

Diagnosis of leaf nutrient levels for optimum productivity of *Citrus reticulata* Blanco grown in black clay soils under a sub-humid tropical climate

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ABSTRACT

Nagpur mandarin (*Citrus reticulata* Blanco) orchards under hot sub-humid tropical climate of Central India were surveyed with a view to diagnose the nutrient constraints through leaf and soil analysis, to understand comparative reliability of leaf versus soil analysis and to identify optimum and critical leaf nutrient levels vis-a-vis fruit yield. A total of 178 km² of Nagpur mandarin growing areas was surveyed covering 112 sites of Central India having black montmorillonitic clay soils. Five to seven months old middle leaves (2nd, 3rd or 4th leaf from non-fruiting shoots) were collected at a height of 1.5 to 1.8 m from the ground. The soil samples were collected at a depth of 0-20 cm and at a distance of 110 to 125 cm from the trunk. The collected leaf and soil samples were analyzed for N, P, K, Ca and Mg content. The leaf analysis showed that nitrogen was deficient in 60.1% orchards, phosphorus low to deficient in 37.7% orchards and potassium was in optimum to high range in as many as 77.6% orchards. Despite sufficient K level as per foliar analysis, the response to K fertilization suggested a hidden-hunger for K. The leaf Ca and Mg levels were found to be low to deficient in 99.6% and 64.1% orchards, respectively. But the soils possessed high available Ca + Mg (871.2 mg kg⁻¹) and K (188.0 mg kg⁻¹) on an average. Under such conditions, the competition between K and Ca or Mg ions at the soil-root interface restricted the uptake of Ca and Mg ions which resulted in low leaf Ca and Mg levels. The leaf nutrient values were more correlated with fruit yield than soil available nutrients. The degree of relationship was still higher in quadratic than in linear correlation analysis. It is suggested that leaf nutrients levels as of: N 2.34%, P 0.08%, K 1.56%, Ca 1.51% and Mg 0.67% for optimum fruit yield of 636.4 fruits plant⁻¹. The critical leaf nutrient level was observed as: N 2.0%, P 0.06%, K 1.35%, Ca 1.35% and Mg 0.23% for fruit yield of 600.0 plant⁻¹. The above information could be fittingly utilised for nutritional evaluation of Nagpur mandarin orchards.

Key words: Central India, fruit yield, leaf nutrient levels, Nagpur mandarin, soil fertility.

INTRODUCTION

Citrus reticulata Blanco cv. Nagpur mandarin is primarily cultivated in black clay soils (Entisol, Inceptisol and Vertisol) under hot sub-humid tropical climate of Central India in an area of 67000 ha with a total annual production of 0.40 million tons. The average productivity of Nagpur mandarin is 6.0 tons ha⁻¹ and is far below the average production of cultivars such as Valencia orange, Washington navel (*Citrus sinensis* Osbeck) and Satsuma mandarin (*Citrus unshiu* Marc) etc. grown in USA, Brazil, China and Japan. Only 2% Nagpur mandarin orchards in Central India receive recommended doses of fertilizers (Deshmukh *et al.* 1988). Most of the mandarin orchards are fertilized with 20 to 50 kg farmyard manure tree⁻¹ year⁻¹. This level is not sufficient to meet the nutritional

requirements of orchards located in Central India (Kohli *et al.* 1992). Inadequate nutrition of these orchards is considered as one of the prime causes for low productivity. Leaf (Jones and Embleton 1969; Du Plessis 1977) and soil analysis (Du Plessis 1977; Jorgensen and Price 1978) are the two available tools of diagnosing the nutrient status of citrus orchards.

The most important criterion of citrus fertilization is to achieve maximum yields (Rosselet *et al.* 1962; De Villiers 1969). However, with more number of fruits tree⁻¹, the desirable size of fruits is difficult to obtain which eventually reduces the export quality of citrus fruits. The nutritional research is, therefore, now directed towards optimum productivity with quality fruits. Such an approach is far more promising in order to maintain the sustained productivity for a number of years without affecting the fruit quality.

No information is available at present regarding the leaf nutrient levels required to maintain optimum yields of any of the commercial mandarin cultivars grown in India. The leaf nutrient standards earlier developed in USA (Jones and Embleton 1969), Brazil (Rodriguez and Gallo 1961), Australia (Gollasch *et al.* 1984) and other citrus growing countries have also not shown promising results under Indian conditions due to differences in cultivar requirement, growth habit, existing cultural practices, soil, climate and yield level. Therefore present investigation was initiated with the objectives to find out the nutrient constraints of Nagpur mandarin orchards through leaf and soil analysis, comparative reliability of leaf versus soil analysis for correct diagnosis of nutritional problems and the optimum and critical leaf nutrient levels in relation to productivity of Nagpur mandarin.

MATERIALS AND METHODS

A nutritional survey of 178 Nagpur mandarin orchards located in hot sub-humid tropical climate of Central India covering 112 sites located in Kalmeshwar, Katol, Narkhed, Ramtek, Hingna and Saoner tehsils of Nagpur district was conducted during 1992-95, which represented an area of 178 km². All the orchards have used the combination of *Citrus jambhiri* Lush as rootstock and Nagpur mandarin as scion. The orchards were established in three soil orders viz., Entisol, Inceptisol and Vertisol derived predominantly from basalt type of parent material having basically montmorillonitic clay. The soil pH varied between 7.2 to 7.8, the electrical conductivity ranged between 0.12 - 0.28 dSm⁻¹ and texture from sandy clay loam to clay. The climate of the area was characterized by hot and dry pre-monsoon summer months (March - May) followed by well defined summer monsoon conditions (June-September). The subsequent short period of October and November receives uncertain and infrequent rains followed by a fairly dry and mild winter (December-February). The mean summer (April, May and June) and winter (December, January and February) temperature vary from 35-45 °C and from 15-22°C, respectively. The annual rainfall ranges from 750-1350 mm of which 80-90% is received during monsoon months (June - September).

Leaf and soil sampling

In hot sub-humid tropical climate of Central India, two major flushes occur in Nagpur mandarin cultivar. The flushes appearing in February are called *Ambia* and those of July *Mrig*. The mandarin

orchards were surveyed during both *Ambia* and *Mrig* flush. The leaf and soil samples were taken between August - October and December - February, respectively (Srivastava *et al.* 1995). A 40-50 middle leaf samples from 2nd, 3rd or 4th leaf from non-fruiting terminals facing all four directions were collected at a height of 1.5 to 1.8 m from the ground. The soil samples were collected from the zone of maximum feeder root concentration at a depth of 0-20 cm and at a distance of 110 to 125 cm from the trunk.

Sample preparation and analysis

The collected 178 leaf samples were thoroughly washed (Chapman 1964), dried and ground to obtain a homogenous sample. The leaf samples were digested in a di-acid mixture of 2 parts of H₂SO₄ and one part HClO₄. The acid digests of 178 leaf samples were analysed for N by micro-Kjeldahl method, P by vanadomolybdophosphoric acid yellow colour method, K by flamephotometric method and Ca and Mg using versene titration method (Jackson 1973). The soil samples were dried at an ambient temperature, ground and sieved through 2 mm sieve. The samples were analysed for available N (Subbiah and Asiza 1956), P using phosphomolybdate blue colour method (Jackson 1973), K flame photometrically, Ca and Mg titrimetrically after extracting the soil with 1 N neutral NH₄OAC (Du Plessis 1977).

Statistical evaluation

The data were subjected to linear and quadratic multiple correlation and regression analyses in order to diagnose the optimum leaf and available soil nutrients in relation to fruit yield. The optimum levels of different nutrients were fixed through multivariate quadratic response model. The critical levels of N, P, K, Ca and Mg were worked out following the procedure suggested by Cate and Nelson (1965). According to this procedure, two lines parallel to X and Y axis were drawn on arithmetic graph paper in such a way that maximum number of observations accommodated in upper right and lower left quadrants. The point of intersection of the lines parallel to X and Y axis was fixed as critical level.

RESULTS AND DISCUSSION

Nutrient constraints of mandarin orchards

Most frequently, leaf analysis is used as a primary indicator of nutrient status of orchards while the

soil analysis is used as an indicator of the nutrient sources available to the plants (Jorgensen and Price 1978). Hence, the leaf and soil analysis in this study were used as a diagnostic criteria for identification of nutritional problems of mandarin orchards.

Foliar diagnosis

The leaf N, P and K content of surveyed orchards of the present study varied from 0.90 to 3.00% (mean 2.06%), 0.04 to 0.24% (mean 0.12%) and from 0.40 to 3.98% (mean 1.46%), respectively. Leaf Ca and Mg showed a variation of 0.42 to 3.10% (mean 1.58%) and 0.12 to 1.36% (mean 0.40%), respectively (Table 1). The nutrient constraints of mandarin orchards were identified according to the leaf nutrient standards developed for sweet orange cultivars Valencia orange and Washington navel (Jones and Embleton 1969). According to above standards, the optimum level of N as 2.4 to 2.6%, P as 0.12 to 0.16% and K as 0.70 to 1.09% were suggested for identifying the nutritional problems of citrus orchards. In the present study, using the same standards, the nitrogen was found to be the most

Table 1. Leaf nutrient content of Nagpur mandarin orchards of Central India (Based on 178 Nagpur mandarin orchards).

Nutrient	Range(%)	Mean(%)	SEm (±)
Nitrogen	0.90-3.00	2.06	0.10
Phosphorus	0.04-0.24	0.12	0.04
Potassium	0.40-3.98	1.46	0.09
Calcium	0.42-3.10	1.58	0.06
Magnesium	0.12-1.36	0.40	0.02

limiting nutrient, deficient in 60.1% orchards of studied area followed by phosphorus low to deficient in 37.7% orchards. the leaf K status was between optimum to high in as many as 77.6% orchards. But our earlier studies on the effect of graded doses of K fertilizer showed very good response to K₂O application at rate of 300 g plant⁻¹ at an initial leaf K content of 0.70% (Kohli *et al.* 1994). Such a response to K application indicated the presence of hidden hunger for K by the crop. Simple leaf analysis at a given time therefore may not correctly delineate the problems associated with K nutrition.

On the basis of optimum leaf Ca at 3.0 to 5.5% and optimum leaf Mg at 0.26 to 0.60% (Jones and Embleton 1969), 99.4% and 64.1% orchards in the present study were observed to have low to deficient level of Ca and Mg, respectively (Table 2). The high soil K fertility level in the black clay soils of Central India would have induced competitive uptake of Ca and Mg which lend support to the low to deficient level of Ca and Mg.

Table 2. Classification of leaf nutrient content into supply levels.

Nutrient	Deficient		Low		Optimum		High		Excess	
	No.	%	No.	%	No.	%	No.	%	No.	%
Nitrogen	107	60.1	31	17.4	27	15.2	27	15.2	03	1.7
Phosphorus	27	15.2	40	22.5	100	56.2	07	3.9	04	2.2
Potassium	-	-	08	4.5	50	28.1	88	49.5	32	18.0
Calcium	70	39.3	107	60.1	1	0.56	-	-	-	-
Magnesium	16	9.0	98	55.1	18	10.1	23	12.9	23	12.9

Table 3: Available nutrient status of Nagpur mandarin orchards soils of Central India.

Nutrient	Range, mg kg ⁻¹	Mean, mg kg ⁻¹	SEm (±)
Nitrogen	85.5-279.7	129.7	4.2
Phosphorus	4.5-30.5	14.4	1.8
Potassium	32.0-382.5	188.0	6.2
Calcium+Magnesium	374.7-2016.0	871.2	11.4

Table 4. Available soil nutrient content into supply levels.

Nutrient element	Low		Index Medium		High	
	No.	%	No.	%	No.	%
Nitrogen	106	59.5	71	40	01	0.5
Phosphorus	74	41.6	86	48.3	18	10.5
Potassium	07	4.0	05	2.8	166	93.2

Diagnosis through soil analysis

The available N, P, K and Ca + Mg contents of the orchards under study varied from 65.5 to 279.7 mg kg⁻¹, 4.5 to 30.5 mg kg⁻¹, 32.0 to 382.5 mg kg⁻¹ and from 374.4 to 2016.0 mg kg⁻¹, respectively (Table 3). Well established standards for available nutrients in soil is not available for evaluating the fertility status of citrus orchard soils. The interpretations were made on the basis of suggested optimum level of N as 125 to 250 mg kg⁻¹ (Subbiah and Asiza 1956), P as 12.5 to 25.0 mg kg⁻¹ (Mohr *et al.* 1965) and K as 90 to 100 mg kg⁻¹ (Du Plessis *et al.* 1975). The available N in the orchards under investigation was found to be in optimum range in 40.5% orchards and low in 59.5% orchards (Table 4). Available P was observed in optimum range in 48.3% orchards and low in 41.6% orchards. Most of the orchards possessed a high level of available K (Table 4). The water soluble plus exchangeable Ca + Mg was invariably high in all the orchards.

Comparative reliability of leaf versus soil analysis

The comparison of linear and quadratic R² values for leaf nutrient content versus fruit yield and available N, P, K and Ca + Mg content in soil versus fruit yield showed a comparatively higher degree of correlation between leaf nutrient content and fruit yield in quadratic relation (Table 5). Only Ca + Mg content in soil showed better correlation with fruit yield as compared to either leaf Ca or Mg alone. These observations indicated the greater reliability of leaf than soil analysis for the diagnosis of status of most

Table 5 Linear and quadratic correlation values (R^2) of leaf nutrient contents and available nutrient in soil with fruit yield.

Fruit yield	N	P	K	Ca	Mg
Leaf nutrient Content	0.232 *(0.233)	0.011 (0.029)	0.000 (0.072)	0.002 (0.0340)	0.058 (0.066)
Soil available nutrients	0.112 (0.148)	0.011 (0.072)	0.015 (0.072)	0.014 **(0.382)	

* Figures in paranthesis indicate quadratic R^2 values

* Correlation was worked out with Ca + Mg content

of the nutrients except Ca and Mg. The poor efficacy of soil over leaf analysis in identifying the nutritional problems could be ascribed to perennial nature of crop having roots active at a considerable depth (Castle and Krezdorn 1975), nature of soil (Buol 1973) and climatic conditions (Davis and Sakamoto 1976) conducive for leaching of applied fertilizers.

The soil available K and leaf K content in the present study was highly correlated ($r = 0.62$) and leaf K content increased at the rate of 0.14% per 10 mg kg⁻¹ increase in available K (leaf K = 0.54 + 0.014 available K). A strong simple predictive correlation between given soil and leaf element such as above could prove very effective in evaluating the response of fertilization.

Leaf nutrients level for optimum yield

The N, P, K, Ca and Mg contents were correlated with fruit yield and a suitable multivariate response function model was developed:

$$Y(\text{fruit yield}) = -2963.93 - 605.17 X_1(N) + 10015.40 X_2(P) - 465.51 X_3(K) + 2879.63 X_4(Ca) + 5589.81 X_5(Mg) + 390.77 X_1^2 + 58889.50 X_2^2 + 149.48 X_3^2 - 949.39 X_4^2 - 3990.72 X_5^2$$

$$(R^2 = 0.773)$$

Using the above equation, the optimum level of N, P, K, Ca and Mg was obtained as 2.34%, 0.08%, 1.56%, 1.51% and 0.67%, respectively for an optimum yield of 636.4 fruits plant⁻¹. On the basis of obtained optimum level of different nutrients, the nutritional problems of the area were identified in the form of sub-optimum level of Mg in 78.7% orchards followed by N in 70.8% orchards, K in 69.1% orchards, Ca in 39.3% orchards and P in only 15.2% orchards (Table 6). Rodriguez and Gallo (1961) suggested optimum limit of N as 2.2 to 2.7%,

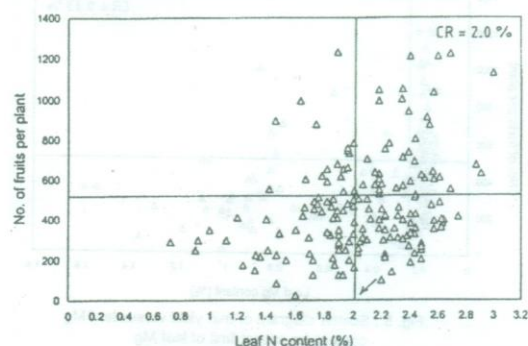
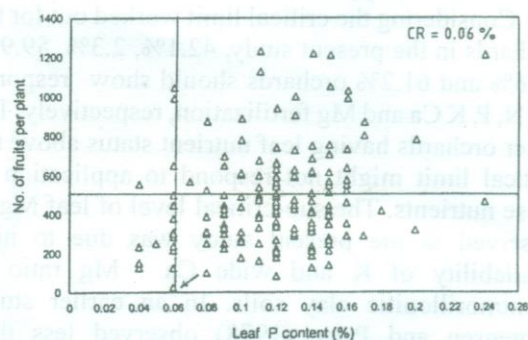
Table 6. Nutrient constraints of mandarin orchards following the observed optimum leaf nutrient level for the area surveyed.

Indices	N		P		K		Ca		Mg	
	No.	%	No.	%	No.	%	No.	%	No.	%
Optimum	52	(29.2)	151	(84.8)	55	(30.9)	108	(60.7)	38	(21.3)
Sub-optimum	126	(70.8)	27	(15.2)	123	(69.1)	70	(39.3)	140	(78.7)

P 0.12 to 0.18%, K 1.0 to 1.7%, Ca 3.0 to 5.5% and Mg 0.30 to 0.60% for citrus orchards in tropical to sub-tropical climate of Brazil. Gollasch *et al.* (1984) suggested optimum limit of N as 2.4 to 2.6%, P 0.12 to 0.16% and K 0.80 to 1.10% for the cultivar Washington navel grown in Australia. Chahill *et al.* (1991) under semi-arid climatic conditions of north-west India, suggested optimum level of leaf N, P, and K as 2.80%, 0.15% and 1.57%, respectively. The optimum leaf nutrient levels observed in the present study were different from those suggested in the past.

Critical leaf nutrient status

The critical limit of different nutrients viz., N, P, K, Ca and Mg was fixed after developing the scatter diagram for each of the nutrients in relation to fruit yield. The critical limit of leaf N was worked out as 2.0% (Fig. 1), P 0.06% (Fig.2), K 1.35% (Fig.3), Ca 1.35% (Fig.4) and Mg 0.23% (Fig.5). These critical limits are fairly comparable with the critical limit of N as 2.3%, P 0.09% and K 0.72% (Chahill *et al.* 1991) suggested for Kinnow mandarin grown in north-west India. Rodriguez and Gallo (1961) observed the critical level of N, P, K, Ca and Mg as 2.20%, 0.12%, 1.00%, 3.00% and 0.30%,

**Fig. 1 :** Scatter diagram of fruit yield versus leaf N content for critical limit of leaf N**Fig. 2 :** Scatter diagram of fruit yield versus leaf P content for critical limit of leaf P

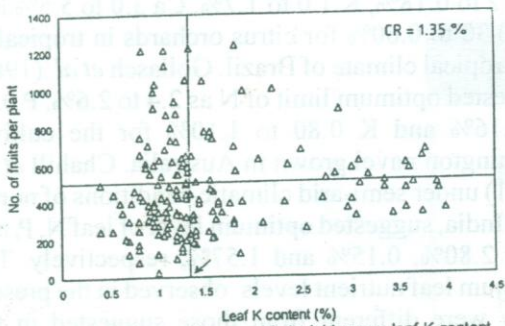


Fig. 3 : Scatter diagram of fruit yield versus leaf K content for critical limit of K

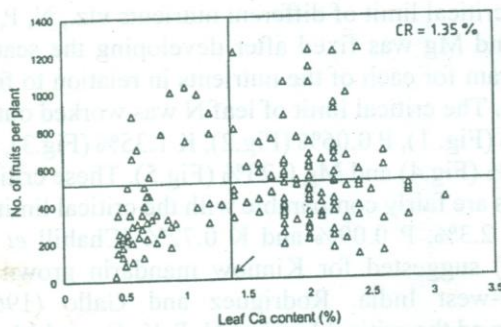


Fig. 4 : Scatter diagram of fruit yield versus leaf Ca content for critical limit of leaf Ca

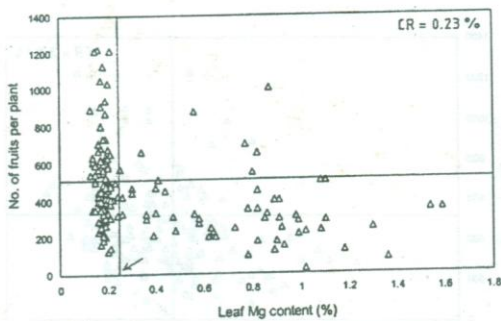


Fig. 5 : Scatter diagram of fruit yield versus leaf Mg content for critical limit of leaf Mg

respectively. The observations of the present study hence illustrated that critical limit of leaf nutrients varied considerably depending upon the citrus cultivar and soil type.

Considering the critical limit worked out for the orchards in the present study, 42.1%, 2.3%, 59.9%, 32.6% and 61.2% orchards should show response for N, P, K Ca and Mg fertilization, respectively. The other orchards having leaf nutrient status above the critical limit might not respond to application of these nutrients. The sub-critical level of leaf Mg as observed in the present study was due to high availability of K and wide Ca : Mg ratio of montmorillonitic clay soils. In an earlier study, Jorgensen and Price (1978) observed less than optimum level of leaf Ca despite high status of

available K and Ca in soil, and was attributed to sampling of leaves younger than spring flush.

Practical utility

In the absence of information on optimum or critical leaf nutrients levels in relation to fruit yield of different citrus cultivars grown in India, a variety of leaf nutrient standards suggested by different research workers are in use. The optimum level of leaf nutrient content observed in the present study can now be effectively utilized in identifying the nutritional problems in citrus orchards of Central India. This may as well apply to other parts of India too, allowing formulation of fertilizer schedule suiting to the requirement of even an individual citrus orchard. The information on critical level of leaf nutrients will further aid in more precise monitoring of nutrient status of orchards and immediate remedy to be adopted. Additional information generated through leaf nutrient analysis may further help in offering a meaningful solution to the nutritional problems of citrus orchards in India.

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