Communications in Soil Science and Plant Analysis
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lcss20

DRIS Norms for Pêra Orange

Amanda Hernandes[a], Henrique Antunes de Souza[b], Daniel Angelucci de Amorim[a], William Natale[a], José Lavres Jr.[c], Antonio Enedi Boaretto[c] & Marcos Antonio Camacho[d]

[a] Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal, Brazil

[b] Empresa Brasileira de Pesquisa Agropecuária/CNPC, Estrada Sobral/Groaíras, Sobral, Brazil

[c] Centro de Energia Nuclear na Agricultura (CENA/USP), Piracicaba, Brazil

[d] Universidade Estadual de Mato Grosso do Sul, Rodovia Aquidauana/Piraputanga, Aquidauana, Brazil
Published online: 10 Nov 2014.

To cite this article: Amanda Hernandes, Henrique Antunes de Souza, Daniel Angelucci de Amorim, William Natale, José Lavres Jr., Antonio Enedi Boaretto & Marcos Antonio Camacho (2014) DRIS Norms for Pêra Orange, Communications in Soil Science and Plant Analysis, 45:22, 2853-2867, DOI: 10.1080/00103624.2014.956933

To link to this article: http://dx.doi.org/10.1080/00103624.2014.956933

Communications in Soil Science and Plant Analysis, 45:2853–2867, 2014

ISSN: 0010-3624 print / 1532-2416 online
DOI: 10.1080/00103624.2014.956933

DRIS Norms for Pêra Orange

AMANDA HERNANDES,[1] HENRIQUE ANTUNES DE SOUZA,[2] DANIEL ANGELUCCI DE AMORIM,[1] WILLIAM NATALE,[1] JOSÉ LAVRES JR.,[3] ANTONIO ENEDI BOARETTO,[3] AND MARCOS ANTONIO CAMACHO[4]

[1]Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal, Brazil
[2]Empresa Brasileira de Pesquisa Agropecuária/CNPC, Estrada Sobral/Groaíras, Sobral, Brazil
[3]Centro de Energia Nuclear na Agricultura (CENA/USP), Piracicaba, Brazil
[4]Universidade Estadual de Mato Grosso do Sul, Rodovia Aquidauana/ Piraputanga, Aquidauana, Brazil

Chemical analysis of leaves is an effective tool for detecting nutritional imbalances and providing data for fertilizer recommendations. Therefore, it is extremely important to establish criteria for interpreting these results. The DRIS (Diagnosis and Recommendation Integrated System) method is an alternative to the interpretation of results of leaf analysis as it allows the calculation of indexes for each nutrient, using its relations with others and comparing them with a reference population. Thus, we aimed to establish preliminary DRIS norms, by both Beaufils's and Jones's methods, and to derive critical levels and nutrient sufficiency ranges in the leaf tissue for Pêra orange, by studying a commercial crop in the growing conditions of the São Paulo state. The methods (Beaufils and Jones) differed in the limiting nutrients in the Pêra orange orchard. The use of regional norms must be prioritized because of differences between the management methods applied. In the methods used, the nutrients that had a greater number of concordant cases in decreasing order: Mn > Mg > B > N > Cu > Fe > Zn > K > P > Ca. Amplitudes related to the DRIS methods used were narrower than the conventional literature.

Keywords *Citrus sinensis* L. Osbeck, nutritional assessment, nutritional diagnosis

Introduction

The orange production in Brazil is about 18.3 million tons in an area of 830,000 ha, with average yield of about 22 tons per hectare (IBGE 2010), which is low, mainly due to the nutritional management culture.

In orange trees, the chemical analysis of leaves, in addition to assessing the nutritional status of culture, is employed to establish the recommendations for nitrogen (N) fertilization. Marschner (1995) emphasizes that for fruits the leaf analysis becomes even more useful than soil analysis.

Received 27 March 2012; accepted 30 May 2014.
Address correspondence to Marcos Antonio Camacho, Universidade Estadual de Mato Grosso do Sul, Rodovia Aquidauana/Piraputanga, km 12. CP 25, CEP 79 200-000, Aquidauana, MS, Brazil. E-mail: camacho@uems.br

The usual methods for interpretation of chemical analysis in leaves are performed from the comparison of nutrient concentrations diagnosed with reference values such as the critical level (CL) or sufficiency ranges (SR), characterized by the independence of nutrients. Thus, the level of a nutrient does not affect the classification of others, but has the serious limitation of not identifying which nutrients are most limiting (Trani, Hiroce, and Bataglia 1983; Raij et al. 1997; Martinez, Carvalho, and Souza 1999). The DRIS method (Diagnosis and Recommendation Integrated System) is an alternative to the interpretation of results of leaf analysis, because the method allows the calculation of indexes for each nutrient, using its relations with others and comparing them with a population reference (Beaufils 1973), instead of the absolute and isolated concentration from each one.

The DRIS index is nothing else than the average of the deviations of relationships containing a nutrient in relation to their optimal values. Each relationship between nutrients in the population of high productivity is a DRIS norm and has their respective mean and standard deviation.

The index of nutrients in a sample can vary from positive to negative, but the sum of these indexes will always be equal to zero. The sum of the absolute values of these indexes is the nutrient balance index (NBI), expressing the nutritional balance of the crop sampled. Lower NBI represents a lower nutrient imbalance.

This work proposes preliminary DRIS norms and derives critical levels and sufficiency ranges of nutrients in the leaf tissue of Pêra orange in growing conditions of the São Paulo State, Brazil.

Material and Methods

The nutritional monitoring of Pêra orange (*Citrus sinensis* L. Osbeck), grafted on Cleopatra tangerine (*Citrus reshni* Hort. ex tan), was done from 50 leaf samples, from a 15-year-old orchard with 7 × 5 m spacing, in the city of Bebedouro, SP, in the Estação Experimental de Citros de Bebedouro (EECB). The soil of the area is a typical Oxisol, medium texture, A moderate, alic (Hapluxtox) (Silva et al. 2007).

The leaf samples were taken at 7, 18, and 30 months after the liming application, done in July 1999. We evaluated foliar concentrations of N, P, K, Ca, Mg, B, Cu, Fe, Mn and Zn. The samples were dried in a dryer with forced-air circulation (65 ± 5 °C) and, after drying, they were crushed and chemical nutrients were determined, according to methods reported in Silva et al. (2009). The information used to form the database and develop DRIS was the total content of nutrients (g kg^{-1} and mg kg^{-1}) in the leaves and the yield of oranges, assessed for the 2000–2001 and 2001–2002 harvests.

For the establishment of DRIS norms, the database was divided into two subpopulations: one with good productivity (or the reference population) and other with poor productivity. The population with good productivity was established from productivities that were greater than the average productivity of the areas plus their standard deviation (m + s), which in this case would be approximately more than 56.47 tons per hectare.

The mean, variance, and coefficient of variation were calculated for the reference group or good and poor productivity, using direct and inverse relations. In the calculations of the DRIS method, only one type of expression is used to relate each pair of nutrients. Thus, as we expected that the relations would have a normal distribution (Beaufils 1973), we conducted the normality test (Shapiro Wilk) for the choice of the relationships between nutrients.

To calculate the functions of the ratio of nutrients, we used two methods: the original method proposed by Beaufils (1973) and the method of physiological diagnosis, proposed by Beaulfils (1971), with the simplified formula by Jones (1981). The choice of methods was due to their utilization, because these two methods are the most applied to the establishment of DRIS norms.

Beaufils (1973)

The function of the relationship of nutrients calculated by Beaufils (1973) is given by the following equations:

$$\text{If } A/B_a < A/B_r:\ f(A/B) = \left\{1 - \left[(A/B_r) \times (A/B_a)^{-1}\right]\right\} \times (100 \times k) \times (cv)^{-1}$$

$$\text{If } A/B_a = A/B_r:\ f\,(A/B) = 0$$

$$\text{If } A/B_a > A/B_r:\ f\,(A/B) = \left\{\left[(A/B_a) \times (A/B_r)^{-1}\right] - 1\right\} \times (100 \times k) \times (cv)^{-1}$$

where A/B is the relation to each two nutrients, A/B_a is the relation to each two nutrients for the sample that you want to evaluate, A/B_r is the relation to each two nutrients of the reference population, k is the constant sensitivity, and cv is the coefficient of variation of the reference population.

Jones (1981)

The function of the relationship of nutrients proposed by Jones (1981) was calculated from the following equation:

$$f(A/B) = \left[(A/B_a) - (A/B_r)\right] \times (k/s)$$

where A/B is the relation to each two nutrients, A/B_a is the relation to each two nutrients for the sample that you want to evaluate, A/B_r is the relation to each two nutrients of the reference population, k is the constant sensitivity, and s is the standard deviation of the reference population.

The value of $k = 1$ was used in the calculation of the two proposed methods.

For the calculation of DRIS indexes, it was applied the general formula proposed by Beaufils (1973), being for a nutrient Y:

$$IY = \frac{\sum_{i=1}^{n} f\left(\frac{Y}{X_i}\right) - \sum_{j=1}^{m} f\left(\frac{X_j}{Y}\right)}{n+m}$$

The nutrient balance index (NBI) was calculated by adding the absolute values obtained for each nutrient:

$$NBI = |IN| + |IP| + |IK| + |ICa| + |IMg| + |IB| + |ICu| + |IFe| + |IMn| + |IZn|$$

The mean nutritional balance index (NBI_m) was calculated by adding the absolute values obtained for each nutrient and dividing it by the total number of nutrients (n) (Wadt et al. 1998):

$$NBI_m = (|IN| + |IP| + |IK| + |ICa| + |IMg| + |IB| + |ICu| + |IFe| + |IMn| + |IZn|) \times n^{-1}$$

The interpretation of DRIS indexes by Jones and Beaufils was performed with the nutrients classified according to the potential response to fertilization (PRF) (Wadt et al. 1998). For greater synthesis, the classes of potential positive response (*p*) and positive or zero (*pz*) and also negative (*n*) and negative or zero (*nz*) were grouped and denominated limiting by deficiency (LD) or excess (LE). The class of null response (*z*) has been named nonlimiting (NL), according to Silva et al. (2005).

For Jones and Beaufils methods, the hypothesis that the frequency with which each nutrient occurred as the primary limiting nutrient by deficiency (i.e., with potential of positive response to fertilization and with high probability) has been attributed to the random. For this, we used the chi-square adjustment test (Silva et al. 2005), at 5% probability, with $n - 1$ degrees of freedom (n = number of analyzed nutrients).

The nutrient that presented the negative index of lower value in relation to indexes of other nutrients, and higher in absolute value than the mean nutritional balance index (NBI_m), was considered the primary limiting nutrient by deficiency. If true, the frequencies observed for all nutrients would be statistically equal. The expected (EF) and observed frequencies (OF) were calculated as follows (Urano et al. 2006):

$$EF\ (\%) = \left[\frac{\left(\frac{total\ number\ of\ plots\ evaluated}{number\ of\ nutrients\ evaluated} \right)}{(total\ number\ of\ plots\ evaluated)} \right] \times 1000$$

$$OF\ (\%) = \left(\frac{number\ of\ plots\ in\ which\ the\ nutrient\ was\ (p)}{total\ number\ of\ plots\ evaluated} \right) \times 100$$

To establish the optimal levels (or critical level, CL) of each nutrient, the relationship of each nutrient with their respective nutrient balance index was trraced. Thus, the excellent foliar concentrations of N, P, K, Ca, Mg, B, Cu, Fe, Mn and Zn for Pêra orange were obtained, equaling zero in all the indexes in the equation ($y = ax + b = 0$), because, theoretically, when all these indexes tends to zero, there is the optimal condition of the plant's nutritional balance. The analysis of relationship between nutrient content and DRIS index were performed using the software SISVAR (Ferreira 2008).

The upper and lower limits of normal range of nutrient concentrations by the method of Jones and Beaufils were determined in a similar way to that used by Urano et al. (2007), which consisted of equalizing statistical models of the relationship of the nutrient content and the DRIS indexes to zero and $\pm 2/3$ of the standard deviation.

Results and Discussion

From 50 samples analyzed, seven were considered good productivity or reference subpopulation (mean ± standard deviation), totaling 14% of the population. The remainder (86%) was considered the subpopulation of poor productivity.

Relations were chosen according to the normality, and in 82% the distribution was normal, so we did not opt for the transformation of the natural logarithm, as recommended by Urano et al. (2006). Thus, the relationships chosen were those that showed normal distribution, whose norms are presented in Table 1.

Table 1
Mean and standard deviation of the relations chosen in the subpopulation of good productivity

Relation	Norm (x)	Standard deviation
N/K	2.9898	0.5795
N/Fe	0.3555	0.1352
N/Mn	0.5550	0.0672
N/B	0.7322	0.1566
N/Cu	4.2024	1.4575
P/N	0.0354	0.0089
P/Mg	0.1521	0.0570
P/B	0.0268	0.0109
P/Cu	0.1385	0.0262
K/P	10.5647	4.2798
K/Ca	0.2592	0.0543
K/Mg	1.4341	0.2561
K/Fe	0.1151	0.0305
K/B	0.2467	0.0350
K/Cu	1.4881	0.7085
Ca/N	1.3465	0.1448
Ca/P	41.0855	14.4239
Ca/Mg	5.5846	0.4670
Ca/Fe	0.4724	0.1773
Ca/Mn	0.7494	0.1340
Ca/Cu	5.7858	2.4139
Mg/N	0.2428	0.0344
Mg/Fe	0.0833	0.0280
Mg/Mn	0.1348	0.0256
Mg/Cu	1.0497	0.4626
Fe/P	109.6730	82.5322
Mn/P	54.0953	13.3159
Mn/K	5.4399	1.1071
Mn/Fe	0.6498	0.2520
Mn/B	1.3322	0.2994
Zn/N	0.951	0.173
Zn/P	27.485	3.758
Zn/K	2.855	0.791
Zn/Ca	0.718	0.172
Zn/Mg	4.008	0.995
Zn/Fe	0.3434	0.1513
Zn/Mn	0.5218	0.0766
Zn/B	0.7071	0.2271
Zn/Cu	3.8410	1.0611
B/Ca	1.0541	0.1756
B/Mg	5.8454	0.8358
B/Fe	0.4779	0.1522
Cu/Fe	0.1011	0.0595
Cu/Mn	0.1464	0.0495
Cu/B	0.2061	0.1083

Both the diagnoses performed by the methods of Jones and Beaufils rejected the hypothesis that the frequencies of diagnoses observed for all nutrients were statistically equal, indicating that the methods were sensitive to diagnosing differences in probability of positive response to fertilization, that is, with deficiency, for the nutrients evaluated (Table 2). Similar results were also obtained by Urano et al. (2006).

Table 3 shows the potential response to fertilization for the two methods, it appears that the diagnoses are different for the two methods worked. Differences between the methods of calculation of DRIS indices produced different values, which can lead to different interpretations of the same sample. The nutrient with the greatest response to fertilization when working by the method of Jones is the P, followed by B and Mn, respectively. When evaluating the potential for fertilization with a high probability of response by the method of Beaufils, nutrients with greater response, in decreasing order, are Mn > B > N > P = Cu > K, respectively. Therefore, it is observed that there were marked differences as to the greater nutrient deficiency between the two methods. As for the nutrients that are in excess or low response to fertilization, by the method of Jones would be, in descending order, Cu > Zn > Mg > Mn > B = K = N, because by the Beaufils method would be Fe > Cu > Mg > Zn > B = P.

In general we can say that there were more cases with null response, or orchards would have adequate levels when using the method of Jones. However, this fact depends on the nutrient in question, so that by Beaufils's method more cases of imbalance were diagnosed. Alvarez and Leite (1999), in a mathematical proof, claim that the use of Beaufils's formula exaggerates the effect of excess or deficiency of the nutrient.

Table 2

Calculation of chi-square for the observed frequencies (%) of N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B as the primary limiting nutrient deficiency,[a] by the method of Jones and Beaufils, on the assumption that the observed frequencies are the result of chance, in leaf samples collected in orchards of Pêra orange, in the subpopulation of poor productivity[b]

	(DRIS Jones)			(DRIS Beaufils)		
Nutrient	OF[c]	EF[c]	(OF – EF)/EF[c]	OF[c]	EF[c]	OF – EF/EF[c]
N	2.3	10	−1.3	14.0	10	2.5
P	93.0	10	0.1	27.9	10	0.6
K	7.0	10	−3.3	16.3	10	1.6
Ca	0.0	10	−1.0	7.0	10	−3.3
Mg	2.3	10	−1.3	2.3	10	−1.3
Fe	0.0	10	−1.0	0.0	10	−1.0
Mn	51.2	10	0.2	55.8	10	0.2
Zn	0.0	10	−1.0	14.0	10	2.5
B	37.2	10	0.4	39.5	10	0.3
Cu	4.7	10	−1.9	11.6	10	6.1
Chi-square			978.3**			353.3**

[a]With the potential positive response to fertilization and most likely (p) as Wadt et al. (1998). [b]Less than the average + standard deviation.

[c]OF and EF correspond to the observed and expected frequencies, respectively.

$^{**}P < 0.01$.

Table 3

Frequency (%) of the potential responses to N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B fertilizer, determined by the methods of Jones and Beaufils, in leaf samples collected in orchards of Pêra orange, in subpopulation of poor productivity[a]

		Potential response to fertilization[b]				
Nutrient	Method	p	pz	z	nz	n
N	DRIS Jones	0	1	38	3	1
	DRIS Beaufils	6	0	36	1	0
P	DRIS Jones	27	13	3	0	0
	DRIS Beaufils	3	9	20	10	1
K	DRIS Jones	0	3	39	0	1
	DRIS Beaufils	1	6	31	5	0
Ca	DRIS Jones	0	0	43	0	0
	DRIS Beaufils	0	3	38	2	0
Mg	DRIS Jones	0	1	35	2	5
	DRIS Beaufils	0	1	28	8	6
Fe	DRIS Jones	0	0	42	0	1
	DRIS Beaufils	0	0	21	3	19
Mn	DRIS Jones	6	16	16	1	4
	DRIS Beaufils	17	7	15	1	3
Zn	DRIS Jones	0	0	35	2	6
	DRIS Beaufils	2	4	29	4	4
B	DRIS Jones	10	6	26	0	1
	DRIS Beaufils	11	6	23	2	1
Cu	DRIS Jones	0	2	29	4	8
	DRIS Beaufils	3	2	20	9	9

[a]Less than the average + standard deviation.

[b]p, positive, with high probability; pz, positive, with low probability; z, null; nz, negative, with low probability; n, negative, with high probability, as in Wadt et al. (1998).

Considering the class of nutritional status (Silva et al. 2005), for comparison between the methods used, it appears that the nutrients that had a greater number of concordant cases in decreasing order were Mn > Mg > B > N > Cu > Fe > Zn > K > P > Ca and that most of the concordant diagnoses were related when assessing the nonlimiting nutrient, followed when assessing the limiting nutrients for deficiency and then limiting by excess (Table 4).

In a study whose objective was to generate norms for DRIS Pêra orange grafted on Cravo lime in the central region of State of Goias, Brazil, Santana et al. (2008) evaluated a database with 303 leaf samples of macro- and micronutrients. The reference population was formed by samples with greater productivity than 22 t ha^{-1}. Taking advantage of the norms generated by the authors, we diagnosed the poor-yield subpopulation of this study by two methods (Jones and Beaufils) (Table 5).

However, through the classes of nutritional status, we also performed comparisons between the diagnoses generated by the norms of this study with the published norms of Santana et al. (2008) (Table 6).

In assessing the nutritional diagnosis by the method of Jones using the norms of Santana et al. (2008), we observed that most of the frequencies were associated with

Table 4

Frequency (%) of concordant diagnostic for assessment of nutritional status of N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B determined by the methods of Jones and Beaufils, in leaf samples collected in the orchard of Pêra orange, in the subpopulation of poor productivity[a]

Nutrient	LD[b]	NL[b]	LE[b]	%
N	16.7	100.0	100.0	72.2
P	100.0	15.0	0.0	38.3
K	42.9	100.0	20.0	54.3
Ca	0.0	100.0	0.0	33.3
Mg	100.0	100.0	50.0	83.3
Fe	100.0	100.0	4.5	68.2
Mn	91.7	100.0	100.0	97.2
Zn	0.0	100.0	100.0	66.7
B	94.1	100.0	33.3	75.8
Cu	40.0	100.0	66.7	68.9

[a]Less than the average + standard deviation.
[b]LD, limiting by deficiency; NL, not limiting; LE, limiting by excess.

Table 5

Frequency (%) of diagnosis of the nutritional status of N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B determined by the methods of Jones and Beaufils, using the norms generated by Santana et al. (2008) in leaf samples collected in orchards of Pêra orange, in the subpopulation of poor productivity of this study[a]

Jones	LD	NL	LE	Beaufils	LD	NL	LE
N	0.0	2.3	97.7	N	0.0	2.3	97.7
P	0.0	100.0	0.0	P	0.0	100.0	0.0
K	0.0	83.7	16.3	K	0.0	67.4	32.6
Ca	0.0	46.5	53.5	Ca	0.0	69.8	30.2
Mg	0.0	0.0	100.0	Mg	0.0	0.0	100.0
Fe	100.0	0.0	0.0	Fe	83.7	16.3	0.0
Mn	0.0	100.0	0.0	Mn	16.3	83.7	0.0
Zn	0.0	100.0	0.0	Zn	23.3	76.7	0.0
B	0.0	100.0	0.0	B	2.3	97.7	0.0
Cu	100.0	0.0	0.0	Cu	65.1	34.9	0.0

[a]Less than the average + standard deviation.
[b]LD, limiting by deficiency; NL, not limiting; LE, limiting by excess.

nonlimiting nutrient class, which was also observed when using the method of Beaufils. Among the limiting nutrient deficiencies we can mention the Fe and Cu by Jones (100%), and for Beaufils they were in the following order: Fe > Cu > Zn > Mn > B. By Jones's method, there was also a greater number of cases in the not-limiting response class, because the method of Beaufils detected greater frequency of cases with excess of nutrients (Table 5).

Table 6

Frequency (%) of concordant diagnostic for assessment of nutritional status of N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B determined by the methods of Jones and Beaufils, among the norms generated in this study and the norms generated by Santana et al. (2008), in leaf samples collected in orchards of Pêra orange, in the subpopulation of poor productivity[a]

Nutrient	Method	LD[b]	NL[b]	LE[b]	%
N	DRIS Jones	0.0	2.6	100.0	34.21
	DRIS Beaufils	0.0	2.6	100.0	34.21
P	DRIS Jones	0.0	100.0	100.0	66.67
	DRIS Beaufils	0.0	100.0	0.0	33.33
K	DRIS Jones	0.0	92.3	100.0	64.10
	DRIS Beaufils	0.0	93.5	100.0	64.52
Ca	DRIS Jones	100.0	46.5	100.0	82.17
	DRIS Beaufils	0.0	78.9	100.0	59.65
Mg	DRIS Jones	0.0	0.0	100.0	33.33
	DRIS Beaufils	0.0	0.0	100.0	33.33
Fe	DRIS Jones	100.0	0.0	0.0	33.33
	DRIS Beaufils	100.0	33.3	0.0	44.44
Mn	DRIS Jones	0.0	100.0	0.0	33.33
	DRIS Beaufils	29.2	100.0	0.0	43.06
Zn	DRIS Jones	100.0	100.0	0.0	66.67
	DRIS Beaufils	100.0	100.0	0.0	66.67
B	DRIS Jones	0.0	100.0	0.0	33.33
	DRIS Beaufils	5.9	100.0	0.0	35.29
Cu	DRIS Jones	100.0	0.0	0.0	33.33
	DRIS Beaufils	100.0	75.0	0.0	58.33
	%	36.75	61.25	45.00	

[a]Less than the average + standard deviation.
[b]LD, limiting by deficiency; NL, not limiting; LE, limiting by excess.

The greatest number of concordant diagnoses, independent of the method used, was for the class of nonlimiting nutrient, followed by limiting by excess and then by limiting by deficiency. Among the methods, the Beaufils method was closer to concordant diagnoses than Jones's method (Table 6). Because of greater productivity worked on the norms generated in this study (Table 1), when compared with the diagnosis, independent of the method of calculation used, the macronutrients were found as limiting by excess by the norms of Santana et al. (2008). There are several factors that may be related to this difference in production, such as the rootstock used, the environmental conditions of each region, and the presence of irrigation, among others. Mourão Filho, Azevedo, and Nick (2002) verified the influence of rootstock on the production and concluded that the fact that the population of Valencia orange trees has been selected in a region of irrigation and classified according to the rootstock has benefited the isolation of these factors. Rodriguez, Rojas, and Sumner (1997), in the definition of DRIS norms in relation to Valencia orange in Venezuela, found no difference or influence of the rootstocks in Volkameriano tangerine and Cleopatra lemon. However, the influence of rootstock on the mineral composition of leaves of Valencia orange is already known and was investigated (Wutscher 1982).

The DRIS was designed to make the interpretation less dependent on variations of sampling with respect to the age and origin of plant tissue, allowing a ranking of limiting nutrients to the growth and emphasizing the importance of nutritional balance of plant (Beaufils 1973), allowing the universal use of DRIS norms. But the universal use of DRIS norms is questionable (Hallmark and Beverly 1991), because differences between norms generated from different populations and local have been found, showing that the DRIS norms are not entirely independent of local conditions or times of sampling (Reis and Monnerat 2002).

The concentration of mobile elements in the leaf decreases with age, whereas the concentration of immobile elements increases, so the relationship between a mobile and an immobile nutrient could not be kept constant along time. This fact brings down one of the premises for the use of DRIS at any sampling time (Reis and Monnerat 2002). In this way, it is suspected that this universality attributed to DRIS norms may be responsible for failure of diagnosis found with this method (Reis and Monnerat 2002).

When comparing the methods of Jones and Beaufils, it appears that the NBI values obtained by the method of Jones had a greater adjustment value of the linear equation when related to productivity (Figure 1) than the NBI values obtained by the method of Beaufils (Figure 2). These calculated values are still low, indicating that other factors must be more strongly related to productivity change.

Mourão Filho, Azevedo, and Nick (2002), to establish DRIS norms for irrigated orchards of Valencia orange on three rootstocks, obtained similar results. The same authors assert that among the three procedures to calculate DRIS indices, tha is, the original method proposed by Beaufils (1973), the method of Beaufils (1973) modified by Elwali and Gascho (1984), and the method of Beaufils (1971) simplified by Jones (1981), the latter showed the most advantages, confirming results obtained by Santos (1997).

Regression equations were adjusted to the relationships between nutrient contents in leaves of Pêra orange and DRIS indices, using the application SISVAR (Ferreira 2008). Linear models were adjusted. For all nutrients there was significance. The coefficients of determination were between 0.67 (Ca) and 0.96 (Fe) for the relationships by the method of Jones and between 0.68 (Ca) and 0.97 (Fe) by the method of Beaufils (Table 7).

The comparison of the ranges of sufficiency of the bulletin of fertilizer recommendation in the state of São Paulo (Quaggio et al. 1997) were performed for Pêra orange, with

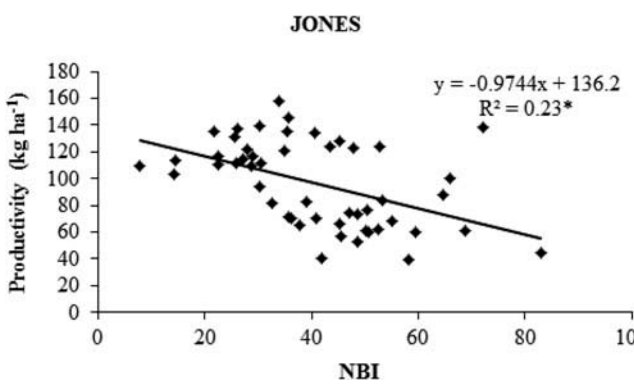

Figure 1. Relationship between the NBI values obtained by the method of Jones and the productivity of Pêra orange.

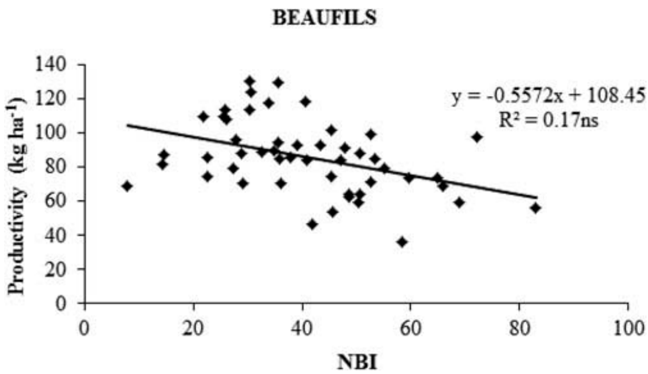

Figure 2. Relationship between the NBI values obtained by the method of Beaufils and the productivity of Pêra orange.

Table 7
Statistical models of the relationships between nutrient levels and DRIS Jones and DRIS Beaufils methods in leaf samples collected in the orchard of Pêra orange

Nutrient	Method	Statistical models	R^2	F
N	DRIS Jones	y = 2.8015x – 62.574	0.72	161.74**
	DRIS Beaufils	y = 3.6423x – 85.055	0.72	200.02**
P	DRIS Jones	y = 136.03x – 149.1	0.89	284.13**
	DRIS Beaufils	y = 43.672x – 36.562	0.86	116.90**
K	DRIS Jones	y = 4.044x – 32.552	0.83	183.69**
	DRIS Beaufils	y = 5.3005x – 43.279	0.82	176.37**
Ca	DRIS Jones	y = 1.4504x – 45.39	0.67	81.63**
	DRIS Beaufils	y = 1.8926x – 60.089	0.68	94.90**
Mg	DRIS Jones	y = 7.6355x – 42.355	0.80	101.06**
	DRIS Beaufils	y = 9.5693x – 53.639	0.80	102.22**
Fe	DRIS Jones	y = 0.2095x – 15.352	0.96	2397.67**
	DRIS Beaufils	y = 0.3767x – 25.68	0.97	2660.07**
Mn	DRIS Jones	y = 1.0311x – 46.058	0.90	845.96**
	DRIS Beaufils	y = 1.3285x – 59.597	0.92	1830.86**
Zn	DRIS Jones	y = 1.5441x – 33.397	0.90	551.91**
	DRIS Beaufils	y = 1.8864x – 43.255	0.91	447.33**
B	DRIS Jones	y = 1.2291x – 41.613	0.93	642.85**
	DRIS Beaufils	y = 1.5308x – 51.006	0.92	479.59**
Cu	DRIS Jones	y = 3.16x – 19.37	0.91	887.06**
	DRIS Beaufils	y = 4.7647x – 29.129	0.95	1469.30**

**$P < 0.01$.

the ranges generated in this study and the two methods used. In Table 8 is presented the sufficiency ranges, and it appears that the amplitudes related to the DRIS methods employed were closer. The same result was obtained by Serra et al. (2010) and Urano et al. (2007). According to Serra et al. (2010) these reference values with lower amplitudes provide greater accuracy in the analysis, reducing the possibility of having poor-productivity crops

Table 8

Normal range of nutrients in leaf samples collected in the orchard of Pêra orange obtained by the DRIS methods of Jones and Beaufils and given in the literature, used to compare the values[a]

Nutrient	Method	Optimal range	Optimal content
	DRIS Jones	21–24	22
N	DRIS Beaufils	22–25	23
	Literature	23–27	***
	DRIS Jones	1.0–1.2	1.1
P	DRIS Beaufils	0.7–1.0	0.8
	Literature	1.2–1.6	***
	DRIS Jones	7–9	8
K	DRIS Beaufils	7–9	8
	Literature	10–15	***
	DRIS Jones	30–33	31
Ca	DRIS Beaufils	30–33	32
	Literature	35–45	***
	DRIS Jones	5.0–6.0	6
Mg	DRIS Beaufils	5.0–6.0	6
	Literature	3.0–4.0	***
	DRIS Jones	50–96	73
Fe	DRIS Beaufils	45–91	68
	Literature	50–120	***
	DRIS Jones	38–52	45
Mn	DRIS Beaufils	38–52	45
	Literature	35–50	***
	DRIS Jones	18–25	22
Zn	DRIS Beaufils	20–26	23
	Literature	35–50	***
	DRIS Jones	29–39	34
B	DRIS Beaufils	29–38	33
	Literature	50–100	***
	DRIS Jones	4.0–8.0	6
Cu	DRIS Beaufils	4.0–8.0	6
	Literature	4.1–10.0	***

[a]Quaggio et al. (1997).
[b]Optimal range estimated from the lower and upper limits equating to zero the equations of relationship of nutrient content and DRIS indexes and ± 2/3 of the standard deviation, according to Urano et al. (2007).

with levels in the normal range, as occurs with the ranges of levels of literature reference, which have greater amplitudes.

In Siciliano lemon, Creste (1996) proved advantages of using the DRIS method in relation to sufficiency ranges, mainly because of their ability to indicate the nutrient deficiency or excess, in order of importance. Bataglia (1989) emphasizes that DRIS can be an alternative for nutritional diagnosis of citrus, but must be used in combination with other diagnostic criteria. Santos (1997) obtained results that the DRIS method was superior to the criterion of sufficiency range for the detection of plants below their potential of productivity, due to nutritional limitations.

In the comparisons between optimal range obtained by the use of DRIS with optimal ranges of literature, for the nutrients P, K, Ca, Zn, and B, these are overestimated and underestimated for the nutrient Mg. Also, the sufficiency ranges and critical levels of bulletins and literature for many different cultures were generated from the experimentation in 1970–1980, when varieties, nutritional requirements, and management were totally different from today. Teixeira et al. (2007) and Teixeira, Zambrosi, and Bettiol Neto (2002) mentioned similar behavior (differences between the ranges of sufficiency) when comparing the ranges generated by the DRIS method with those the literature recommends, in studies that compare the generation of DRIS norms in banana with the critical levels.

To perform diagnostics with the purpose of complementary recommendations of fertilization, many studies have shown advantages of DRIS in relation to the critical level (Jones 1981; Walworth and Sumner 1987), considering that making the diagnosis takes into account the nutritional balance based on nutritional standards of reference or norms. This is particularly important in high levels of production, where the nutritional balance is often the critical factor in determining plant productivity. The norms, or composition of reference for the nutritional balance of a particular culture, can be extrapolated to different regions of the country. Diagnoses can be made at different stages of plant development independently of cultivar and the production-limiting nutrients can be readily identified and ordered according to their importance in limiting productivity.

The importance of DRIS for the culture of the Pêra orange is given mainly because it is a perennial crop for which the nutritional disorders affect plants cumulatively over the years, besides the fact that this correction of deficiency or excess often cannot be made during the crop cycle, making the diagnosis a fundamental factor at the beginning of it.

Conclusions

The methods differed between the limiting nutrients in Pêra orange orchard.

The use of regional norms must be prioritized because of differences between the management applied.

In the methods used, it appears that the nutrients that had a greater number of concordant cases in decreasing order were Mn > Mg > B > N > Cu > Fe > Zn > K > P > Ca.

The amplitudes related to the DRIS methods used were narrower than the conventional literature.

References

Alvarez, V. V. H., and R. A. Leite. 1999. Statistics fundamentals of the forms used for DRIS index calculus. *Brazilian Soil Science Society Bulletim* 24:20–25.

Bataglia, O. C. 1989. DRIS-Citros: An alternative for evaluate the plant nutrition. *Laranja* 10:565–576.

Bataglia, O. C., A. M. C. Furlani, J. P. F. Teixeira, P. R. Furlani, and J. R. Gallo. 1983. *Métodos de Análise Química de Plantas* [*Methods of Chemical Analysis of Plants*]. Campinas, Brazil: Instituto Agronômico.

Beaufils, E. R. 1973. Diagnosis and recommendation integrated system (DRIS). *Soil Science Bulletin* 1. Pietermaritzburg: University of Natal.

Elwali, A. M. O., and G. J. Gascho. 1984. Soil testing, foliar analysis, and DRIS as guide for sugarcane fertilization. *Agronomy Journal* 76:466–470.

Escano, C. R., C. A. Jones, and G. Vehara. 1981. Nutrient diagnosis in corn grow on Hydric Dystrandepts, II: Comparision of two systems of tissue diagnosis. *Soil Science Society of America Journal* 45:1140–1144.

Ferreira, D. F. 2008. Sisvar: A program for analysis and statistics class. *Revista Científica Symposium* 6:36–41.

Hallmark, W. B., and R. B. Beverly. 1991. Review: An update in the use of the diagnosis and recommendation integrated system. *Fertilité* 8:74–88.

Hanson, R. G. 1981. DRIS evaluation of N, P, K status of the determinant soybean in Brazil. *Communications in Soil Science and Plant Analysis* 12:933–948.

IBGE (Instituto Brasileiro de Geografia e Estatística). N.d. *Levantamento sistemático da produção agrícola* [*Crop production survey*]. Available at http://www.ibge.gov.br

Jones, C. A. 1981. Proposed modifications of the diagnosis and recommendation integrated system (DRIS) for interpreting plant analyses. *Communications in Soil Science and Plant Analysis* 12:785–794.

Jones, C. A., and J. E. Bowen. 1981. Comparative DRIS and crop log analysis diagnosis of sugarcane tissue analysis. *Agronomy Journal* 73:941–944.

Marschner, H. 1995. *Mineral nutrition of higher plants*, 2nd ed. San Diego: Academic Press.

Martinez, H. E. P., J. G. Carvalho, and R. B. Souza. 1999. Diagnose foliar [Foliar diagnoses]. In *Recomendações para o uso de corretivos e fertilizantes em Minas Gerais* [*Recommendations for use of the fertilizers and correctives in the Minas Gerais state*], 5ª Aproximação, ed. A. C. Ribeiro, P. T. G. Guimarães, and V. V. H. Alvarez, 143–168. Viçosa: Comissão de Fertilidade do Solo do Estado de Minas Gerais.

Mourão Filho, F. d. A. A., J. C. Azevedo, and J. A. Nick. 2002. Functions and ratio order of the nutrients at the establishment of DRIS norms in 'Valencia' sweet orange. *Pesquisa Agropecuária Brasileira* 37 (2): 185–192.

Munson, R. D., and W. L. Nelson. 1973. Principles and practices in plant analysis. In *Soil testing and plant analysis*, ed. L. M. Walsh and J. D. Beaton, 223–248. Madison: SSSA.

Quaggio, J. A., B. Raij, and C. T. Piza Jr. 1996. Frutíferas [Fruit trees]. In *Recomendações de Adubação e Calagem para o Estado de São Paulo* [*Recommendations for fertilizer and liming to the state of São Paulo*], ed. B. van Raij, H. Cantarella, J. A. Quaggio, and A. M. C. Furlani, 121–153. Campinas, Brazil: Instituto Agronômico.

Raij, B., D. R. Fernandes, E. G. Oliveira, and E. Malavolta. 1996. Café [Coffe plants]. In *Recomendações de Adubação e Calagem para o Estado de São Paulo* [*Recommendations for fertilizer and liming to the state of São Paulo*], ed. B. van Raij, H. Cantarella, J. A. Quaggio, and A. M. C. Furlani, 97–101. Campinas, Brazil: Instituto Agronômico.

Reis Jr., R. A., and P. H. Monnerat. 2002. Sugarcane nutritional diagnosis with DRIS norms established in Brazil, South Africa, and the United States. *Journal of Plant Nutrition* 25: 2831–2851.

Rodriguez, O., E. Rojas, and M. Sumner. 1997. Valencia orange DRIS norms for Venezuela. *Communications in Soil Science and Plant Analysis* 28: 1461–1468.

Santana, J. G., W. M. Leandro, R. V. Naves, and P. P. Cunha. 2008. DRIS norms interpretation for plant tissue and soil for "Pêra" orange in the Goiás State central region. *Pesquisa Agropecuária Tropical* 38:109–117.

Santos, W. R. 1977. *Evaluation of the nutritional equilibrium of the macronutrients in citrus with different fertilizations*. Thesis, Piracicaba, Esalq.

Serra, A. P., M. E. Marchetti, A. C. T. Vitorino, J. O. Novelino, and M. A. Camacho. 2010. Determination of normal nutrient ranges for cotton by the CHM, CND, and DRIS methods. *Brazilian Journal of Soil Science* 34:105–113.

Silva, G. G. C., J. C. L. Neves, V. H. Alvarez, and F. P. Leite. 2005. Evaluation of the universality of DRIS, M-DRIS, and CND norms. *Brazilian Journal of Soil Science* 29:755–761.

Silva, M. A. C., W. Natale, R. M. Prado, M. C. M. Correa, E. S. Stuchi, and I. Andrioli. 2007. Surface liming application in the soil with adult orange cv. Pêra. *Revista Brasileira de Fruticultura* 29:606–612.

Silva, M. A. C., W. Nalate, R. M. Prado, and M. K. Chiba. 2009. Liming and manganese foliar levels in orange. *Journal of Plant Nutrition* 32:694–702.

Teixeira, L. A. J., W. R. Santos, and O. C. Bataglia. 2002. The N and K diagnosis on banana plants using the Diagnosis and Recommendation Integrated System (DRIS) and critical value approach. *Revista Brasileira de Fruticultura* 24:530–535.

Teixeira, L. A. J., F. C. B. Zambrosi, and J. E. Bettiol Neto. 2007. Nutritional diagnosis in banana in the state of São Paulo (Brazil): DRIS norms and critical levels. *Revista Brasileira de Fruticultura* 29:613–620.

Trani, P. E., R. Hiroce, and O. C. Bataglia. 1983. *Análise foliar: amostragem e interpretação* [*Leaf analysis: Sampling and interpretation*]. Campinas: Fundação Cargill.

Urano, E. M. O., C. H. Kurihara, S. Maeda, A. C. T. Vitorinom, M. C. Gonçalves, and M. C. Marchetti. 2006. Soybean nutritional status evaluation. *Pesquisa Agropecuária Brasileira* 41:1421–1428.

Urano, E. M. O., C. H. Kurihara, S. Maeda, A. C. T. Vitorino, M. C. Gonçalves, and M. C. Marchetti. 2007. Determination of optimal nutrient contents for soybean by the mathematical chance, Diagnosis and Recommendation Integrated System, and compositional nutrient diagnosis methods. *Brazilian Journal of Soil Science* 31:63–72.

Wadt, P. G. S., R. F. Novais, V. V. H. Alvarez, S. Fonseca, N. F. Barros, and L. E. Dias. 1998. Nutrient application potential response of eucalypt plantation as evaluated by three methods of estimating DRIS indices. *Brazilian Journal of Soil Science* 22:661–666.

Walworth, J. L., and M. E. Sumner. 1987. The diagnosis and recommendation integrated system. In *Advances in Soil Science*, v.6, p.149–188. New York: Springer.

Wutscher, H. K. 1982. The influence of medium heterogeneity and three rootstocks on growth and nutrient levels of greenhouse-grown Valencia orange trees. *Journal of the American Society for Horticultural Science* 107:235–239.