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Development of leaf nutrient norms and identification of yield-limiting nutrients using DRIS in sapota cv. Kalipatti

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ABSTRACT

A survey was conducted in 106 orchards growing sapota cv. Kalipatti in Raichur, Dharwad and Belgaum districts of Northern Karnataka for developing leaf nutrient norms through Diagnosis and Recommendation Integrated System (DRIS) for nutrient management. Leaf samples collected were processed and analyzed for macro-and micronutrient status and a data bank was established. The entire population was divided into two sub-groups, namely, low-and high-yielding types to derive the norms. Fifty-five nutrient expressions were chosen as diagnostic norms using DRIS, which have shown higher variance and lower coefficient of variation that are found to have greater diagnostic precision viz., N/K (1.731), N/Ca (0.928), Mg/N (0.360), Fe/N (99.89), N/Cu (0.104), N/B (0.037), Mg/Ca (0.329), Ca/B (0.040), Mg/S (1.103), Fe/Mg (278.6), Mg/Zn (0.037), Mg/B (0.013), Fe/Zn (10.39) etc. The nutritional balance index (NBI) indicated an overall imbalance of nutrients based on sum of the indices, irrespective of sign. Diagnosis of nutrient imbalance through DRIS indices indicated that potassium, boron and zinc to be the most common yield-limiting nutrients in the orchards. In addition, five nutrient ranges/ standards were derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient, to serve as a guide for diagnostics. Optimum leaf N ranged from 1.51 to 2.09%, P from 0.06 to 0.15% and K from 0.83 to 1.44%. The optimum concentration ranged from 1.36 to 2.34% for Ca, 0.54 to 0.68% for Mg and 0.48 to 0.80 for S. Among the micronutrients, optimum Fe, Mn, Zn, Cu and B concentrations ranged from 109 to 206 mg kg^{-1}, 49 to 99 mg kg^{-1}, 13.3 to 21.9 mg kg^{-1}, 3.76 to 9.10 mg kg^{-1} and 34.8 to 66.8 mg kg^{-1}, respectively, for sapota cv. Kalipatti.

Key words: DRIS, norms, indices, nutrients, sapota, Kalipatti

INTRODUCTION

Sapota, *Manilkara achras* (Mill.) is an important fruit crop belonging to the family Sapotaceae. Deficiency of major and micronutrients causes considerable yield reduction in sapota cv. Kalipatti resulting in economic loss. In order to avoid yield loss, its nutrient requirements need to be carefully monitored through soil or leaf analysis for evolving nutrient management strategies. Leaf analysis is considered a more direct method of plant nutritional status evaluation than soil analysis, especially, for fruit crops as these differ from seasonal crops in nutrient requirement due to their size, population density, rate of growth and rooting pattern. Among several approaches adopted for interpretation of leaf analysis data, Diagnosis and Recommendation Integrated System (DRIS) is considered the best as it uses nutrient ratios and simultaneously identifies imbalances, deficiencies and excesses in crop nutrients, and, ranks them in the order of importance (Beaufils, 1973). This methodology has been successfully used to interpret results of foliar analysis in crops such as grape (Bhargava and Raghupathi, 1995) and papaya (Anjaneyulu, 2007). As no established standards are available for sapota cv. Kalipatti, an attempt was made to develop leaf nutrient norms/standards using Diagnosis and Recommendation Integration System (DRIS).

MATERIAL AND METHODS

Sapota orchards in Raichur, Dharwad and Belgaum districts of Karnataka State were surveyed during 2007-08 and leaf samples were collected for developing DRIS norms from 106 orchards by selecting the 10th leaf from apex, which is an index leaf (recently matured leaf), as outlined by Bhargava (2002). From each orchard, 25 to 30 trees were selected and 50 leaves were collected randomly to form a composite and representative sample. Samples were decontaminated by sequential wash with tap water, followed by 0.2% detergent solution and N/10 HCl solution, to remove residues of chemical spray on the leaf. This was followed by washes in single and double distilled water. Excess water was removed by pressing the leaves between folds of blotting paper and the samples dried in an oven at 75^0 C for 72 h. After complete drying, the samples were powdered in Cyclotec Mill and were analyzed for P, K, Ca, Mg, S, Fe, Mn, Zn, and Cu by taking one-gram of the sample and digesting it in di-acid mixture (9:4 ratio of nitric and perchloric acids) using standard analytical methods (Jackson, 1973). Nitrogen was estimated by micro-kjeldhal method, whereas P, K and S were analyzed by vanado-molybdate, flame-photometer and turbidity methods, respectively. Calcium, magnesium and the micronutrients, viz., Fe, Mn, Cu and Zn were analyzed using atomic absorption spectrophotometer (Perkin-Elmer-A-Analyst-200). Boron was estimated by ashing one-gram of leaf sample in a muffle furnace and its extraction using dilute HCl. The analysis was carried out by curcumin method. Thus, a data bank was established for the entire population.

Computation of DRIS norms

DRIS norms were calculated as described by Beaufils (1973). The whole population was divided into two sub-groups, namely low-and high-yielding types, taking 10 tonnes ha^{-1} as the cut-off yield. The cut-off yield was positioned in such a way that the high-yielding sub-population reflected conditions that are deemed desirable (Beaufils, 1973). Nutrient ratios whose variance ratios (variance of low yielding/variance of high yielding population) varied significantly were selected as DRIS norms. Individual nutrients were also considered for computation of DRIS norms in the same way as the nutrient ratios. Altogether, fifty-five ratios involving two nutrients were selected for the eleven nutrients.

Computation of DRIS indices and nutritional balance index (NBI)

DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. The DRIS indices were calculated as described by Walworth and Sumner (1987) using the following formula. An example for one nutrient is given below:

$$N = 1/10[f (N/P)-f (K/N) +f (N/Ca) +f (N/Mg) +f (N/S)-f (Fe/N) +f (N/Mn)-f (Zn/N)+f (N/Cu)-f (B/N)]$$

$$f (N/P) = \left| \frac{N/P}{n/p} - 1 \right| \frac{1000}{CV}$$

Where N/P > n/p

$$f (N/P) = \left| 1 - \frac{n/p}{N/P} \right| \frac{1000}{CV}$$

Where, N/P< n/p

where N/P is the actual value of the ratio of N and P in the plant under diagnosis and n/p is the value of the norm, and CV is the co-efficient of variation. Similarly, indices for other nutrients were calculated using appropriate formulae.

The absolute sum values of nutrient indices generated an additional index called 'Nutritional Balance Index' (NBI). This was worked out by taking the actual sum of the DRIS indices irrespective of sign.

Leaf nutrient guides/ranges

Five leaf nutrients guide/ ranges have been derived using mean and standard deviation (SD) as deficient, low, optimum, high and excess for each nutrient. The 'optimum' nutrient range is the value derived from "mean – 4/3 SD to mean + 4/3 SD". The range 'low' was obtained by calculating "mean – 4/3 SD to mean – 8/3 SD" and the value below "mean – 8/3 SD" was considered as 'deficient'. The value from "mean + 4/3 SD to mean + 8/3 SD" was taken as 'high' and the value above "mean + 8/3 SD" was taken as 'excessive' (Bhargava and Chadha, 1993).

RESULTS AND DISCUSSION

Leaf nutrients status of the entire population

Leaf N ranged from 1.36 to 2.31% with a mean value of 1.79% in the whole population but K ranged from 0.65 to 1.55% indicating, that, variation in leaf N concentration was much higher compared to K in sapota. However, leaf P ranged from 0.064 to 0.229%, which is much lower to either N or K. Similarly, the concentration range of Ca was much higher than that of K indicating dominance of the divalent calcium over monovalent potassium and, thus, possible antagonism between the two nutrients. Wide variation was observed in S concentration ranging from 0.27 to 0.86%. Among micronutrients, leaf Cu concentration ranged from 4.20 to 15.9 mg kg^{-1} and wide range was noticed for leaf Fe, Mn, Zn and B (Table 1).

Table 1. Range and mean of leaf nutrient concentration in the entire population

Nutrient	Unit	Range	Mean
N	%	1.36 - 2.31	1.79
P	%	0.064 - 0.229	0.109
K	%	0.65 - 1.55	0.99
Ca	%	1.11 - 2.89	1.96
Mg	%	0.46 - 0.73	0.64
S	%	0.27 - 0.86	0.58
Fe	mg kg^{-1}	100 - 278	178
Mn	mg kg^{-1}	18.4 - 97.4	51.7
Zn	mg kg^{-1}	10.0 - 43.0	17.1
Cu	mg kg^{-1}	4.2 - 15.9	7.26
B	mg kg^{-1}	21.6 - 82.7	48.8

Table 2. DRIS ratio norms for sapota

Selected Ratio	DRIS norm	CV (%)	Selected Ratio	DRIS norm	CV (%)
N/P	18.55	28	Ca/S	3.432	26
N/K	1.731	23	Fe/Ca	92.080	25
N/Ca	0.928	20	Mn/Ca	26.540	38
Mg/N	0.360	11	Ca/Zn	0.116	23
N/S	3.112	25	Cu/Ca	3.656	36
Fe/N	99.89	19	Ca/B	0.040	22
N/Mn	0.038	26	Mg/S	1.103	19
N/Cu	0.104	18	Fe/Mg	278.600	19
Zn/N	3.963	30	Mg/Mn	0.013	28
N/B	0.037	23	Mg/Zn	0.037	16
P/K	0.102	40	Cu/Mg	10.980	28
P/Ca	0.055	44	Mg/B	0.013	20
P/Mg	0.166	37	Fe/S	307.300	27
P/S	0.183	42	Mn/S	88.590	39
P/Fe	0.0006	41	Zn/S	30.540	29
P/Mn	0.002	42	Cu/S	11.990	28
P/Zn	0.006	38	S/B	0.012	27
P/Cu	0.015	27	Mn/Fe	0.300	41
P/B	0.002	42	Fe/Zn	10.390	22
Ca/K	1.943	30	Cu/Fe	0.040	26
Mg/K	0.621	23	Fe/B	3.667	28
S/K	0.585	31	Mn/Zn	3.045	40
Fe/K	170.5	24	Cu/Mn	0.149	38
Mn/K	49.72	41	Mn/B	1.062	40
Zn/K	16.72	22	Cu/Zn	0.407	30
Cu/K	6.728	32	Zn/B	0.362	27
B/K	49.36	32	Cu/B	0.145	37
Mg/Ca	0.329	14	—	—	—

CV = Co-efficient of variation expressed as per cent

DRIS ratio norms for sapota

Fifty-five nutrient ratio expressions were chosen as diagnostic norms from high- yielding population and were presented along with their co-efficient of variations (Table 2). As suggested by Walworth and Sumner (1987), nutrient ratios with lower co-efficient of variation and higher variance were selected as diagnostic norms, as these were found to have greater diagnostic precision. Important nutrient ratio expressions were N/K (1.731), N/Ca (0.928), Mg/N (0.360), Fe/N (99.89), N/Cu (0.104), N/B (0.037), Mg/Ca (0.329), Ca/B (0.040), Mg/S (1.103), Fe/Mg (278.6), Mg/Zn (0.037), Mg/B (0.013), Fe/Zn (10.39), etc. Maintaining ratios of some expressions at an optimum, when these were with large coefficient of variation, is much less critical for performance of the crop (Anjaneyulu, 2007). Therefore, nutrients considered as yield-building components need to be kept in a state of relative balance to achieve maximum efficiency of dry matter production.

DRIS indices and nutritional balance index (NBI)

DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. Relative abundance of each nutrient was evaluated by comparing all ratios containing that particular nutrient with DRIS norms. Thus, nutrients were arranged in the order of importance in which they limit yield (Table 3). DRIS simultaneously identified imbalances, deficiencies and excesses in crop nutrients and ranked them in order of importance (Walworth and Sumner, 1987). As the value of each ratio function was added to one index sub-total, and subtracted from another prior to averaging, all indices were balanced around zero. Therefore, nutrient indices summed up to zero indicating an optimum level, negative values showing a relative deficiency and positive values a relative excess of that nutrient (Mourao Filho, 2004).

The absolute sum values of nutrient indices generated an additional index called the “Nutritional Balance Index” (NBI). This indicated an overall imbalance of nutrients in each low-yielding orchard, based on the sum of indices, irrespective of sign. Higher the NBI, larger is the plant nutritional imbalance and, thus, lower the yield (Mourao Filho, 2004). Yield-limiting nutrients differed from orchard to orchard, though some nutrients were more prominent. Thus, diagnosis of nutrient imbalance through DRIS indices showed that K was the most common yield-

Table 3. DRIS indices, order of nutrient requirement and nutritional balance index (NBI) for selected low-yielding sapota orchards

Sl. No.	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B	NBI	Order of limiting nutrients
1	-48	1	116	188	121	111	-88	-87	-147	68	-235	1210	B>Zn>Fe>Mn
2	76	252	-109	24	61	-65	87	-14	-103	217	-426	1434	B>K> Zn>S
3	19	-25	-183	-105	45	97	-54	-110	39	117	159	952	K>Mn>Ca>Fe
4	-8	51	-145	-2	45	131	126	25	-109	64	-178	884	B>K>Zn>N
5	68	-16	-108	-52	-105	135	150	337	-198	-27	-184	1380	Zn>B>K>Mg
6	-46	10	-125	141	61	84	138	163	-1	-23	-402	1194	B>K>N>Cu
7	107	-18	-117	98	95	-14	2	29	-203	-30	51	764	Zn>K>Cu>P
8	90	-70	-111	77	42	-28	-45	12	-22	-6	62	566	K>P>Fe>S
9	142	-54	-92	102	73	-52	-61	-6	-88	-3	39	712	K>Zn>Fe>P
10	33	-57	-167	149	39	-91	68	-114	-12	18	134	882	K>Mn>S>P

limiting nutrient among macronutrients, and, B and Zn among micronutrients. Low availability of micronutrients may be attributed to high pH and presence of high amounts of calcium carbonate in soil in many of the orchards (Raghupathi and Bhargava, 1998).

Leaf nutrient standards for sapota

Optimum N ranged from 1.51 to 2.09% indicating that a minimum of 1.51 % N needs to be maintained in the leaf for better growth and production in sapota (Table 4). Optimum K concentration ranged from 0.83 to 1.44%, reflecting a wide variation. Calcium content in sapota leaves was higher compared to N, P and K nutrients, indicating higher root activity and adequate absorption of Ca from a soil rich in Ca. Physiological role of Ca in vital functions of a plant is well-known. It appears that calcium concentration in the plant is largely governed by new flushes and flowering pattern in the case of sapota. Optimum leaf Mg norms for sapota were 0.54 to 0.68%. Raghupathi and Bhargava (1998) noticed a similar range for Ca and Mg in pomegranate growing in Bijapur district of Karnataka. Sulphur content was higher compared that in other fruit crops, and optimum S concentration ranged from 0.48 to 0.80%. Optimum Fe and Mn concentration ranged from 109 to 206 mg $kg^{-1}$and 49 to 99 mg kg^{-1}, respectively. Wider optimum ranges observed might be due to larger variations in available Fe and Mn in the orchards surveyed. Optimum Zn, Cu and B concentration ranged from 13.3 to 21.9 and 3.76 to 9.10 and 34.8 to 66.8 mg kg^{-1}, respectively. Similar, wider optimum ranges have been observed in other fruit crops like papaya and pomegranate (Anjaneyulu, 2007; Raghupathi and Bhargava, 1998).

Classification of low-yielding orchards

Classification of the orchards based on leaf nutrient norms is presented in Table 5. Classification of the orchards indicated that leaf N was at an optimum in 92 % of the orchards surveyed. Potassium was found to be the major yield-limiting nutrient as leaf K was optimum only in 31 % of the orchards. Among micronutrients, B and Zn were the major yield-limiting nutrients as B was optimum only in 33 % of the orchards, whereas Zn was optimum in 51 % of the orchards. Similar type of classification was reported in papaya (Anjaneyulu, 2007). Thus, the study indicates that DRIS system, which is a holistic approach, identified nutrient imbalances in sapota crop and, therefore, proved to be an important technique for evolving nutrient management strategies for realizing higher yields. Optimum ranges developed will serve as a guide for quick and routine diagnostic advisory purpose in sapota.

Table 4. Leaf nutrient standards for sapota cv. Kalipatti

Nutrient	Unit	Deficient	Low	Optimum	High	Excessive
N	%	<1.22	1.22 - 1.50	1.5 - 2.09	2.10 - 2.37	>2.37
P	%	<0.008	0.008 - 0.060	0.061 - 0.150	0.151 - 0.210	>0.21
K	%	<0.51	0.51 - 0.82	0.83 - 1.44	1.45 - 1.82	>1.82
Ca	%	<0.87	0.87 - 1.35	1.36 - 2.34	2.35 - 2.83	>2.83
Mg	%	<0.47	0.47 - 0.53	0.54 - 0.68	0.69 - 0.75	>0.75
S	%	<0.32	0.32 - 0.47	0.48 - 0.80	0.81 - 0.96	>0.96
Fe	mg kg^{-1}	<61	61.00 - 108	109 - 206	207 - 254	>254
Mn	mg kg^{-1}	<23	23.00 - 48	49 - 99	100 - 135	>135
Zn	mg kg^{-1}	<9.00	9.10 - 13.2	13.3 - 21.9	22.0 - 26.2	>26.2
Cu	mg kg^{-1}	<1.09	1.09 - 3.75	3.76 - 9.10	10.0 - 11.7	>11.7
B	mg kg^{-1}	<18.7	18.70 - 34.7	34.8 - 66.8	66.9 - 82.9	>82.9

Table 5. Classification of low-yielding sapota orchards (%) based on leaf nutrient standards

Element	Deficient	Low	Optimum	High	Excessive
N	0	6	92	2	0
P	0	0	81	14	5
K	0	69	31	0	0
Ca	0	14	67	19	0
Mg	3	3	75	19	0
S	3	31	66	0	0
Fe	0	3	72	19	6
Mn	3	41	56	0	0
Zn	0	49	51	0	0
Cu	0	0	81	13	6
B	0	56	33	11	0

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