age or plant part sampled. However, according to this experiment results (Table 3), differences were observed in nutrient ratios between the phenological periods analyzed, diverging from Jones (1993) and Bailey et al. (1997) affirmatives.

Consequently, it is possible to verify that the established standards have differences according to the phenological stage of yellow passion fruit plants,

TABLE 3 DRIS standards (norms)—mean (M) and variation coefficient (CV, in%)—proposed for yellow passion fruit in different phenological fluxes in the Northern Rio de Janeiro region, originated from nutrient foliar contents data form Carvalho (1998)

	Norms by sampling period												
	May		October		January			May		October		January	
Ratio	M	CV	M	CV	M	CV	Ratio	M	CV	M	CV	M	CV
N/P	15.2	5.5	14.7	4.2	14.1	6.9	Ca/S	3.0	12.8	2.4	20.4	3.6	20.2
N/K	1.8	5.2	2.0	14.2	1.5	13.4	Cl/Ca	1.9	6.6	1.9	13.9	2.1	9.5
N/Ca	4.8	17.4	6.0	19.9	3.5	19.4	B/Ca	2.7	21.3	2.5	9.7	4.5	11.4
N/Mg	20.9	7.4	20.3	10.7	13.0	11.1	Fe/Ca	10.9	18.6	10.6	16.8	12.1	20.7
N/S	14.2	5.5	13.8	5.9	12.3	7.2	Mn/Ca	6.4	19.6	6.3	27.3	4.1	21.6
N/Cl	2.5	19.6	3.2	11.2	1.7	14.7	Zn/Ca	2.6	9.6	3.4	22.0	2.4	12.7
N/B	1.8	8.2	2.4	13.6	0.8	22.9	Mg/S	0.7	6.6	0.7	9.8	1.0	10.9
Fe/N	2.3	12.2	1.8	5.8	3.4	9.8	Cl/Mg	8.5	17.4	6.4	15.8	7.8	11.6
Mn/N	1.4	24.1	1.0	14.6	1.2	22.7	B/Mg	11.7	10.2	8.7	20.6	16.9	18.2
N/Zn	1.8	12.9	1.8	3.9	1.4	11.6	Fe/Mg	47.1	10.3	36.1	13.1	44.5	9.2
K/P	8.3	8.2	7.5	13.8	9.5	11.7	Mn/Mg	28.4	22.8	21.4	22.3	15.6	25.1
Ca/P	3.2	20.8	2.5	20.9	4.1	19.9	Zn/Mg	11.4	12.7	11.6	12.3	9.1	13.0
Mg/P	0.7	11.3	0.7	9.0	1.1	8.0	Cl/S	5.7	15.6	4.3	12.2	7.4	16.1
S/P	1.1	9.9	1.1	5.8	1.1	9.4	B/S	7.9	9.7	5.8	15.0	16.3	23.5
Cl/P	6.3	23.7	4.6	11.9	8.5	14.0	Fe/S	32.0	12.1	24.4	7.8	42.3	8.5
B/P	8.5	9.7	6.3	15.4	18.5	21.7	Mn/S	19.2	21.6	14.4	17.5	14.8	27.0
Fe/P	34.5	13.9	26.2	8.5	48.4	9.5	Zn/S	7.7	9.9	7.8	8.5	8.7	15.2
Mn/P	20.9	27.3	15.4	16.3	16.9	25.2	B/Cl	1.4	23.5	1.4	11.0	2.2	10.6
Zn/P	8.4	16.9	8.4	6.0	9.9	11.5	Fe/Cl	5.7	20.7	5.7	7.9	5.8	16.2
K/Ca	2.6	17.3	3.0	13.8	2.4	17.1	Mn/Cl	3.3	17.7	3.4	19.5	2.0	19.3
K/Mg	11.4	6.4	10.4	20.5	8.7	13.8	Zn/Cl	1.4	11.4	1.8	12.8	1.2	9.0
K/S	7.7	6.7	7.0	14.4	8.4	18.2	Fe/B	4.1	15.5	4.2	11.4	2.7	24.1
K/Cl	1.4	19.1	1.6	13.1	1.1	12.5	Mn/B	2.5	27.4	2.5	22.2	0.9	20.9
B/K	1.0	9.3	0.8	10.5	2.0	19.7	B/Zn	1.0	16.4	0.7	15.6	1.9	14.1
Fe/K	4.1	13.0	3.5	13.5	5.2	16.6	Mn/Fe	0.6	20.5	0.6	17.0	0.4	27.3
Mn/K	2.5	22.9	2.1	18.2	1.8	23.5	Fe/Zn	4.2	17.3	3.1	7.6	5.0	16.8
Zn/K	1.0	12.6	1.1	16.1	1.0	9.9	Mn/Zn	2.5	19.5	1.8	13.7	1.7	18.4
Ca/Mg	4.4	15.0	3.5	24.8	3.8	15.6							

and that standards established at only one period may not be adequate to access the real nutritional status of the crop. Careful reflection must be considered before affirming that results are independent from age or plant part sampled, when nutritional diagnosis of passiflora is performed trough DRIS method. Evaluating the influence of age or leaf position in the branch of yellow passion fruit, over the nutritional status diagnosis made trough DRIS method, Freitas and Monnerat (2004) concluded that leaf standardization is essential for sampling purposes, not only for DRIS but also for the use of critical levels or sufficiency ranges. The grater the difference of age between the standard leaf (from where the nutrient concentration standards were obtained), and those sampled, the higher will be the nutritional disequilibrium with consequently higher difficulties for a correct diagnosis.

TABLE 4 Mean content and standard deviation of nutrients from passiflora foliar dry matter, under different productivity levels in the Northern Rio de Janeiro region

	Productivity level and sampling period					
	<10 t ha^{-1} year^{-1}			>20 t ha^{-1} year^{-1}		
Nutrient	May	October	January	May	October	January
N (g kg^{-1})	40 ± 6.3	47.8 ± 3.3	37.7 ± 10.8	42.5 ± 4.6	45.7 ± 4.5	43.6 ± 7.4
P (g kg^{-1})	2.5 ± 0.3	2.75 ± 0.15	2.13 ± 0.6	2.6 ± 0.3	2.79 ± 0.11	2.64 ± 0.3
K (g kg^{-1})	22.8 ± 4.3	30 ± 2.1	28.2 ± 5.8	19.7 ± 1.7	26.9 ± 3.17	28.8 ± 6.8
Ca (g kg^{-1})	14.7 ± 4.6	8.8 ± 2	8.87 ± 2.98	15.5 ± 4.6	10.2 ± 1.02	10.9 ± 2
Mg (g kg^{-1})	3 ± 1.1	2.5 ± 0.6	2.16 ± 0.95	3 ± 0.5	2.76 ± 0.23	2.57 ± 0.5
S (g kg^{-1})	3.9 ± 0.8	3.9 ± 0.4	2.83 ± 1.06	4 ± 0.5	4 ± 0.21	3.6 ± 0.8
Cl (g kg^{-1})	25.7 ± 5.1	21.8 ± 1.4	21.8 ± 4.7	23.9 ± 6.5	19.9 ± 2.8	26.3 ± 1.6
B (mg kg^{-1})	41.5 ± 8.1	26.8 ± 2.3	30.7 ± 2.5	34.3 ± 7.9	28.1 ± 2.2	31 ± 3.5
Fe (mg kg^{-1})	119 ± 13.3	101 ± 14.3	70.4 ± 10.7	101 ± 13.8	105 ± 4.4	74.8 ± 7.9
Mn (mg kg^{-1})	67.9 ± 21.7	49.4 ± 14.8	55.9 ± 35.5	78.8 ± 22	65.8 ± 16.9	105 ± 49
Zn (mg kg^{-1})	28 ± 3.5	28.8 ± 4.1	27.2 ± 6.8	28.8 ± 3.7	34.8 ± 4.5	38.6 ± 8.5
Productivity (t ha^{-1} year^{-1})		8.59 ± 1.07			23.7 ± 4.27	

In a general way, considering the standard deviation, the mean concentration of nutrients, did not differed between low and medium productivity levels into the same phenological period (Table 4).

Phosphorus had the most negative DRIS index, superior in absolute value to IENM (index of mean nutritional equilibrium), on both levels of productivity in October (Table 5). In general, when observing mean content of P (Table 4) an compared with this nutrient contents in the standard crop in the same period (Table 2), it is possible to verify that this nutrient contents are lower than in the standard crop, but into the range considered adequate by Menzel et al. (1993), Carvalho et al. (2001, 2002), and Alves (2003), thus differentiating results obtained by DRIS method in the studied region, from the ranges considered as adequate for phosphorus by many authors.

Potassium had the most negative DRIS index (Table 5), and the higher, in absolute value, compared to IENM in May for both productivity levels, with K contents in the medium productivity crops (Table 4), at lower values than contents found on the standard crop (26.3 ± 1 g kg^{-1}). Mean contents of this nutrient at low productivity crops (<10 t ha^{-1} year^{-1}), are in agreement with the observed mean values for the areas considered as standard (Table 2), inside the adequate range.

For the medium productivity crops (Table 4), K contents were lower than those found by Carvalho et al. (2001, 2002) and may be limiting productivity. In October and January (Table 5) it was observed that K was not the most negative value, due to the crops being fertilized with this nutrient during these periods. Santos et al. (2004), establishing DRIS standards for the nutritional diagnosis of dwarf coconut, observed that the less productive

TABLE 5 Nutritional Limiting Order (NLO), from yellow passion fruit crops, in two productivity levels and different phenological stages in the Northern Rio de Janeiro region

Crop	May	October	January
		NLO from low productivity crops (<10 t ha^{-1} year^{-1})	
19	N>P	P>Ca>Mg	Mg>Fe
20	N>P	P>Mn	Mg>Fe
21	N>P	P>Mn	Fe>Mg
23	N>P>K	P>Zn	Fe>B
24	P>N>K	P>Mn	Fe>P>Mg
30	K>P>Zn	P>N	Fe>B
39	K>Zn	P>Zn	Fe>K
		NLO from medium productivity crops (>20 t ha^{-1} year^{-1})	
6	K>P>N	P>N	Fe>B>Mg
9	K>P>Fe	P>N	Fe>B
12	N>K>P	N>P	Fe>B>Mg
14	K>P	P>N>K	Fe>B
16	K>P>N	P>N	Fe>B
29	K	P>N	B>Fe>Mg
37	K>N>P	P>Mn>N	Fe>B
45	K>B	P	Fe>B

crops had lower K contents and lower K DRIS indexes. Nitrogen was also a nutrient with the most negative index in the majority of crops with a productivity under 10 t ha^{-1} year^{-1} in May (Table 5), with mean content (40 ± 6.3 g kg^{-1}) under the standard crop contents (48.1 ± 1.4 g kg^{-1}), but still inside a range considered adequate by Carvalho et al. (2001, 2002) and Alves (2003) for the northern Rio de Janeiro region.

Iron had the most negative index and higher in absolute value than IENM, in almost all the crops of medium productivity and in five crops of low productivity in January (Table 5). Contents from low and medium productivity levels (Table 4), were lower than the contents observed in the standard crop for Fe (Table 2). Iron contents in the low and medium productivity level crops, were under the range considered adequate by Menzel et al. (1993), but inside the range considered adequate for the whole culture cycle by Carvalho et al. (2001, 2002) and Alves (2003), in the same geographical region.

In October, in areas considered of medium productivity, nitrogen was the second most negative value in the majority of crops, however its content of 45.7 ± 4.5 g kg^{-1} (Table 5), is inside the range observed in standard crops (48.9 ± 1.4 g kg^{-1}) for the same phenological stage (Table 2). The obtained results are in agreed with other authors findings (Table 1), thus indicating that the observed contents are probably not limiting productivity.

There were differences for the nutritional limiting order (NLO) between the time periods analyzed into each productivity level; however, when comparing the two levels of productivity, it is clear that nutrients having the most negative DRIS indexes (thus probably limiting productivity), were P and Fe in the majority of crops during October and January, respectively, with N being the second most negative nutrient on medium productivity crops in October, and B in January. During May, K was the most negative DRIS index in medium productivity crops, and may be also limiting productivity. Nitrogen was the most negative in four crops with productivity under 10 t ha^{-1} $year^{-1}$ during the same period (Table 5).

Probably the small NLO variation, when comparing the low with the medium productivity level of yellow passion fruit crops, inside each phenological flux, may be due to the high mean productivity from the standard crop if compared with the productivity of crops under evaluation, almost not differentiating diagnosis for the medium and low productivity in relation to NLO. The reason for this small difference may be, at least in part, due to non nutritional causes as climatic factors, diseases, pests, pollination and others that limit production.

While studding DRIS standards and adequate leaf nutrient concentrations for coffee in the Southern region of Minas Gerais, Brazil, Reis Júnior et al. (2002) established that potassium was one of the most negative nutrients. Costa (1995), while studding the use of DRIS for the evaluation of the nutritional status of papaw, observed that the higher nutritional limitations, due to macro-nutrient deficiency in low productivity crops, were for P, K and Ca on the dry season and for Ca and Mg during the rainy season.

When considering the negative signal of DRIS index calculated on each one of the 54 crop areas, it was notice that during May, K had a negative index in 87% of the crops, P in 53.7%, and N in 42.6% of the crop areas, being these the nutrients having the higher frequencies of negative indexes and higher, in absolute value, to IENM. When considering which nutrient, inside each crop, had the most negative index, thus may being the most limiting one, K is at the top in 66.7% of the crop areas. This suggests that limitation by this nutrient is higher than limitation due to phosphorus and nitrogen (Table 6).

Still in samples from May, Mg in 68.5 and Ca in 53.7% of the crop areas, appeared as the nutrients having higher frequency of positive indexes and higher to IENM in absolute value. This more positive indexes on Mg and Ca during May, approximately six months after plantation, may be due to the application of calcareous performed at the beginning of the plantation implementation and formation of the crops evaluated (Table 6).

Phosphorus was the nutrient having a negative index and higher to IENM in absolute value, in 100% of the sampled crop areas and nitrogen in 59.3% in October (Table 6), with P having showed the most negative index in 88.9% of the crop areas and N just in 7.4%. Thus, P would be the most limiting nutrient to productivity during this period. Chlorine, in 74.1% of crop areas, had a positive index and higher to IENM in absolute value, being the most positive in 37% of crops (Table 6).

TABLE 6 Number and frequency of samples with negative (ID−) and positive (ID+) DRIS indexes, higher in absolute value to IENM, and number and frequency of samples with minor (<ID) or major (>ID) DRIS index into each sample among 54 yellow passion fruit crops, in different phenological stages

	IN	IP	IK	ICa	IMg	IS	ICl	IB	IFe	IMn	IZn
					May 2003						
ID−	23.0	29.0	47.0	4.0	—	1.0	1.0	5.0	2.0	3.0	10.0
%	42.6	53.7	87.0	7.4	—	1.8	1.8	9.3	3.7	5.5	18.5
ID+	—	—	—	29.0	37.0	9.0	4.0	22.0	2.0	9.0	3.0
%	—	—	—	53.7	68.5	16.7	7.4	40.7	3.7	16.7	5.5
<ID	13.0	9.0	36.0	1.0	—	—	—	—	—	1.0	—
%	24.1	16.7	66.7	1.9	—	—	—	—	—	1.9	—
>ID	—	—	—	9.0	18.0	2.0	—	16.0	—	6.0	—
%	—	—	—	16.7	33.3	3.7	—	29.6	—	11.1	—
					October 2003						
ID−	32.0	54.0	13.0	2.0	3.0	—	—	—	—	9.0	13.0
%	59.3	100.0	24.1	3.7	5.5	—	—	—	—	16.7	24.1
ID+	—	—	10.0	1.0	10.0	5.0	40.0	20.0	22.0	14.0	17.0
%	—	—	18.5	1.8	18.5	9.3	74.1	37.0	40.7	25.9	31.5
<ID	4.0	48.0	—	—	—	—	—	—	—	2.0	—
%	7.4	88.9	—	—	—	—	—	—	—	3.7	—
>ID	—	—	—	—	2.0	1.0	20.0	7.0	8.0	8.0	8.0
%	—	—	—	—	3.7	1.9	37.0	13.0	14.8	14.8	14.8
					January 2004						
ID−	—	2.0	17.0	2.0	20.0	—	—	46.0	54.0	—	—
%	—	3.7	31.5	3.7	37.0	—	—	85.2	100.0	—	—
ID+	15.0	—	15.0	1.0	5.0	13.0	13.0	—	—	38.0	31.0
%	27.8–	27.8	1.8	9.3	24.1	24.1	—	—	70.4	57.4	
<ID	—	—	1.0	—	2.0	—	—	8.0	43.0	—	—
%	—	—	1.9	—	3.7	—	—	14.8	79.6	—	—
>ID	1.0	—	11.0	—	—	1.0	1.0	—	—	31.0	7.0
%	1.9	—	20.4	—	—	1.9	1.9	—	—	57.4	12.9

In the analysis performed in January, Fe was noticed as the nutrient having negative index and higher to IENM in absolute value, in 100% of the crops, and the most negative in 79.6%, suggesting that this nutrient would be limiting productivity during this period. Boron also had negative DRIS index and higher to IENM in absolute value in 85.2% of the crops, however only in 14.8% of the crops it was the nutrient with the most negative index (Table 6).

CONCLUSIONS

In a general way, mean nutrient content did not differed between the two productivity levels into each phenological stage. There were differences for the nutritional limitation order between the phenological stages of the crop. Potassium in May, phosphorus in October, and iron in January were the nutrients having most negative DRIS indexes and higher, in absolute value, to Mean Nutritional Equilibrium Index in the Northern region of Rio de Janeiro, Brazil.

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