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Leaf analysis interpretation in relation to optimum yield of Khasi mandarin (*Citrus reticulata* Blanco)

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ABSTRACT

Cultivar-based nutrient diagnostics are widely used for identifying nutrient deficiencies in commercial citrus orchards. But, the precision of diagnosis is limited by the interpretation tools used in establishing the diagnostic limits. Two commonly used interpretation tools, MQRA and DRIS were tested for their diagnosis, and found to predict different optimum limits. DRIS-based analysis showed optimum values as: 2.52-2.61% N, 0.04-0.05% P, 1.63-1.82% K, 1.32-1.48% Ca, 0.10-0.18% Mg, 214-308 mg/kg Fe, 92-110 mg/kg Mn, 9-12 mg/kg Cu and 9-12 ppm Zn in relation to fruit yield of 9-11 tons/ha/year, while MQRA established the optimum values as : 2.28% N, 0.06% P, 1.68% K, 1.28% Ca, 0.13% Mg, 252 mg/kg Fe, 84 mg/kg Mn, 5 mg/kg Cu, and 10 mg/kg Zn for optimum fruit yield of 7 tons/ha/year. Due to diagnostic values varying in their optimum limits, two statistical models diagnosed contrasting nutritional problems. These observations suggest that two different sets of nutritional problems could be diagnosed if the same set of leaf analysis data is subjected to different interpretation tools. However, DRIS values were further observed much nearer to high performance orchards compared to MQRA. All the orchard sites were diagnosed with the multiple deficiencies of nutrients like Zn > P > Ca > Mg > N > Cu in decreasing order.

Key words: Nutrient diagnostics, 'Khasi' mandarin, optimum yield, DRIS

INTRODUCTION

Developing nutrient diagnostics is a complex exercise because of its specificity to site and cultivar type. The utility of conventional leaf analysis as a diagnostic tool is cut short due to strong influence of leaf age on nutrient composition due to sink-source relationship (Srivastava *et al.* 1999). The currently available interpretation tool like multivariate quadratic regression analysis (MQRA) is applicable only to narrowly specified developmental stage of crop i.e. using stable period for index leaf sampling (Bhargava and Srivastava 2006), besides being recommended on the basis of single value concentration. Absence of commonality in nutrient diagnostic methods amounts to large variation in the field suggested nutrient limits-

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due to variation in interpretation tools used in arriving at these values. Such attempts could be largely attributed to erroneous identification of problems and, hence, suboptimum orchard production continues unabated. This is very much evident from far lower productivity of citrus orchards in northeast India including Nagaland (5.6 tons/ha) compared to national average of 10.1 tons/ha/year (Srivastava and Singh 2006).

Diagnosis and recommendation integrated system (DRIS) on the other hand has certain advantages over conventional MQRA-based interpretation tools (Beverly 1987; Hundal and Arora 2001). These include: ability of DRIS to reflect nutrient balance that remains fairly stable across different developmental stages, well proven ability to identify the order in which different nutrients are responsible for limiting the fruit yield, and more importantly its ability to make diagnosis at any stage of crop development so that timely remediation of any nutrient constraint could be effectively addressed. Limited efforts in the past have successfully established the DRIS norms (Beverly *et al.,* 1984; Sumner 1985; Varalaxmi and Bhargava 1998; Hundal and Arora 2001) for cultivars such as, 'Valencia' sweet orange (*Citrus sinsensis* Osbeck), 'Kagzi' lime (*Citrus aurantifolia* Swingle), and 'Kinnow' mandarin, (a hybrid of *Citrus deliciosa* Ten and *Citrus nobilis* Lour). No sincere effort has been made to develop DRIS norms for any of the major mandarin cultivars, especially those grown under soil-climate of southeast Asia (Ghosh and Singh 1993). 'Khasi' mandarin (*Citrus reticulata* Blanco) is one such cultivar grown under soil and climate of northeast India, different from the other mandarin belts elsewhere in the world. In this background, efforts were made to analyse difference in optimum leaf nutrient limits in relation to interpretation tools like MQRA versus DRIS analysis and validate the results by comparing with leaf nutrient composition from high performance orchards.

MATERIALS AND METHODS

Experimental set-up

A set of 12 'Khasi' mandarin orchards (exclusively seedlings) was earmarked out of 42 total number of orchards studied through benchmark survey. These earmarked orchards were represented by different locations viz., Socunoma and Tsuuma areas of Dimapur; Jalukie from Peren; Janbonthung, Pongidong and Baktu areas from Wokha district; Tokongin, Chungtia, Aliba, Longnak and Thensa areas of Mokokuchung districts of Nagaland. The orchards selected were established on different physiographic positions like plainland, hill slope, valley land etc. Agro-climatically, these orchards belong to humid tropical climate with mean annual rainfall of 2100 mm (major proportion received during June to October), maximum and minimum temperatures varying from 18.2-28.8°C and 7.2-18.1°C, respectively, with annual variation in relative humidity of 52-86%. The major soil orders of the orchards established were : Entisols, Inceptisols, Alfisols, and Ultisols. The final set of orchards were studied three times to accommodate year-to-year fruit yield variation. All the interpretation were made on the basis of 36 data sets.

Leaf sampling and analysis

The spring flush index leaves (5-7 month old) from non-fruiting terminals were collected. Simultaneously, fruit yield data were also recorded. The leaf samples were thoroughly washed (Chapman 1964), ground using Willey Grinding Machine to obtain homogenous samples (30-40 mesh sieve) and subsequently digested in tri-acid mixture of $HClO_4$: HNO_3: H_2SO_4 in 2:5:1. Analyses consisted of : (Chapman and Pratt 1961) N by auto-nitrogen analyser (Model-Perkin Elmer-2410), P using vanadomolybdo-phosphoric acid method, K flame photometrically, Ca, Mg through versene titration and micronutrients (Fe, Mn, Cu and Zn) by atomic absorption spectrophotometer (Model GBC-908).

Statistical analysis

The optimum values of leaf nutrient concentration in relation to fruit yield (Srivastava and Singh 1998) were fixed through MQRA ($Y = a + b_1 x_1 + b_2 x_2$ .... $b_n x_n + b_1 x_1^2$ .... $b_n x_n^2$, where a is intercept, b_1--b_n regression coefficient, x_1 --- x_n independent variables, and Y as dependent variable for yield). Similarly, for DRIS analysis, procedure initially developed by Beaufils (1973) and modified by Bhargava (2002) using PC-based programme was used. DRIS technique consists of describing the nutrient status of high yielding population, and identifying variation from those conditions in unknown samples. These observations were divided into high-and-low yielding sub-populations, using 50 kg/tree as cut-off yield level (averaged yield level usually obtained at growers' field) to separate the sub-populations. For the two sub-populations, the mean (x^{-}), standard deviation, and variance (S^2) were calculated for each nutrient concentration and all ratios between nutrient concentrations (N/P, N,/K, P/K, etc.). A variance ratio (S^2 for low-yielding population/S^2 for high yielding population) was calculated for each nutrient concentration, and for two ratios involving each pair of nutrients, finally selecting the one with the larger variance ratio. The mean and coefficient of variation (CV) values in the high-yield population for the selected ratios were used for calculating DRIS indices. The nutrient with the most negative index was considered the most deficient and most limiting to fruit yield and vice-versa.

The following procedure initially developed by Beaufils (1973) and modified by Bhargava (2002) was used through a PC based program for the development of DRIS norms: i. defining the parameters to be improved and the factors likely to affect them, ii. collection of all reliable data available from the fields and experimental plots, iii. study the relationship between the yield and available nutrients in soil, iv. establishment of a relationship between the yield and leaf nutrient composition using the following steps: a. each internal plant parameter was expressed in as far as possible e.g. N/DM, N/P, P/N, N x P etc.; b. the whole population was divided into a number of subgroups based on the economic optimum; c. the mean of each sub-population was calculated for the various forms of expressions; d. if necessary, class interval limits between the average and the outstanding yields were readjusted, so that the means of below average populations remain comparable; e. Chi-square test was performed to ensure that populations confirm to normal distribution; f. the variance ratios between the yield of sub-populations for all forms of expressions were calculated together with the coefficient of variation; g. the forms of expressions, for which significant variance ratios were obtained and essentially the same mean values for the population were selected in expression with common nutrient; and h.for the calculation of DRIS indices based on leaf analysis the following equations were developed:

where N/P is the actual value of the ratio of N and P in the plant under diagnosis, n/p the value of the norm (the mean value of high yielding orchards), and CV, the coefficient of variation for population of high yielding orchards.

The norms for classification of nutrients in leaves were derived using them as mean of high yielding orchards as the mean for optimum. The optimum range of optimum is the value derived from mean - 4/3 to +4/3 standard deviation. The lowest range was obtained by calculating –4/3 to mean –8/3 standard deviation, and the value below mean –8/3 standard deviation was considered deficient. The value from mean +4.3 to mean +8.3 standard deviation was considered as an excess limit.

$$N = 1/9\,[f(N/P) + f(N/K) + f(N/Ca) + f(N/Mg) + f(N/Fe) + f(N/Mn) + f(N/Cu) + f(N/Zn)]$$

where, f(N/P) for example =

$$\left(\frac{N/P}{n/p} - 1\right)\left(\frac{1000}{CV}\right) \quad \text{When } N/P > n/p$$

and

$$\left(1 - \frac{n/p}{N/P}\right)\left(\frac{1000}{C/V}\right) \quad \text{When } N/P > n/p$$

RESULTS AND DISCUSSION

Interpretation tool and diagnostic limit

The leaf nutrient composition showed a variation of different nutrients viz., 2.12-2.92% N, 0.06-0.08% P, 1.62-1.89% K, 1.28-1.59% Ca, 0.12-0.18% Mg, 212-406 mg/kg Fe, 81-116 mg/kg Mn, 4-18 mg/kg Cu and 8-14 mg/kg Zn with a fruit yield of 3-20 tons/ha/year (Table 1).

The optimum values predicted through DRIS were observed as: 2.52-2.61% N, 0.04-0.05% P, 1.63-1.82% K, 1.32-1.48% Ca, 0.10-0.18% Mg, 214-308 mg/kg Fe, 92-110 mg/kg Mn, 9-12 mg/kg Cu and 9-12 mg/kg Zn in relation to fruit yield of 9-11 tons/ha/year (Table 2). These values find no match with the values for different citrus cultivars grown under similar agro-climate. For example, in China the optimum leaf nutrient values measured 3.0-3.5 % N, 0.15-0.18 % P, 1.0-1.6 % K, 2.5-5.0 % Ca, 0.30-0.60 % Mg, 50-120 mg/kg Fe, 25-100 mg/kg Mn, 4-100 mg/kg Cu, and 25-100 mg/kg Zn for 'Satsuma' mandarin on Trifoliate orange grown on quaternary red earth using third leaf from vegetative terminals (Wang 1985). Such variation emerging out of the cultivars

Table 1. Leaf nutrient composition of 'Khasi' mandarin orchards in relation to fruit yield at different locations in Nagaland

Sr. No	Location	Macronutrients (%)					Micronutrients (mg/kg)				Yield (tons/ ha/ year)
		N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	
1.	Socunoma, Dimapur	2.12	0.06	1.79	1.32	0.12	406	86	5	8	5
2.	Tsuuma, Dimapur	2.20	0.06	1.74	1.28	0.12	318	81	4	8	3
3.	Jalukie, Peren	2.22	0.07	1.62	1.29	0.12	312	82	6	8	4
4.	Janbonthung, Wokha	2.61	0.06	1.82	1.42	0.15	248	106	8	12	15
5.	Pongidong, Wokha	2.32	0.06	1.78	1.32	0.14	266	92	10	13	13
6.	Baktu, Wokha	2.22	0.06	1.68	1.29	0.14	261	82	16	14	9
7.	Tokongin, Moksokuchung	2.40	0.07	1.80	1.48	0.18	280	104	16	13	15
8.	Chungtia, Mokokuchung	2.82	0.08	1.72	1.59	0.18	222	116	18	14	20
9.	Aliba, Mokokuchung	2.92	0.08	1.89	1.52	0.18	222	112	16	13	18
10.	Aliba, Mokokuchung	2.52	0.06	1.79	1.40	0.14	246	100	16	14	14
11.	Longnak, Mokokuchung	2.48	0.06	1.48	1.39	0.14	272	96	12	11	12
12.	Thensa, Mokokuchung	2.82	0.07	1.71	1.50	0.18	212	114	18	14	17

grown under similar soil and climate was largely ascribed to the cultural practices in addition to rootstock behaviour in nutrient acquisition and transport.

While, MQRA determined the optimum values as : 2.28% N, 0.06%P, 1.68% K, 1.28% Ca, 0.13% Mg, 252 mg/kg, Fe, 84 mg/kg Mn, 5 mg/kg Cu, and 10 mg/kg Zn in relation to optimum fruit yield of 7.3 tons/ha/year according to equation : Y (Yield) = $255.90 + 6.12x_1(N) + 22.12\ x_2\ (P) + 4.32\ x_3\ (K) + 11.12\ x_4\ (Ca) + 9.21x_5\ (Mg) + 0.02x_6(Fe) + 142.89\ x_7(Mn) + 589.62x_8\ (Cu) + 82.68\ x_9\ (Zn) - 182.11x_1^2 - 5001.10x_2^2 + 42.11x_3^2 - 812.32x_4^2 - 318.21x_5^2 - 0.02x_6^2 - 0.41x_7^2 - 28.19x_8^2 - 6.11x_9^2$. Under similar conditions in Brazil the optimum leaf nutrients values were observed as : 2.3-2.7% N, 0.12-0.16% P, 1.0-1.5% K, 3.5-4.5% Ca, 0.25-0.40% Mg, 50-120 mg/kg Fe, 35-50 mg/kg Mn, 4-10 mg/kg Cu, and 35-50 mg/kg Zn for 'Pera' sweet orange on Rangpur lime rootstock (Quaggio *et al.*, 1996).

Comparison of diagnostic values

The original field observations were partitioned using the data on leaf nutrient levels in relation to fruit yield (Table 3). The optimum values obtained using DRIS analysis corroborated with original field values suggesting good predictability of DRIS analysis in addressing the nutritional problems existing in the orchards.

Table 2. DRIS-based leaf nutrient limits in relation to fruit yield of 'Khasi' mandarin grown in northeast India

Nutrients	Indices				
	Deficient	Low	Optimum	High	Excess
N(%)	<1.83	1.83-2.51	2.52-2.61	2.62-2.82	>2.82
P(%)	<0.03	0.03-0.04	0.04-0.05	0.05-0.08	>0.08
K(%)	<1.42	1.42-1.62	1.63-1.82	1.82-2.10	>2.10
Ca(%)	<1.19	1.19-1.31	1.32-1.48	1.49-1.82	>1.82
Mg(%)	<0.08	0.08-0.09	0.10-0.18	0.19-0.26	>0.26
Fe (mg/kg)	<182	182-213	214-308	308-450	>450
Mn (mg/kg)	<69	69-91	92-110	111-128	>128
Cu (mg/kg)	<7	7-8	9-12	13-17	>17
Zn (mg/kg)	<6	6-8	9-12	13-18	>18
Yield (tons/ha/ year)	<5	5-9	9-11	11-19	>19

Two statistical models predicated different optimum nutrient concentration and fruit yield, and diagnosed contrasting nutritional problems. These observations suggest that two different sets of nutritional problems could be diagnosed depending upon the diagnostic tool used for interpretation of leaf analysis data. DRIS-derived values were observed very much close to the values obtained from high performance orchards (2.38-2.48% N, 0.06-0.07% P, 1.52-1.72% K, 1.29-1.39% Ca, 0.12-0.16% Mg, 212-222 mg/kg Fe, 81-90 mg/kg Mn, 6-9 mg/kg Cu, 10-14 mg/kg Zn and 12-20 tons/ha/year), suggesting the good predictability of the model to be able to address the problems existing in field (Table 4). Similar attempts were earlier made by Chundawat *et al.*, (1991) for acid lime orchards based on nutritional status of elite orchards, which suggested optimum levels as: 2.20-2.80 % N, 1.00-1.89 % P and 0.71-1.14 % K. The citrus fertilizer requirement was, hence, determined as 600-800 g N, 200-250 g P, 300-400 g K, 100-125 g Mn, 75-100 g Cu and 150-200 g Zn/tree/year as adopted in high performance orchards, considering DRIS-derived optimum fruit yield of 9-11 tons/ha/year.

Table 3. Leaf nutrient levels at different productivity levels of 'Khasi' mandarin orchards based on original orchard data

Nutrients	Yield levels (tons/ha/year)				
	0-4	4-8	8-12	12-20	20-24
N(%)	2.20	2.17	2.35	2.46	2.85
P(%)	0.06	0.07	0.07	0.07	0.08
K(%)	1.58	1.71	1.74	1.78	1.77
Ca(%)	1.28	1.31	1.34	1.41	1.54
Mg(%)	0.12	0.12	0.14	0.15	0.18
Fe(mg/kg)	318	359	266	260	219
Mn(mg/kg)	81	84	89	100	114
Cu(mg/kg)	4	6	10	13	18
Zn(mg/kg)	8	8	13	13	14

Table 4. Comparison of DRIS-derived values with high performance orchards

Nutrients	High performance orchards	DRIS-derived values
N(%)	2.38-2.48	2.52-2.61
P(%)	0.06-0.07	0.04-0.05
K(%)	1.52-1.72	1.63-1.82
Ca(%)	1.28-1.39	1.32-1.48
Mg(%)	0.12-0.16	0.10-0.18
Fe (mg lkg)	212-222	214-308
Mn (mg lkg)	81-90	92-110
Cu (mg lkg)	6-9	9-12
Zn (mg lkg)	10-14	9-12
Yield (tons/ha/year)	12-20	9-11

Zn and P deficiencies are corrected, Ca would be the next nutrient followed by Mg, N and Cu in that order to limit fruit yield. The large scale B-deficiency was predominantly observed in the form of hard peel of fruits with juice vesiculation. Considering the location specific multiple nutrient deficiencies, site specific nutrient management strategy using variable rate application technology has proved very effective in maintaining optimum orchard productivity.

In a long-term experiment, the large fruit yield difference of 8.4 tons/ha/year and 5.2 tons/ha/year, initially observed on shallow soil (Typic Ustorthent) and deep soil (Typic Haplustert) in an orchard size of 11 ha, increased to respective fruit yield

Table 5. Nutrient diagnosis using DRIS indices in 'Khasi' mandarin (*Citrus reticulata* Blanco) orchards through leaf analysis (on mean basis)

Nutrients found low and deficient							Nutrients found high and excess			Yield (tons/ha/year)
Nutrient	Zn	P	Ca	Mg	N	Cu	Mn	K	Fe	
Status	10.1	0.06	1.26	0.16	2.18	6.8	98.2	1.72	264.6	11
DRIS Indices	-218	-141	-95	-79	-65	-23	164	182	275	

All the orchard sites were diagnosed to have the problem of multiple deficiencies of nutrients such as Zn > P > Ca > Mg > N> Cu in the order of decreasing intensities (Table 5). These observations further suggested that if Zn, being the most deficient nutrient, is rectified, the next nutrient that will limit the fruit yield, would be P. If of 17.4 and 19.4 tons/ha/year with corresponding fertilizer doses (g/tree/year) of 1200 N – 600 P – 600 K – 75 Fe - 75 Mn -75 Zn – 30 B, and 600 N – 400 P – 300 K – 75 Fe – 75 Mn –75 Zn – 30 B, suggesting the necessity of fertilizer application on variable rate application for rationality in fertilizer use (Srivastava *et al.*, 2006)

CONCLUSION

These results suggest that the leaf nutrient values obtained from high performance orchards could very well serve as benchmark values for identifying nutrient deficiencies of 'Khasi' mandarin orchards, in the absence of well establish nutrient diagnostics. Since the development of nutrient diagnostics is time consuming, it holds field utility only when the values are validated through field response studies.

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