DRIS norms for 'Valencia' sweet orange on three rootstocks(1)

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Abstract – Diagnosis and Recommendation Integrated System (DRIS) applies nutrient ratios instead of the isolated concentration values of each nutrient in interpretation of tissue analysis. The objectives of this research were to establish adequate DRIS norms for 'Valencia' sweet orange irrigated commercial groves budded on three rootstocks and correlate indexes of nutrition balance with yield. Experiments were conducted in São Paulo State, Brazil. Rootstocks Rangpur lime, Caipira sweet orange, and *Poncirus trifoliata*, with more than six years old and yield above 40 ton ha^{-1} were utilized. Data referred to yield, tree spacing, rootstock and foliar concentrations of N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B in non fruiting terminals for each grove were processed for the years 1994 through 1998. DRIS indexes were calculated by Nick criterion for choosing the ratio order of the nutrients and Jones calculation method of the ratio functions. Indexes of nutritional balance calculated from DRIS norms presented high correlation with yield for the three scion/rootstock combinations. DRIS norms defined in this research are valid, since leaf sampling is done on non fruiting terminals and the grove is irrigated.

Index terms: citrus, foliar diagnosis, nutrient balance, plant nutrition.

Normas DRIS para laranjeira 'Valência' sobre três porta-enxertos

Resumo – O sistema integrado de diagnose e recomendação (DRIS – Diagnosis and Recommendation Integrated System) utiliza relações entre nutrientes em vez da concentração absoluta e isolada de cada um deles na interpretação da análise de tecidos. O objetivo deste trabalho foi estabelecer normas para o método DRIS em pomares comerciais irrigados de laranjeira 'Valência' sobre três porta-enxertos e correlacionar os índices de balanço nutricional com a produtividade. Os experimentos foram conduzidos no Estado de São Paulo, com os porta-enxertos limão 'Cravo', laranja 'Caipira' e *Poncirus trifoliata*, com mais de seis anos, e produtividade acima de 40 t ha^{-1}. Dados de produtividade, espaçamento, porta-enxerto e teores foliares de N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn e B em ramos não frutíferos, de cada talhão, de 1994 a 1998, foram processados. A escolha da ordem da razão dos nutrientes foi determinada segundo o método Nick, e as funções das razões dos nutrientes foram calculadas de acordo com o método Jones. Os índices de balanço nutricional calculados por meio das normas geradas apresentaram alta correlação com produtividade nas três combinações enxerto/porta-enxerto. As normas DRIS definidas são aplicáveis desde que a amostragem de folhas seja realizada em ramos não frutíferos e os pomares sejam irrigados.

Termos para indexação: citro, diagnose foliar, equilíbrio nutricional, nutrição vegetal.

Introduction

The usual methods for leaf analysis interpretation are based on the comparison of the nutrient concentration with critical reference values (sufficiency range approaches). Concentration values above or below reference values are associated with decrease in vegetative growth, yield, and quality. These methods consider the association of isolated concentration values with deficiency or excess, without considering the nutritional balance. Moreover, investigations related to this subject indicate great difficulty in the establishment of consistent critical values and its relationship with high yields, especially because the nutritional status varies with leaf tissue maturation, and also due to sink and concentration effects in high or low yield years. Therefore, sampling is an essential step for better efficiency of these methods.

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DRIS (Diagnosis and Recommendation Integrated System) applies nutrient ratios instead of absolute concentration values of each one for leaf analysis interpretation. DRIS norms have been developed for several field, forest, and horticultural crops, and have been applied as an additional tool for nutritional status diagnosis in the United States, Canada, and China (Lopes, 1998; Hallmark & Beverly, 1991).

Beverly (1987) suggested three modifications in DRIS method and proposed two new methods of diagnosis in 'Valencia' sweet orange, already defined in a previous investigation (Beverly et al., 1984). The author emphasized that the logarithmic transformation, population parameters, and use of a single calculation method may reduce systematic errors, simplify the diagnostic method, and extend its applicability. The two new proposed methods use individual nutrient concentration values, instead of ratios.

Investigations by Woods & Villiers (1992), in South Africa, pointed out that DRIS can be successfully applied in nutrient diagnosis of 'Valencia' sweet orange groves. The authors correlated yield (kg per plant) and quality (fruit mass) with DRIS indexes, working in a database with more than 1,700 observations. DRIS norms were also evaluated in field fertilization trials, and successfully associated with increases in yield and fruit quality.

Cerda et al. (1995) developed DRIS norms for nutrient status diagnosis in 'Verna' lemons, cultivated in Murcia and Alicante, Spain. Selected standard population (high-yield population) presented yield equal or above 125 kg per plant. DRIS norms determinations were influenced by scion/rootstock combination and by sampling time. Under high salinity conditions, DRIS was not efficient to indicate if the nutritional deficiency was caused by high salinity or lack of fertilizers.

Rodriguez et al. (1997) developed DRIS norms for 'Valencia' sweet orange, considering differences in plant age and in rootstock, in several regions within the four more important States in Venezuela. Standard population was selected in a group of the top-20%-yielding trees. Norms calculated were compared with those previously developed. In general, the results agreed with previous investigations. The authors suggested that DRIS can be an economically, fast and reliable alternative to nutrient diagnosis.

In Brazil, investigations about DRIS in citrus are rare. Creste (1996), in 'Siciliano' lemon, organized a databank with leaf analysis in fruiting terminals, from plants with different ages, rootstocks and harvest years. Standard populations were grouped according to yield above 80 ton ha^{-1}. After calculation of DRIS norms, the method was evaluated in field conditions. DRIS was considered an efficient method, especially because it takes into account deficient or excess nutrients in an order of importance.

Santos (1997) utilized a databank of leaf analysis from a N, P, K-fertilization field trial network and commercial groves in São Paulo State to evaluate DRIS. Among three DRIS index calculation methods, the one proposed by Jones (1981) showed more advantages.

Citrus nutritional status can be affected by numerous factors, such as soil and climatic effects, scion/rootstock combination, depth of root system, pests and diseases.

This work focused on the establishment of adequate DRIS norms for 'Valencia' sweet orange on three rootstocks, and on the correlation between them and the yield.

Material and Methods

This study was carried out with data from irrigated 'Valencia' sweet orange groves budded on Rangpur lime (*Citrus limonia* L. Osbeck), 'Caipira' sweet orange (*Citrus sinensis* L. Osbeck), and *Poncirus trifoliata*, over six years old and yield above 40 ton ha^{-1}. Groves were located at a commercial citrus farm, in Mogi Guaçú, SP, Brazil. Data referred to yield, tree spacing, rootstock and leaf N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B concentrations in non fruiting terminals of each grove were processed from 1994 through 1998. Leaf sampling was proceeded according to Hanlon et al. (1995).

Leaf analysis and yield data were organized in a large database, classified by grove referential number, rootstock, plant density (number of plants per hectare), leaf sampling and harvest year.

The nutrient ratio order criterion used was described by Nick (1998). The ratio functions of nutrients were calculated according to Jones (1981). The index of nutritional balance (INB) was calculated by the average of all DRIS indexes (including I_{DM}) irrespective of sign (Nick, 1998).

Population was classified, for each rootstock, according to yield in a decreasing order. Data was analyzed for each year or a combination of years, considering the influence of non nutritional factors affecting yield, such as diseases and the effect of climate on flowering (Mourão Filho et al., 2002). Simulations varying standard (high-yield) population size were performed. DRIS norms and indexes were calculated in each simulation. Adjusted equation, R^2, for each regression analysis was registered. Standard population selected was that which induced the highest R^2 in regression analysis.

Results and Discussion

Adjusted equation of INB versus yield of 'Valencia' sweet orange on Rangpur lime resulted in calculated R^2 of 0.62 (Figure 1A). The study included 12 groves of this scion/rootstock combination with data referred to 1995 leaf sampling and harvest year (Table 1).

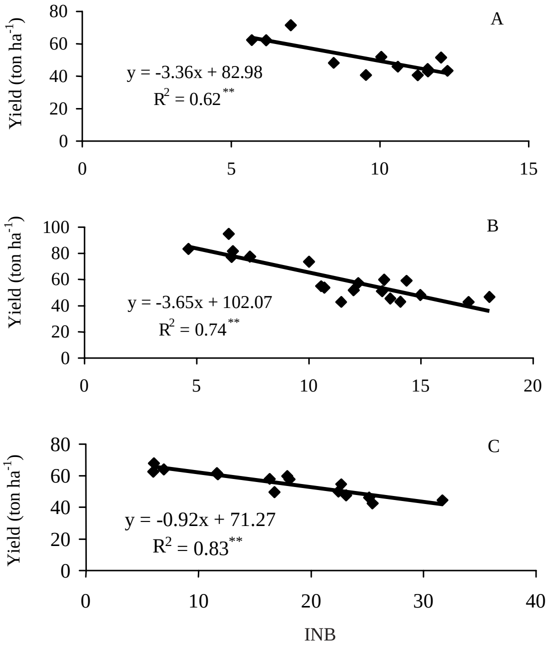

Figure 1. Adjusted regression equation between indexes of nutritional balance (INB) and yield (ton ha^{-1}) for 'Valencia' sweet orange on Rangpur lime (A), Caipira sweet orange (B) and *Poncirus trifoliata* (C). **Significant at 1% level (F test).

Yield of the selected population of 'Valencia' sweet orange on Rangpur lime varied from 40.5 to 71.5 ton ha^{-1}, and the reference population presented 62.2 to 71.5 ton ha^{-1} (numbers 1 through 12). Plant density did not vary much among population tested (222 to 247 plants per hectare), as well as plant age, which for most groves, varied between 22 and 33 years. Only grove referential number 12 was 11-year-old at the time of study. In general, groves were considered in full production after six years from planting. Considering that all groves were irrigated, and kept under toping and hedging pruning, it is very likely that the root system of an 11-year-old grove already explores all available soil around, for the same spacing, in a similar way as in an older grove. Therefore, these groves were analyzed within the same population.

Selection of the standard population of 'Valencia' sweet orange on Rangpur lime took into consideration the yield potential of the scion/rootstock combination. All groves included in the low-yield population were considered with potential to increase yield levels up to those presented by the standard population. Those groves with yield bellow 40 ton ha^{-1} were not included in DRIS analysis because non-nutritional factors might have influenced fruit production. Considering the fact that Rangpur lime is very susceptible to Citrus Blight (Castle et al., 1993), the high incidence of this disorder may have played an important role in decreasing yield, especially in those groves older than 20 years.

DRIS norms for 'Valencia' sweet orange on Rangpur lime were calculated and are valid for this scion/rootstock combination, since leaf samples are collected in non fruiting terminals and the groves are irrigated.

Correlation coefficient values (r) between each pair of nutrient ratios (A/B or B/A) and yield are also reported herein (Table 2). These values were determined from the analyzed populations (standard and low-yield populations), and are useful to verify the influence of each pair of nutrients on yield; the theoretical basis of the r value criterion according to Nick (1998), was applied in this research. The pairs of nutrients with r values over 0.5, irrespective to sign, are 1/Ca, 1/S, Ca/N, N/S, P/S, Ca/K, K/S, K/Zn, Mg/Ca, 1/Zn, B/Ca, Fe/Ca, Mn/Ca, Mg/S, Mg/Zn, B/S, Cu/S, Fe/S, Mn/S, B/Zn, and Mn/Zn.

Table 1. Yield, macro and micronutrient concentrations in leaf samples from non fruiting terminals of 'Valencia' sweet orange groves budded on the rootstocks (RT) Rangpur lime (RL), Caipira sweet orange (CP), *Poncirus trifoliata* (TR) utilized for the establishment of DRIS norms according to the grove referential number (NM), plant density in number of plants per hectare (DEN), grove age in years (GA) and leaf sampling and harvest year (HY). Mogi Guaçú, SP, Brazil. 1994, 1995.

NM	RT	DEN	GA	HY	Yield (ton ha^{-1})	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
						---------------------- (%) ----------------------						----------------- (ppm) -----------------				
1	RL	222	30	1995	40.5	2.56	0.17	1.84	3.28	0.45	0.23	30	79	106	21	26
2	RL	222	30	1995	40.7	3.09	0.17	1.68	3.54	0.39	0.28	44	291	168	26	33
3	RL	222	29	1995	43.0	3.18	0.16	1.61	3.82	0.43	0.28	37	53	166	19	18
4	RL	222	29	1995	43.2	2.70	0.12	1.60	3.57	0.39	0.34	74	121	178	18	17
5	RL	222	30	1995	44.4	2.80	0.16	2.22	3.51	0.38	0.28	39	76	180	30	18
6	RL	222	30	1995	46.0	3.02	0.17	2.45	2.92	0.38	0.22	35	77	135	21	23
7	RL	222	30	1995	48.1	4.02	0.15	2.07	3.46	0.44	0.22	44	215	156	13	18
8	RL	222	30	1995	51.5	3.00	0.18	2.30	2.61	0.42	0.29	41	47	96	16	20
9	RL	222	30	1995	51.9	3.36	0.16	2.30	3.30	0.42	0.28	31	149	175	18	18
10	RL	247	22	1995	62.2	2.91	0.25	1.53	2.56	0.39	0.30	41	75	114	30	13
11	RL	222	33	1995	62.4	3.08	0.16	1.68	2.67	0.38	0.27	40	254	142	20	24
12	RL	247	11	1995	71.5	2.41	0.12	1.99	2.39	0.48	0.10	65	153	169	29	13
13	CP	222	30	1994	42.8	3.32	0.12	1.84	3.98	0.28	0.18	47	43	136	10	16
14	CP	222	30	1995	43.0	2.86	0.16	2.14	3.17	0.39	0.17	38	130	172	14	18
15	CP	222	30	1994	43.0	2.93	0.12	1.91	2.80	0.31	0.21	54	40	145	11	16
16	CP	222	29	1994	45.4	3.32	0.10	1.15	3.26	0.25	0.14	38	49	83	13	14
17	CP	222	30	1994	46.7	3.08	0.12	1.76	3.31	0.30	0.15	44	47	176	10	22
18	CP	222	31	1995	48.3	2.66	0.16	2.22	2.30	0.40	0.18	51	100	158	21	14
19	CP	247	11	1995	51.1	2.95	0.17	2.30	4.41	0.38	0.13	67	195	168	18	21
20	CP	222	31	1995	51.7	3.18	0.16	2.14	3.21	0.33	0.19	37	146	147	20	12
21	CP	222	31	1995	53.7	3.04	0.16	2.07	3.83	0.35	0.18	41	149	150	10	22
22	CP	222	31	1995	54.8	2.76	0.15	2.07	2.24	0.42	0.24	38	156	127	26	13
23	CP	222	31	1995	57.3	3.33	0.16	2.14	3.95	0.40	0.15	44	126	155	21	11
24	CP	313	9	1994	59.1	2.70	0.08	0.92	2.57	0.30	0.17	69	47	126	11	16
25	CP	278	30	1994	59.9	2.84	0.13	1.53	3.51	0.28	0.19	54	70	152	12	14
26	CP	370	14	1995	73.6	2.94	0.17	2.22	3.51	0.47	0.28	43	317	219	26	21
27	CP	370	13	1994	77.1	3.37	0.11	1.30	3.29	0.30	0.19	49	114	107	35	15
28	CP	370	14	1995	77.5	2.27	0.16	2.22	4.05	0.54	0.34	34	200	176	21	22
29	CP	370	13	1994	81.5	2.84	0.09	1.38	2.65	0.28	0.20	35	101	98	28	17
30	CP	370	14	1995	83.4	3.14	0.15	1.68	4.28	0.47	0.28	49	243	152	22	20
31	CP	370	13	1994	94.9	2.77	0.15	1.68	3.95	0.38	0.19	60	187	129	51	14
32	TR	313	6	1994	42.6	2.88	0.14	1.15	3.90	0.49	0.22	52	3	107	35	15
33	TR	247	11	1994	44.4	2.60	0.16	0.61	3.00	0.30	0.15	65	21	66	21	18
34	TR	278	14	1994	46.0	2.84	0.16	1.22	3.15	0.43	0.18	72	30	77	20	14
35	TR	313	12	1994	47.4	2.95	0.15	1.53	3.55	0.47	0.21	36	21	70	17	15
36	TR	313	12	1994	49.5	2.77	0.15	1.30	3.45	0.40	0.18	35	57	78	12	14
37	TR	313	12	1994	49.9	2.91	0.14	1.07	3.10	0.47	0.16	36	49	68	10	17
38	TR	313	11	1994	54.6	2.97	0.15	1.45	3.30	0.38	0.23	33	17	67	19	16
39	TR	556	12	1994	57.7	3.26	0.16	0.99	3.20	0.33	0.16	32	59	81	21	16
40	TR	222	30	1994	57.9	2.65	0.14	1.38	2.89	0.43	0.21	51	71	126	40	18
41	TR	222	32	1994	59.8	3.12	0.17	1.68	3.60	0.34	0.16	56	59	97	26	25
42	TR	222	32	1994	60.6	2.72	0.13	1.53	3.97	0.41	0.17	50	73	124	10	17
43	TR	222	31	1994	61.4	2.74	0.11	1.91	3.06	0.43	020	54	69	123	15	17
44	TR	222	31	1994	61.4	2.74	0.11	1.91	3.06	0.43	0.20	54	69	123	15	17
45	TR	222	32	1994	62.6	2.66	0.11	1.38	2.81	0.36	0.26	44	61	121	16	21
46	TR	222	32	1994	63.9	2.58	0.15	1.68	2.53	0.33	0.25	27	83	106	11	18
47	TR	222	32	1994	67.8	3.07	0.14	1.53	3.88	0.38	0.21	40	67	128	19	17

Adjusted equation of INB versus yield of ‘Valencia’ sweet orange on Caipira sweet orange resulted in calculated R^2 of 0.74 (Figure 1B). The study included 19 groves of this scion/rootstock combination with data referred to 1994 and 1995 leaf sampling and harvest years (Table 1). Yield of the selected population varied from 42.8 to 94.9 ton ha^{-1}, and the standard population was grouped by those groves with yield between 77.5 and 94.9 ton ha^{-1} (numbers 13 through 31). Plant density varied more intensively in this population (222 to 370 plants per hectare), as well as plant age (9 to 31 years). Caipira rootstock, as any other sweet orange variety, is very susceptible to *Phytophthora* (Castle et al., 1993), and this fact may have played an important role in decreasing yield. Younger groves were also those with higher plant densities and presented higher yields. However, as well as already discussed for ‘Valencia’ on Rangpur lime, plant age probably is not an important factor. Considering that the groves are irrigated and kept under pruning, it is likely that a nine-year-old grove already explore all available soil around, for a similar plant spacing, as well as older groves.

Moreover, the cut-off limit of the standard population selected for Caipira rootstock is different

Table 2. Mean and standard deviation (SD) of DRIS norms for ‘Valencia’ sweet orange on Rangpur lime and correlation coefficient (r) between each nutrient ratio pair (A/B or B/A) and yield. Mogi Guaçú, SP, Brazil. 1995.

Ratio	r	Mean	SD	Ratio	r	Mean	SD
1/N	0.2414	0.3611	0.0389	K/B	-0.2763	0.0366	0.0047
P	0.0847	0.1767	0.0544	K/Cu	-0.2039	0.0133	0.0056
K	-0.0493	1.7333	0.1915	Fe/K	-0.0942	81.3194	4.8179
1/Ca	0.8664	0.3945	0.0181	Mn/K	0.3075	15.3618	3.1939
Mg	0.2629	0.4167	0.0450	K/Zn	0.5382	0.1136	0.0340
1/S	0.6058	5.6790	3.0591	Mg/Ca	0.8356	0.1652	0.0256
1/B	-0.3258	0.0216	0.0044	Ca/S	0.2996	14.1074	6.9465
1/Cu	-0.2109	0.0079	0.0040	B/Ca	0.6684	19.3979	5.5307
Fe	-0.1012	141.6667	22.4549	Ca/Cu	-0.3955	0.0201	0.0101
Mn	0.3311	26.3333	4.4969	Fe/Ca	0.6428	56.1420	10.8908
1/Zn	0.6285	0.0652	0.0166	Mn/Ca	0.6932	10.4478	2.0979
P/N	0.1724	0.0626	0.0165	Zn/Ca	-0.1023	6.5021	1.7645
K/N	0.1266	0.6323	0.1370	Mg/S	0.5918	2.5025	1.6252
Ca/N	-0.6399	0.9128	0.0561	Mg/B	-0.2873	0.0088	0.0010
Mg/N	0.3327	0.1522	0.0335	Mg/Cu	-0.1938	0.0033	0.0015
N/S	0.5381	15.0691	6.4237	Fe/Mg	-0.2145	339.3584	34.4188
B/N	0.3317	18.0158	6.3482	Mn/Mg	0.2048	63.3238	10.1278
N/Cu	-0.2310	0.0222	0.0118	Mg/Zn	0.6551	0.0276	0.0088
Fe/N	0.0826	51.8012	13.2617	B/S	0.6201	311.6049	239.3273
Mn/N	0.3796	9.6120	2.3147	Cu/S	0.5080	906.9136	523.1050
Zn/N	-0.4602	5.8846	1.4010	Fe/S	0.5415	865.3086	586.1800
P/K	0.1336	0.1063	0.0428	Mn/S	0.6291	154.6914	96.2613
Ca/P	-0.4938	15.6147	4.0227	Zn/S	0.1028	87.4074	35.3970
Mg/P	0.2083	2.6450	1.0143	B/Cu	-0.0798	0.3763	0.1625
P/S	0.6674	0.8753	0.2497	B/Fe	0.3672	0.3420	0.0438
B/P	0.2118	318.5556	161.6229	B/Mn	-0.0660	1.8693	0.3689
Cu/P	0.1960	1,054.1667	548.3245	B/Zn	0.5235	3.2735	1.3635
P/Fe	0.1222	0.0013	0.0006	Fe/Cu	-0.3015	1.0612	0.3935
Mn/P	0.3580	162.2222	56.2128	Mn/Cu	-0.0588	0.2228	0.1332
Zn/P	-0.4987	103.4444	40.1574	Cu/Zn	0.5040	9.3739	2.5945
Ca/K	-0.5337	1.4878	0.2057	Mn/Fe	0.3261	0.1919	0.0520
K/Mg	-0.1619	4.1633	0.2037	Fe/Zn	0.4055	9.2286	2.9099
K/S	0.5344	10.4074	6.7279	Mn/Zn	0.6336	1.7906	0.6776

from the one chosen for ‘Valencia’ sweet orange on Rangpur lime; in the first yield varied from 77.5 to 94.9 ton ha^{-1}, whereas in Rangpur lime, the maximum yield of the standard population was 71.5 ton ha^{-1}.

DRIS norms for ‘Valencia’ sweet orange on Caipira sweet orange, as well as correlation coefficient values (r) between each pair of nutrient ratios (A/B or B/A) and yield are also reported (Table 3). The pairs of nutrients with r values over 0.5, irrespective to sign, are 1/S, N/S, Cu, Mn, Cu/N, Mn/N, Cu/P, Mn/P, K/Mg, S/K, Cu/K, Mn/K, Ca/Cu, Mn/Ca, Cu/Mg, Mg/Fe, Mn/Mg, S/Fe, Mn/S, Mn/B, Cu/Fe, Cu/Zn, Mn/Fe, and Mn/Zn (Table 3).

Adjusted equation of INB versus yield of ‘Valen-

Table 3. Mean and standard deviation (SD) of DRIS norms for ‘Valencia’ sweet orange on Caipira sweet orange and correlation coefficient (r) between each nutrient ratio pair (A/B or B/A) and yield. Mogi Guaçú, SP, Brazil. 1994, 1995.

Ratio	r	Mean	SD	Ratio	r	Mean	SD
1/N	0.2586	0.3680	0.0448	K/B	-0.1370	0.0418	0.0142
1/P	0.0140	7.6736	1.9919	Cu/K	0.7687	104.8077	26.6716
K	-0.2152	1.7400	0.3030	K/Fe	-0.1740	0.0127	0.0011
Ca	0.2654	3.7325	0.6363	Mn/K	0.7867	18.3004	7.9778
Mg	0.3795	0.4175	0.0976	K/Zn	-0.2458	0.0965	0.0155
1/S	-0.5332	4.1939	0.9682	Ca/Mg	-0.1547	9.1164	1.0450
B	0.0439	44.5000	10.7355	Ca/S	-0.2705	15.3092	3.3844
Cu	0.5627	182.7500	51.5479	Ca/B	0.1687	0.0870	0.0200
1/Fe	0.0888	0.0076	0.0017	Ca/Cu	-0.5316	0.0213	0.0031
Mn	0.7874	30.5000	12.1347	Fe/Ca	-0.2976	37.1525	3.9578
1/Zn	-0.1178	0.0564	0.0099	Mn/Ca	0.6037	8.4507	3.3910
P/N	0.1198	0.0510	0.0139	Zn/Ca	-0.1168	5.0161	1.0505
K/N	-0.0718	0.6514	0.1934	S/Mg	0.2819	0.6099	0.0768
Ca/N	0.3944	1.3766	0.3022	Mg/B	0.2424	0.0100	0.0036
Mg/N	0.3712	0.1558	0.0510	Cu/Mg	0.5860	435.0528	70.1496
N/S	-0.5154	11.6674	3.1625	Mg/Fe	0.5229	0.0030	0.0001
N/B	-0.1515	0.0645	0.0124	Mn/Mg	0.6930	79.9770	39.1490
Cu/N	0.5772	67.1417	19.6330	Zn/Mg	-0.2330	45.2126	9.1847
Fe/N	0.0450	51.7545	15.8121	S/B	0.3710	0.0061	0.0025
Mn/N	0.7944	11.1320	4.3350	S/Cu	-0.4507	0.0015	0.0004
Zn/N	0.2019	6.7753	1.7504	S/Fe	0.5577	0.0018	0.0002
P/K	0.4453	0.0790	0.0106	Mn/S	0.5703	137.1893	81.1705
P/Ca	-0.2369	0.0366	0.0022	Zn/S	-0.3833	73.7047	7.3100
P/Mg	-0.4897	0.3329	0.0370	Cu/B	0.4978	4.2110	1.2557
S/P	0.4753	1.8701	0.3719	B/Fe	0.1308	0.3345	0.0971
P/B	-0.0209	0.0032	0.0009	Mn/B	0.7404	0.6792	0.1586
Cu/P	0.7309	1,309.7222	186.3943	Zn/B	0.1111	0.4436	0.1489
Fe/P	-0.1209	1,015.5556	95.8007	Cu/Fe	0.7215	1.3038	0.2296
Mn/P	0.7695	232.2569	94.0142	Mn/Cu	0.0599	0.1864	0.0888
P/Zn	-0.0873	0.0077	0.0019	Cu/Zn	0.5425	10.1348	2.8775
K/Ca	-0.3483	0.4717	0.0646	Mn/Fe	0.7162	0.2363	0.1116
K/Mg	-0.6445	4.2588	0.4912	Zn/Fe	0.1917	0.1346	0.0239
S/K	0.5797	0.1445	0.0197	Mn/Zn	0.6216	1.8361	1.0746

cia’ sweet orange on *Poncirus trifoliata* resulted in calculated R^2 of 0.83 (Figure 1C). The study included 16 groves of this scion/rootstock combination with data referred to 1994 sampling year and harvest year (Table 1).

Yield of the selected population varied from 42.6 to 67.8 ton ha^{-1} and the standard population presented 62.6 to 67.8 ton ha^{-1} (numbers 32 through 47). Among scion/rootstock combinations tested, this was the one that presented higher variation in plant density (222 to 556 plants per hectare), even though the very high plant density was observed only in the grove referential number 39. Average grove age also varied (6 to 32 years), and this fact seemed not to be relevant for DRIS norms calculation. It must be pointed out that the younger groves are also those with higher plant densities. Therefore, considering the conditions of this study, younger high-density groves may have the same yield potential as older low-density groves.

Considering the effect of the scion/rootstock combination, selected cut-off limit of standard population of ‘Valencia’ on *Poncirus trifoliata* was different from the other combinations (Table 1). In this case, yield of standard population varied from 62.6 to 67.8 ton ha^{-1}, much lower than the average yield in ‘Valencia’ on ‘Caipira’ sweet orange (77.5 to 94.9 ton ha^{-1}), and in ‘Valencia’ on Rangpur lime (62.2 to 71.5 ton ha^{-1}). All groves included in the low-yield population presented yield above 40 ton ha^{-1}, and were considered with potential to increase yield.

DRIS norms for ‘Valencia’ sweet orange on *Poncirus trifoliata*, as well as correlation coefficient values (r) between each pair of nutrient ratios (A/B or B/A) and yield were calculated and established (Table 4). The pairs of nutrients with r values over 0.5, irrespective to sign, are K, Cu, Fe, 1/Zn, K/N, Cu/N, Fe/N, K/P, Cu/P, P/Fe, P/Zn, K/Ca, Mg/K, S/K, B/K, Cu/K, Mn/K, Cu/Ca, Ca/Fe, Cu/Mg, Fe/Mg, Mg/Zn, Cu/S, Fe/S, Cu/B, Fe/B, Cu/Fe, Cu/Mn, Cu/Zn, and Mn/Fe.

It is important to point out that, for all three rootstochs in spite of different regression equations, INB was highly correlated with yield, which decreased with the increase of nutritional imbalance (Figure 1A, 1B e 1C). This is a strong evidence that the method used to calculate DRIS indices and, therefore, INB, took into consideration the right criteria, especially the selection of specific standard populations for each scion/rootstoch combination.

According to previous investigations by other authors, calculated norms can be as much representative as more specific high- and low-yield populations are selected. Databases to be used for calculation of DRIS norms may have variable size, according to the method (Letzsch & Sumner, 1984), and may not be directly related to the quality of the standards (Walworth et al., 1988). Possibly, more general DRIS norms may result in lower diagnosis efficiency. The high quality of the observations must be the main characteristic in searching and choosing the database, as oppose as quantity.

In this work, ‘Valencia’ sweet orange, older than six years and with yield above 40 ton ha^{-1}, was the selected population to optimize DRIS efficiency. The establishment of DRIS norms was based on restricted databases, but extremely uniform and with high quality, varying from 12 to 19 observations.

Considering the significant influence of the soil and climatic conditions, scion and rootstock variety, this work shows that DRIS norms for citrus must be calculated for specific conditions, when higher correlation between INB and yield is achieved. These results were also found by Nick (1998), calculating DRIS norms in coffee. Therefore, general DRIS norms (Rodriguez et al., 1997; Santos, 1997), in spite of being more extended, may present less application when applied in specific conditions such as those of the present work.

The establishment of DRIS norms was made within specific populations, with segregation by rootstock, leaf sampling and harvest year. Simulation of DRIS norms involving populations grouped by several leaf sampling and harvest years (1994 through 1998) did not result in high correlation between INB and yield (Mourão Filho et al., 2002). The most reasonable explanation for this fact could be the great influence of climate on flower bud induction and the different degree of incidence of diseases, such as Postbloom Fruit Drop (*Colletotrichum gloesporioides*) throughout the study period, affecting yield more significantly than nutritional factors. Separation of the populations of

Table 4. Mean and standard deviation (SD) of DRIS norms for 'Valencia' sweet orange on *Poncirus trifoliata*, and correlation coefficient (r) between each nutrient ratio pair (A/B or B/A) and yield. Mogi Guaçú, SP, Brazil. 1994.

Ratio	r	Mean	SD	Ratio	r	Mean	SD
N	0.0172	2.7700	0.2146	B/K	-0.5611	24.6998	6.5357
1/P	0.4380	7.6335	1.0487	Cu/K	0.5809	45.7995	2.5548
K	0.6495	1.5300	0.1225	K/Fe	-0.0779	0.0131	0.0020
1/Ca	0.1969	0.3363	0.0578	Mn/K	-0.5110	10.1867	2.5951
Mg	-0.3552	0.3567	0.0205	Zn/K	-0.3710	12.3476	2.0357
S	0.3346	0.2400	0.0216	Ca/Mg	0.1606	8.5609	1.1678
B	-0.2882	37.0000	7.2572	S/Ca	0.3665	0.0818	0.0198
Cu	0.8359	70.3333	9.2856	B/Ca	-0.2151	12.2132	2.4406
Fe	0.7068	118.3333	9.1773	Cu/Ca	0.7752	23.9275	6.5347
Mn	-0.2290	15.3333	3.2998	Ca/Fe	-0.7166	0.0258	0.0032
1/Zn	-0.5455	0.0540	0.0047	Ca/Mn	0.1602	0.2033	0.0222
N/P	0.4797	21.1035	2.9094	Ca/Zn	-0.4586	0.1675	0.0430
K/N	0.6323	0.5561	0.0677	S/Mg	0.4923	0.6775	0.0895
N/Ca	0.2230	0.9192	0.0953	B/Mg	-0.1785	103.1012	16.5656
Mg/N	-0.3076	0.1290	0.0048	Cu/Mg	0.8420	199.0918	37.1749
S/N	0.3096	0.0877	0.0136	Fe/Mg	0.8350	331.3884	7.2019
B/N	-0.2796	13.3453	2.4907	Mn/Mg	-0.1302	42.5926	6.9290
Cu/N	0.8041	25.6423	4.6383	Mg/Zn	-0.5437	0.0193	0.0022
Fe/N	0.6489	42.7559	1.9483	B/S	-0.3609	155.9023	34.9649
Mn/N	-0.2330	5.4892	0.8695	Cu/S	0.7015	295.2210	43.1796
N/Zn	-0.4665	0.1502	0.0225	Fe/S	0.5490	499.6361	79.5179
K/P	0.6287	11.5580	0.7070	S/Mn	0.3741	0.0167	0.0048
Ca/P	0.2483	23.3755	4.6868	S/Zn	-0.1125	0.0129	0.0007
Mg/P	0.0705	2.7290	0.4381	Cu/B	0.7056	2.0451	0.7370
S/P	0.4535	1.8434	0.3741	Fe/B	0.7424	3.2920	0.4845
P/B	0.0661	0.0039	0.0013	Mn/B	-0.0601	0.4153	0.0458
Cu/P	0.8336	528.8167	35.5322	B/Zn	-0.4972	1.9827	0.3572
P/Fe	-0.6722	0.0011	0.0002	Cu/Fe	0.5577	0.6035	0.1272
Mn/P	-0.1120	118.1674	31.9509	Cu/Mn	0.5900	4.9614	1.8309
P/Zn	-0.6564	0.0073	0.0014	Cu/Zn	0.7337	3.8190	0.7019
K/Ca	0.6464	0.5165	0.1116	Mn/Fe	-0.6058	0.1281	0.0185
Mg/K	-0.8101	0.2352	0.0279	Fe/Zn	0.4384	6.3934	0.8050
S/K	-0.5055	0.1582	0.0219	Mn/Zn	-0.4056	0.8302	0.2124

'Valencia' sweet orange groves according to rootstocks was not carried out by Rodriguez et al. (1997), in Venezuela, who worked with Cleopatra mandarin and Volkamer lemon, as rootstocks. In the present work, this procedure was a high-priority.

Another important factor to be discussed refer to the yield of the standard (high-yield) population. The criterion to select the standard population must be specific to establish adequate norms in each case. Therefore, the results of the present work do not agree with previous research works, in which the standard population cut-off limit must be strict (Letzsch & Sumner, 1984; Beverly & Worley, 1992; Raghupathi & Bhargava, 1999), but do agree with those in which the standard population was defined by more variable and arbitrary criteria (Nick, 1998).

Conclusions

1. Indexes of nutritional balance (INB), calculated from established norms, present high correlation with yield for all three scion/rootstock combinations.

2. DRIS norms defined in this work are applicable, since leaf samples are collected in non fruiting terminals and the groves are irrigated.

References

BEVERLY, R. B. Modified DRIS method for simplified nutrient diagnosis of ‘Valencia’ oranges. **Journal of Plant Nutrition**, New York, v. 10, p. 1401-1408, 1987.

BEVERLY, R. B.; STARK, J.C.; OJALA, J. C.; EMBLETON, T. W. Nutrient diagnosis of ‘Valencia’ oranges by DRIS. **Journal of the American Society for Horticultural Science**, v. 109, p. 649-654, 1984.

BEVERLY, R. B.; WORLEY, R. E. Preliminary DRIS diagnostic norms for Pecan. **HortScience**, Alexandria, v. 27, p. 271, 1992.

CASTLE, W. S.; TUCKER, D. P. H.; KREZDORN, A. H.; YOUTSEY, C. O. **Rootstocks for Florida citrus**. Gainesville: University of Florida, 1993. 92 p.

CERDA, A.; NIEVES, M.; MARTINEZ, V. An evaluation of mineral analysis of Verna lemons by DRIS. **Communications in Soil Science and Plant Analysis**, New York, v. 26, p. 1697-1707, 1995.

CRESTE, J. E. **Uso do DRIS na avaliação do estado nutricional do limoeiro Siciliano**. 1996. 120 f. Tese (Doutorado em Nutrição Vegetal) - Universidade Estadual Paulista, Botucatu, 1996.

HALLMARK, W. B.; BEVERLY, R. B. Review: an update in the use of the diagnosis and recommendation integrated system. **Journal of Fertilizer Issues**, Manchester, v. 8, p. 74-88, 1991.

HANLON, E. A.; OBREZA, T. A.; ALVA, A. K. Tissue and soil analysis. In: TUCKER, D. P. H.; ALVA, A. K.; JACKSON, L. K.; WHEATON, T. A. (Ed.). **Nutrition of Florida citrus trees**. Gainesville: University of Florida, 1995. p. 13-16. (SP, 169).

JONES, W. W. Proposed modifications of the diagnosis and recommendation integrated system (DRIS) for interpreting plant analyses. **Communications in Soil Science and Plant Analysis**, New York, v. 12, p. 785-794, 1981.

LETZSCH, W. S.; SUMNER, M. E. Effect of population size and yield level in selection of diagnosis and recommendation integrated system (DRIS) norms. **Communications in Soil Science and Plant Analysis**, New York, v. 15, p. 997-1006, 1984.

LOPES, A. S. **Manual internacional de fertilidade do solo**. 2. ed. Piracicaba: Potafos, 1998. 177 p.

MOURÃO FILHO, F. A. A.; AZEVEDO, J. C.; NICK, J. A. Funções e ordem da razão dos nutrientes no estabelecimento de normas DRIS em laranjeira ‘Valência’. **Pesquisa Agropecuária Brasileira**, Brasília, v. 37, n. 2, p. 185-192, fev. 2002.

NICK, J. A. **DRIS para cafeeiros podados**. 1998. 86 f. Dissertação (Mestrado em Nutrição Vegetal) - Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, 1998.

RAGHUPATHI, H. B.; BHARGAVA, B. S. Preliminary nutrient norms for ‘Alphonso’ mango using diagnosis and recommendation integrated system. **Indian Journal of Agricultural Sciences**, New Delhi, v. 69, p. 648-650, 1999.

RODRIGUEZ, O.; ROJAS, E.; SUMNER, M. Valencia orange DRIS norms for Venezuela. **Communications in Soil Science and Plant Analysis**, New York, v. 28, p. 1461-1468, 1997.

SANTOS, W. R. dos. **Avaliação do equilíbrio nutricional dos macronutrientes em citros com diferentes adubações**. 1997. 112 f. Dissertação (Mestrado em Nutrição Vegetal) - Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, 1997.

WALWORTH, J. L.; WOODDARD, H. J.; SUMNER, M. E. Generation of corn tissue norms from a small, high-yield data base. **Communications in Soil Science and Plant Analysis**, New York, v. 19, p. 563-577, 1988.

WOODS, D. B.; VILLIERS, J. M. Diagnosing the nutrient status of ‘Valencia’ oranges in Southern Africa. In: INTERNATIONAL CITRUS CONGRESS, 7., 1992, Acireale. **Proceedings**... Acireale: International Society of Citriculture, 1992. p. 556-559.