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Nutrient indexing in Khasi mandarin grown on Indian Alfisols

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A B S T R A C T

Extensive surveys were carried out covering a many as 40 orchards of Khasi mandarin in Nungba sub-division under Tamenglong district of Manipur, India. DRIS-based analysis predicted the optimum values of available nutrients in soil as: N 142.4-222.3 %, P 5.9-8.2%, K 110.5-270.3%, Ca 152.4-281.3%, Mg 28.3-79.4%, Fe 32.4-49.2ppm, Mn 26.6-41.1ppm, Cu 0.89-1.4ppm, Zn 1.2-2.4 ppm in relation to fruit yield of 28.2-49.6 kg/tree. While DRIS indices developed revealed an optimum value of different nutrients as: 1.86-2.62%N, 0.08-0.10%P, 0.89-1.86%K, 1.62-2.12% Ca, 0.40-0.50% Mg, 119.4-219.4 ppm Fe, 58.7-84.7 ppm Mn, 2.2-3.3 ppm Cu, and 20.8-29.8 ppm Zn in relation to fruit yield of 28.2-49.6 kg/tree. Nutrient constraints in the form of N, P, Ca, Mg, Cu, and Zn were identified using these diagnostics which must find a due place in a fertilizer program of mandarin orchards of the region to obtain sustainable optimum fruit yield. Various nutrients in the order of decreasing influence on yield were rated as: : Zn < P < Ca < Mg < N < K < Fe < Mn < Cu through leaf analysis. While through soil analysis, DRIS indices showed different nutrients influencing the fruit yield as: Ca < Mg < P < Zn < N < K < Cu < Mn < Fe.

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1. Introduction

Globally, citrus is one of the important fruit crops being cultivated in an area of 3.35 million ha with a total production of 91 million tons. The current average productivity of citrus orchards in India is 8.9 tons/ha compared to 4.52 tons/ha obtained in northeast India (Srivastava and Singh, 2002a), the region historically believed to have witnessed the dissemination of citrus to other parts of the world. Cultivation of Khasi mandarin (Citrus reticulata Blanco) in northeast India is mainly confined to mid-hills upto an elevation of 1200 m above mean sea level under humid tropical climate. The highest quantum of production harvested globally is represented by soil orders viz., Alfisol, Oxisol, Ultisol, Entisol, and Inceptisol (Srivastava and Singh, 2002b). Resultantly, the orchards continue to produce sub-optimally due to increasing gap between the amounts of nutrients added to that of annual demand with orchard age (Srivastava and Singh, 2009a; 2009b). The establishment of citrus orchards on steep slopes without contour trench planting or terracing has accelerated the menace of the problem by exposing the comparatively more acidic and infertile sub-surface having poor nutrient reserve to support the required nutrition of plants (Srivastava and Singh, 2002a). Of the different diagnostic tools, leaf and soil- based nutrient standards have established their superiority over rest of the diagnostic methods(Srivastava and Singh, 2001a; 2006). In the background of this information, the studies were carried out with the objectives viz. i. determination of optimum limit of soil available nutrient and leaf nutrient concentration in relation to fruit yield through nutrient indexing and ii. identifying nutrient constraints influencing fruit yield.

2. Materials and methods

Extensive surveys were carried out covering a many as 40 orchards of Khasi mandarin in Thangal village of the sub-division Nungba under Tamenglong district in the year 2010-2011. The present study was carried out in one experimental locations i.e. Thangal village under Nungba sub-division. The geographical co-ordinates of Nungba is 240 45’0” north latitude and 93026’0” east longitude. The mean summer and mean winter temperature of this region varied from 31^{o}C - 4^{o}C and annual rainfall as 3135 mm with relative humidity of 76-92%. Tamenglong district’s topography is made up of mostly of rugged hills, lofty mountains and rolling valleys with occasional human habitation in the bucolic hamlets. The district encompasses an area of 4391 sq. km. and stretches across the latitudinal parallel to 240 59’ north and the longitudinal meridian of 930 30’ east.

2.1. Soil and leaf sampling

Soil samples were collected from skirt belt/perimeter of trees, the zone having maximum concentration of feeder roots at soil depth of 0-20 cm (Srivastava et al., 2001). Likewise; the leaf positions from non-fruiting terminals covering 2-10% trees at a height of 1.5-1.8 m from the ground were sampled (Srivastava et al., 1999).

2.2. Analytical methods

Collected soil samples were air dried, ground, and passes through 2mm sieve, and subjected to analysis of available nitrogen using Alkaline Permanganate Method (Subbiah and Asija, 1956), Bray-P using ammonium fluoride extraction by shaking 1g soil in 20 ml of 0.03 N NH4F in 0.025 N HCl for 30 min., Ca, Mg, and K extractable in 1 N neutral NH4OAc in 1:2 soil : extractant ratio after shaking for 30 min. (Lanyon and Heald, 1982) and micronutrients (Zn, Cu, Mn and Fe) in 0.05 M (pH 7.3) DTPA- CaCl2 after shaking 20 g soil and 50 ml extracatant together for 2 hours (Lindsay and Norvell, 1978).

Leaf samples were thoroughly washed (Chapman, 1964) and ground using a Wiley-Grinding machine to obtain homogenous samples. Tri-acid (HClO4: HNO3: H2SO4 in 2:5:1) extracts of leaf samples (Chapman and Pratt, 1961) were subjected to analysis of P using vanadomolybdophosphoric acid (ammonium molybdate + ammonium metavanadate) method, K flame photometrically, Calcium and magnesium by versene titration (Lanyon and Heald, 1982) using ammonium purpurate (muroxide) and Erichrome Black-T as indicators for Ca and Ca+ Mg, respectively, and micronutrients by Atomic Absorption Spectrophotometer (GBC 908). While, total N in leaves was determined using auto-nitrogen analyzer.

3. Results and discussion

3.1. Optimum soil fertility limit

Optimization of soil properties is an emerging field of investigation. It represents a new stage in managing soil fertility in which the transition is made from simple improvement of soil properties to regulation of these properties aimed to bring them into agreement with plant needs in order to achieve maximum yields (Srivastava and Singh, 2001a; 2001b). DRIS-based analysis predicted the optimum values of available N 142.4-222.3 mg/kg, P 5.9-8.2mg/kg, K 110.5-270.3 mg/kg, Ca 152.4-281.3 mg/kg, Mg 28.3-79.4mg/kg, Fe 32.4-49.2mg/kg, Mn 26.6-41.1 mg/kg, Cu 0.89 - 1.4 mg/kg, Zn 1.2 - 2.4 mg/kg in relation to fruit yield of 28.2 - 49.6 kg/tree (Table 1). These findings are in line as earlier reported by Srivastava and Singh (2003b; 2004).The earlier studies from central India reported the optimum soil available nutrients (mg/kg) as: 92.8 - 110.2 N, 7.2 - 8.0 P, 201.2 - 228.1 K, 10.6 - 12.3 Fe, 7.2 - 9.1 Mn, 1.1 - 1.2 Cu, and 0.72 - 0.78 Zn in relation to fruit yield of 35.7 - 46.2 kg/tree using 'Nagpur' mandarin as a test crop through multivariate quadratic regression models (Srivastava and Singh, 2001c; 2002 b). A soil testing program, thus, can identify areas which are either under-or over-fertilized to enable more efficient use of fertilizers.

Table 1

Soil fertility guide (derived from DRIS based analysis) for Khasi mandarin grown in Manipur.

Parameters	Indices				
	Deficient	**Low**	**Optimum**	**High**	**Excess**
N (mg/kg)	< 86.3	86.3 - 142.3	142.4 - 222.3	222.4 - 313.0	> 313.0
P (mg/kg)	< 3.4	3.4 - 5.8	5.9 - 8.2	8.3 - 10.4	> 10.4
K (mg/kg)	< 82.2	82.2 - 110.4	110.5 - 270.3	270.4 - 310.9	> 310.9
Ca (mg/kg)	< 86.3	86.3 - 152.3	152.4 - 281.3	281.4 - 382.3	> 382.3
Mg (mg/kg)	< 6.9	6.9 - 28.2	28.3 - 79.4	79.5 - 102.3	> 102.3
Fe (mg/kg)	< 22.3	22.3 - 32.3	32.4 - 49.2	49.3 - 61.4	> 61.4
Mn (mg/kg)	< 18.2	18.2 - 26.5	26.6 - 41.1	41.2 - 52.3	> 52.3
Cu (mg/kg)	< 0.61	0.61 - 0.88	0.89 - 1.4	1.5 - 2.3	> 2.3
Zn (mg/kg)	< 0.52	0.52 - 1.1	1.2 - 2.4	2.5 - 3.9	> 3.9
Yield (kg/tree)	< 12.7	12.7 - 28.1	28.2 - 49.6	49.7 - 58.9	> 58.9

Mean DRIS indices suggested deficient to low level of Ca, Mg, P, Zn, N, and K due to their negative values in decreasing order. While those of Cu, Mn and Fe on account of their increasing positive indices was found in high to excess limit. While through soil analysis, DRIS indices revealed different nutrients to be ordered as: Ca < Mg < P < Zn< N< K < Cu < Mn < Fe (Table 2). The work on fertility constraint diagnosis through soil test based DRIS norms is limited. The high negative index shows that the corresponding nutrient is relatively deficient. Alternatively, a large positive index indicates that the nutrient is excessive in quantity. The data showed that the deficiency of Ca, Mg, P, Zn, N and K due to their negative values in decreasing order (Fig. 1). Using the progressive nutrient diagnosis, if the first limiting factor Ca is corrected by its supply, the next nutrient that will limit the yield is Mg. Further, if Ca and Mg are satisfied, the next limiting nutrient is P and Zn followed by N and K. Similar results were also observed by Srivastava et al. (2007) using the Khasi mandarin orchards of entire northeast India.

Table 2

Identifying nutrient constraints in Khasi mandarin using soil analysis-based DRIS (Diagnosis and recommendation integrated systems) analysis.

	Nutrient found deficient and low(n=30)						Nutrients found high and excess(n=10)		
	Ca	**Mg**	**P**	**Zn**	**N**	**K**	**Cu**	**Mn**	**Fe**
Concentration (mg/kg)	91.4	11.2	2.9	0.52	111.6	89.8	1.6	44.3	59.2
DRIS indices	- 190	- 140	- 110	- 90	- 40	- 20	+ 80	+ 210	+ 350

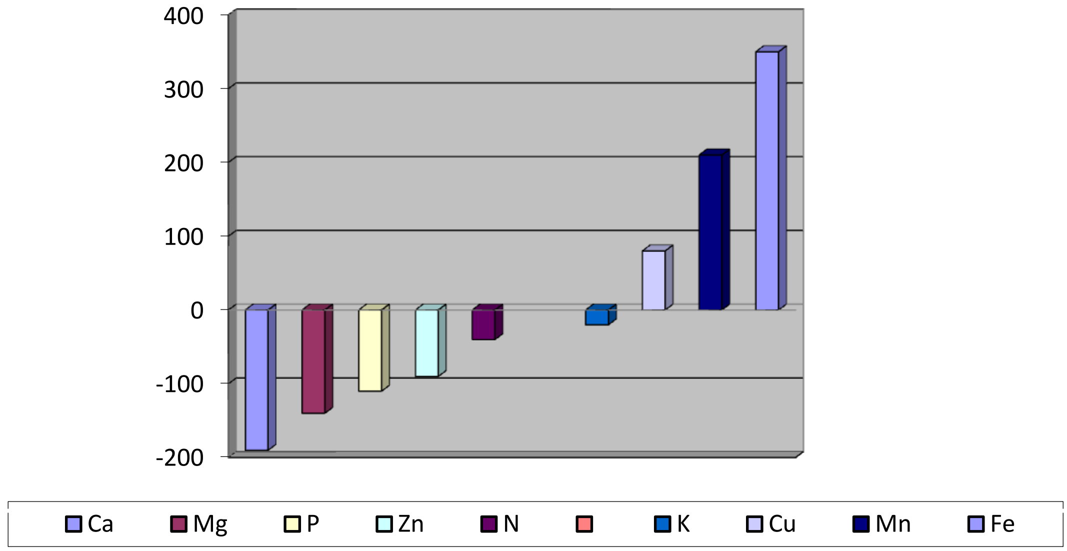

Fig. 1. Identifying nutrient constraints in Khasi mandarin using soil analysis-based DRIS analysis.

3.2. Leaf nutrient diagnostics

Occurrence of single or multiple nutrient deficiencies in citrus orchards is reported from all the six continents (Srivastava and Singh, 2003a). These deficiencies are if not addressed in-time through suitable diagnostic norms, the orchards coupled with reduced longevity continue to impart recurrent loss in production and imbalances the production economics. Leaf analysis as a method of assessing the crop nutrient requirements is based on the assumption that within certain limit, there exists a positive relation between doses of the nutrient supplied, leaf nutrient content, and yield (Srivastava and Singh, 2003b). The components of these means were weighted by the reciprocals of the CVs of the high to low yielding orchards (variance ratio SA/SB) which indicated a significant difference with reference to all the nutrients. These differences are indicative of the importance of leaf nutrient concentration in influencing the fruit yield.

The developed DRIS indices predicted optimum value of different nutrients as: 1.86 - 2.62% N, 0.08 - 0.10% P, 0.89 - 1.86% K, 1.62 - 2.12% Ca, 0.40 - 0.50% Mg, 119.4 - 219.4 ppm Fe, 58.7 - 84.7 ppm Mn, 2.2 - 3.3 ppm Cu, and 20.8 - 29.8 ppm Zn in relation to fruit yield of 28.2 - 49.6 kg/tree for Khasi mandarins grown in Manipur(Table 3). The results are accordance with the findings of Srivastava and Singh (2004; 2008).

Table 3

Leaf nutrient indices (derived from DRIS based analysis) for Khasi mandarin grown in Manipur.

Nutrient	Indices				
	Deficient	**Low**	**Optimum**	**High**	**Excess**
N (%)	< 1.52	1.52 - 1.85	1.86 - 2.62	2.63 - 2.92	> 2.92
P (%)	< 0.05	0.05 - 0.07	0.80 - 0.10	0.11 - 0.12	> 0.12
K (%)	< 0.56	0.56 - 0.88	0.89 - 1.86	1.87 - 2.28	> 2.28
Ca (%)	< 1.48	1.48 - 1.61	1.62 - 2.12	2.13 - 2.48	> 2.48
Mg (%)	< 0.28	0.28 - 0.39	0.40 - 0.50	0.51 - 0.62	> 0.62
Fe (ppm)	< 81.4	81.4 - 119.3	119.4 - 219.4	219.5 - 320.3	> 320.3
Mn (ppm)	< 36.3	36.3 - 58.6	58.7 - 84.7	84.8 - 118.2	> 118.2
Cu (ppm)	< 1.1	1.1 - 2.1	2.2 - 3.3	3.4 - 4.8	> 4.8
Zn (ppm)	< 11.2	11.2 - 20.7	20.8 - 29.8	29.9 - 37.8	> 37.8
Yield(kg/tree)	< 12.7	12.7 - 28.1	28.2 - 49.6	49.7 - 58.9	> 58.9

Various nutrients in the order of decreasing influence on yield were rated as Zn < P < Ca < Mg < N < K < Fe < Mn < Cu through leaf analysis (Table 4). Nutrient deficiencies of Zn, P, Ca, Mg, N, and K due to their negative values in decreasing order was observed through leaf analysis. The high negative index shows that the corresponding nutrient is relatively deficient. While, other nutrients viz., Fe, Mn, and Cu, with increasing positive indices were observed in high to excess limit. A large positive nutrient index (more negative an index, the more lacking is the nutrient) indicates that the corresponding nutrient is present in relatively excessive quantity. Using the progressive nutrient diagnosis, if the first limiting factor Zn is corrected by its supply, the next nutrient that will limit the yield is P. Further, if Zn and P are satisfied, the next limiting nutrient is Ca and Mg followed by N and K (Fig. 2). These results are in conformity with the findings of Srivastava et al. (2007).

Table 4
Identifying nutrient constraints in Khasi mandarin using leaf analysis-based (Diagnosis and recommendation integrated system) analysis.

	Nutrient found deficient and low(n=30)						**Nutrients found high and excess (n=10)**		
	Zn	**P**	**Ca**	**Mg**	**N**	**K**	**Fe**	**Mn**	**Cu**
Concentration (mg/kg)	14.2	0.05	1.47	0.28	1.58	0.72	220.4	110.4	3.4
DRIS indices	-160	-140	-110	-100	-60	-40	+110	+210	+290

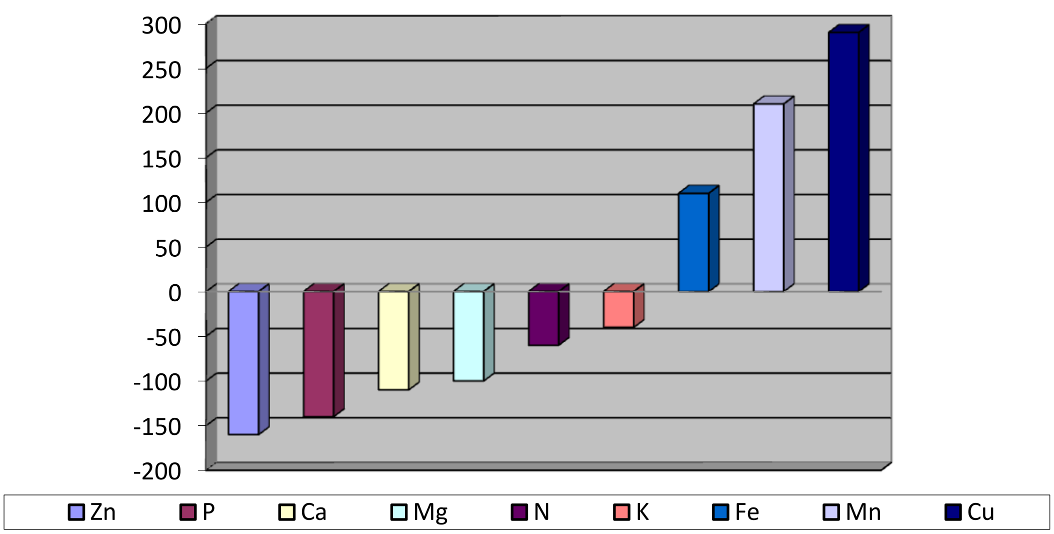

Fig. 2. Identifying nutrient constraints in Khasi mandarin using leaf analysis-based DRIS analysis.

3.3. Correlation studies

3.3.1. Soil available nutrients with fruit yield

Available N, P and K were significantly correlated with fruit yield (r = 0.706, p=0.01), (r = 0.613, p=0.01), and (r = 0.482, p=0.01), respectively. Both calcium and magnesium strongly influenced the fruit yield (r = 0.678 and r = 0.618, p=0.01). The fruit yield was significantly correlated with available Cu (r = 0.422, p=0.05), Zn (r = 0.732, p=0.01), indicating the much higher significance of Zn-nutrition over rest of the other micronutrients (Table 5). These results are in accordance to those in the book entitled "Citrus in NEH Region" authored by Singh et al. (2006).

3.3.2. Leaf nutrient concentration with fruit yield

Correlation coefficients of leaf nutrients indicated that fruit yield was more strongly correlated with nutrients such as N (r = 0.604, p = 0.01), P (r = 0.582, p = 0.01), K (r = 0.383, p = 0.01), Ca(r = 0.612, p = 0.05), Mg (r = 0.608, p = 0.05), Cu (r = 0.412, p = 0.05) and Zn (r = 0.682, p = 0.01) over Fe (r = 0.224) and Mn (r = 0.182) (Table 6). Similar results have also been reported by Srivastava and Singh (2005).

Table 5

Correlation coefficients of soil available nutrients with fruit yield.

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Fruit yield	0.706**	0.613**	0.482**	0.678**	0.618**	0.232	0.280	0.422*	0.732**

* Sig. (*P=0.05*) at 39 degree of freedom

** Sig. (*P = 0.01*) at 39 degree of freedom

Table 6

Correlation coefficients of leaf nutrient concentration with fruit yield.

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Fruit yield	0.604**	0.582**	0.383**	0.612*	0.608*	0.224	0.182	0.412*	0.682**

* Sig. (*P=0.05*) at 39 degree of freedom

** Sig. (*P = 0.01*) at 39 degree of freedom

3.3.3. Changes in soil fertility in response to management

Comparison of soil N, P, K, Ca, Mg and Zn under managed vs. unmanaged orchards showed significant difference. Available N, P, K, Ca, Mg, and Zn content of the soils varied significantly between managed (142.8, 7.9, 178.4, 172.4, 56.1 and 0.78 mg/kg, respectively) and unmanaged orchards (111.4, 6.4, 112.3, 98.8, 42.3, 0.52 mg/kg, respectively). Available micronutrients like Fe, Mn and Cu of soil did not vary significantly between managed (38.2, 29.6 and 1.6 mg/kg respectively) and unmanaged orchards (39.4, 29.2 and 1.9 mg/kg respectively). These observations are in compliance with those of Srivastava and Singh (2004). Fruit Yield (kg/tree) of managed and unmanaged orchards differed significantly. Fruit yield of managed orchards was observed to be significantly higher (38.4 kg/tree) as compared to yield of unmanaged orchards (21.3 kg/tree) (Table 7). A similar finding was also reported by Kumar et al. (2011). It could be due to the old age of the orchard and physiological and nutritional disorders.

Table 7

Changes in soil fertility, leaf nutrient composition and fruit yield in response to management

Orchard type	**Macronutrients**					**Micronutrients**			
	N	**P**	**K**	**Ca**	**Mg**	**Fe**	**Mn**	**Cu**	**Zn**
Available pool of nutrients in soil (mg/kg)									
Tmang	142.8	7.9	178.4	172.4	56.1	38.2	29.6	1.6	0.78
Tunmang	111.4	6.4	112.3	98.8	42.3	39.4	29.2	1.9	0.52
$t_{(P=0.05)}$	4.6	0.14	10.4	9.2	1.4	NS	NS	NS	0.10
Leaf nutrient composition (macronutrients in % and micronutrients in ppm)									
Tmang	2.22	0.10	1.19	1.94	0.56	192.3	38.4	0.92	24.6
Tunmang	1.82	0.07	0.79	1.11	0.42	198.4	39.2	0.72	19.2
$t_{(P=0.05)}$	0.24	0.01	0.18	0.21	0.10	NS	NS	0.11	1.8
Fruit yield (kg/tree)									
Tmang	38.4								
Tunmang	21.3								
$t_{(P=0.05)}$	4.2								

Tmang and Tunmang stand for high and low yield plant units.

3.3.4. Changes in leaf nutrient status in response to management

Leaf nutrients like N, P, K, Ca2+, Mg2+ (macronutrients in %), Cu and Zn (micronutrients in ppm) showed a significant variation when their nutrient status in managed (2.22 % , 0.10 %, 1.19 %, 1.94 %, 0.56 %, 0.92 ppm, 24.6

ppm, respectively) and unmanaged orchards (1.82 %, 0.07 %, 0.79 %,11.1 %, 0.42 %, 0.72 ppm and 19.2 ppm, respectively) was compared. Leaf macronutrient such as N, P, K, Ca2+, Mg2+ was higher in managed trees than unmanaged orchards. Leaf micronutrients (Cu and Zn,) were, significantly higher in managed trees (0.92 ppm and 24.6 ppm, respectively) than unmanaged orchards (0.72 ppm and 19.2 ppm, respectively). Whereas leaf Fe and Mn did not vary significantly between managed (192.3 ppm and 38.4 ppm, respectively) and unmanaged orchards (198.4 ppm and 39.2 ppm, respectively) (Table 7). Similar result was reported by Srivastava and Singh (2004).

Fruit yield of managed orchards was observed to be significantly higher (38.4 kg/tree) as compared to yield of unmanaged orchards (21.3 kg/tree). A similar finding was also reported by Kumar et al. (2011). It could be due to the old age of the orchard and physiological and nutritional disorders.

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