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FERTILITY INDEXING FOR ACID LIME GROWING SMECTITE SOILS

A.K. SRIVASTAVA[1] AND PRAKASH PATIL*

National Research Centre for Citrus, Nagpur, (Maharashtra) 440 010
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ABSTRACT

Acid lime (Citrus aurantifolia Swingle) is one such citrus cultivar grown far and wide across India, irrespective of soil and climate. Precision citriculture is fast growing in dimension in the light of fertilizer use efficiency. Attempts were made to develop soil fertility indices through DRIS (Diagnosis and Recommendation Integrated System) in relation to fruit yield using smectite rich black soils of western Maharashtra. The optimum soil fertility indices were suggested as : 106.3-118.2 mg kg^{-1} $KMNO_4$-N, 9.2-14.6 mg kg^{-1} Olsen-P, 102.4-146.6 mg kg^{-1} NH_4OAc-K, 210.3-318.7 mg kg^{-1}, NH_4OAc-Ca, 89.6-106.3 mg kg^{-1} NH_4OAc-Mg, 4.6-12.3 mg kg^{-1} DTPA-Fe, 3.2-10.1 mg kg^{-1} DTPA-Mn, 0.80-1.40 mg kg^{-1} DTPA-Cu, and 0.78-0.89 mg kg^{-1} DTPA-Zn in relation to optimum fruit yield of 22.0-41.2 kg $tree^{-1}$. These indices identified the deficiency of N (69.8% orchards), Zn(61.2% orchards), Mn(58.2% orchards), P (56.2% orchards) and K (40.3% orchards), suggesting the extent of multiple nutrient deficiencies of acid lime orchards.

Key words: Acid lime, soil fertility, DRIS indices, western Maharashra

INTRODUCTION

Development of soil-plant nutrient diagnostics has been the popular area of investigation, worldover using a variety of diagnostic tools (Srivastava *et al*., 2008). The currently available diagnostic methods are applicable only to narrowly specify developmental stage of crop (Srivastava and Singh, 2005) and accordingly, soil fertility evaluation is performed (Srivastava and Singh, 2002) since nutrient supply acts in tandem through soil-plant continum. The work on soil fertility indexing is very limited since in citrus, leaf analysis is usually considered comparatively more effective diagnostic tool (Srivastava and Singh, 2001). Diagnosis and recommendation integrated system (DRIS) is claimed to have certain advantages over other conventional interpretation tools (Beverly, 1987). DRIS has been able to identify nutrient constraint early in crop growth and allows sufficient time for remediation of identified problem right in the same season of crop (Walworth and Sumner, 1987). Limited effort has been devoted to develop DRIS norms for acid lime (*Citrus aurantifolia* Swingle) emphasizing soil fertility evaluation (Srivastava *et al*., 2001). In this background, the studies were carried out with two objectives *viz*., i. establishing soil fertility analysis-based DRIS indices in relation to optimum fruit yield, and ii. diagnosing the nutrient constraints and their frequency distribution.

MATERIALS AND METHOD

Experimental details: A total of 25 Acid lime orchards were surveyed in western Maharashtra comprising areas like: Devlali, Kolsaguha, Hiwrejare, Koligaon, Loni, Mahadevawadi, Madevargaon, Ghargaon, Srivanda of Ahmednagar district. Leaf and soil samples were collected in addition to data on fruit yield. All the acid lime orchards were established on different physiographic positions such as table land, piedmont, escarpment, and plain land. The soils were taxonomically classified as soil orders viz., Entisols (Typic/Lithic Ustorthent), Inceptisols (Typic/Lithic/Vertic Ustochrept), and Vertisols (Udic/Typic Pellustert/ Haplustert) derived from smectite rich (2:1 expanding type of mineral) basalt type of parent material. The region was climatically classified as sub-humid tropical in nature.

Sampling and analysis: The soil samples were collected at 0-20 cm depth from beneath the perimeter of trees. The collected soil samples were air dried ground and passed through 2 mm sieve, and subjected to analysis of free $CaCO_3$ content (Chapman and Pratt, 1961). Soil fertility analyses consisted of: alkaline $KMNO_4$ distillation for available N (Subbaiah and Asiza, 1956), $NaHCO_3$ (pH 8.3) extractable P as Olsen-P, 1N neutral NH_4OAc extractable-K, Ca and Mg (Knudsen *et al*., 1982; Lanyon *et al*., 1982), and 1N (pH 7.3), DTPA-$CaCl_2$ extractable Fe, Mn, Cu and Zn (Lindsay and Norvell, 1978).

Procedure of DRIS norms: The procedure as 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 the

Email: 1 aksrivas2007@gmail.com
**Indian Institute of Horticultural Research, Hessaraghatta, Lake Post Office, Bangalore (Karnataka) 560 089 Email: pnp@iihr.ernet.in*

available from the fields and experimental plots, iii. study the relationship between the yield and available nutrients in soil, iv. establishment of relationship between the yield and leaf nutrient composition using the following steps: a. each internal plant parameter is expressed in as forms as possible e.g. N/DM, N/P, P/N, N x P etc.; b. the whole population is divided into a number of sub-groups based on the economic optimum; c. the mean of each sub-population is calculated for the various forms of expressions; d. if necessary, class interval limits between the average and the outstanding yields are re-adjusted, so that the means of below average populations remain comparable; e. Chi-square test is performed to know that the population of orchards confirms a normal distribution; f. the variance ratios between the yield of sub-populations (using 50 kg tree^{-1} as cut-off yield level (averaged yield level usually obtained at growers' field) to separate the sub-populations) for all the forms of expressions are calculated together with the coefficient of variation; g. the forms of expressions, for which significant variance ratios (S_A for low-yielding population/S_B for high yielding population) were obtained and essentially the same mean values for the population were selected in expression with common nutrient, 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 is considered the most deficient and most limiting to fruit yield and vice-versa, and h. The following equations were developed for the calculation of DRIS indices based on leaf analysis:

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

where, f (N/P) = for example

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

and

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

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.

DRIS norms for soils were calculated in a manner identical to that described for leaf tissue data (Filho, 2004). The norms for classification of nutrients in leaves were derived using them as mean of high yielding orchards as the mean for optimum. The range of optimum was the value derived from mean - 4/3 to +4/3 standard deviation. The range of low 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 (Bhargava, 2002).

RESULTS AND DISCUSSION

Soil fertility norms

The soil test values in low yielding orchards were observed as 102.30 mg kg^{-1} $KMnO_4$-N (18.20% CV), 4.21% Olsen-P (11.91% CV), 101.39 mg kg^{-1} NH_4OAc-K (28.12% CV), 161.20 mg kg^{-1} NH_4OAc-Ca (10.32% CV), 61.19 mg kg^{-1} NH_4OAc-Mg (6.92% CV), 1.31 mg kg^{-1} DTPA-Fe (16.92% CV), 2.80 mg kg^{-1} DTPA-Mn (9.89% CV), 0.32 mg kg^{-1} DTPA-Cu (8.32% CV) and 0.49 mg kg^{-1} DTPA-Zn (10.10% CV) with 17.30 kg tree^{-1} fruit yield (17.18% CV). These values were contrastingly different in high yielding orchards, reading as : 117.80 mg kg^{-1} $KMnO_4$-N (11.32% CV), 10.92 mg kg^{-1} Olsen-P(16.20% CV), 182.17 mg kg^{-1} NH_4OAc-K (16.92% CV), 382.19 mg kg^{-1} NH_4OAc-Ca (8.12% CV), 112.13 mg kg^{-1} NH_4OAc-Mg (4.39% CV), 17.82 mg kg^{-1} DTPA-Fe (21.32% CV), 11.90 mg kg^{-1} DTPA-Mn (11.20% CV), 1.64 mg kg^{-1} DTPA-Cu (6.42% CV) and 0.90 mg kg^{-1} DTPA-Zn(12.31% CV) with fruit yield of 48.21 kgtree^{-1} (10.20% CV).

DRIS-based soil nutrient norms predicted the optimum values of $KMnO_4$-N 106.3-118.2 mg kg^{-1}, Olsen-P 9.22-14.6 mg kg^{-1}, NH_4OAc-K 102.4 – 146.6 mg kg^{-1}, NH_4OAc-Ca 210.3 – 318.7 mg kg^{-1}, NH_4OAc-Mg 89.6 – 106.3 mg kg^{-1}, DTPA-Fe 4.6-12.3 mg kg^{-1}, DTPA-Mn 3.2 – 10.1 mg kg^{-1}, DTPA-Cu 0.80 – 1.40 mg kg^{-1} and DTPA-Zn 0.78-0.89 mg kg^{-1} in relation to optimum fruit yield of 22.0 – 41.2 kg tree^{-1}. These values in order to obtain fruit yield of 41.2 – 58.3 kg tree^{-1} as high yield, a different soil test values would be required to be maintained. These values comprise of : 118.2 – 134.1 mg kg^{-1} $KMnO_4$-N, 14.6 – 20.2 mg kg^{-1} Olsen-P, 146.6 – 191.6 mg kg^{-1} NH_4OAc-K, 318.7 – 462.8 mg kg^{-1} NH_4OAc-Ca, 106.3 – 142.3 mg kg^{-1} NH_4OAc-Mg, 12.3 – 20.2 mg kg^{-1} DTPA-Fe, 10.1 – 14.6 mg kg^{-1} DTPA-Mn, 1.40–2.10 mg kg^{-1} DTPA-Cu and 0.89 – 1.06 mg kg^{-1} DTPA-Zn (Table 1). Studies by Srivastava and Singh (2001) suggested optimum soil fertility norms for Nagpur mandarin as: $KMNO_4$-N 94.8-154.8 mg kg^{-1}, Olsen-P 6.6-15.9 mg kg^{-1}, NH_4OAc-K 146.8-311.9 mg kg^{-1}, NH_4OAc-Ca 408.1-616.0 mg kg^{-1}, NH_4OAc-19. Mg 85.2-163.2 mg kg^{-1}, DTPA-Fe 10.9-25.2 mg kg^{-1}, DTPA-Mn 7.5-23.2 mg kg^{-1}, DTPA-Cu 2.5-5.1 mg kg^{-1} and DTPA-Zn 0.59-1.26 mg kg^{-1} for optimum fruit yield of 47.7-117.2 kg tree^{-1}. 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 norms (derived from DRIS based analysis) in acid lime grown in western Maharashtra

Available nutrients	**DRIS norms**				
	Deficient	**Low**	**Optimum**	**High**	**Excess**
$KMnO_4$- N (mg kg^{-1})	<98.2	98.2-106.3	106.3-118.2	118.2-134.1	>134.1
Olsen-P (mg kg^{-1})	<3.8	3.8-9.2	9.2-14.6	14.6-20.2	>20.2
NH_4OAc-K (mg kg^{-1})	<78.3	78.3-102.4	102.4-146.6	146.6-191.6	>191.6
NH_4OAc-Ca (mg kg^{-1})	<151.6	151.6-210.3	210.3-318.7	318.7-462.8	>462.8
NH_4OAc-Mg(mg kg^{-1})	<52.1	52.1-89.6	89.6-106.3	106.3-142.3	>142.3
DTPA-Fe(mg kg^{-1})	<1.2	1.2-4.6	4.6-12.3	12.3-20.2	>20.2
DTPA-Mn(mg kg^{-1})	<1.12	1.12-3.2	3.2-10.1	10.1-14.6	>14.6
DTPA-Cu(mg kg^{-1})	<0.20	0.20-0.80	0.80-1.40	1.40-2.10	>2.10
DTPA- Zn(mg kg^{-1})	<0.45	0.45-0.78	0.78-0.89	0.89-1.06	>1.06
Fruits yield(kg tree^{-1})	<12.1	12.1-22.8	22.0-41.2	41.2-58.3	>58.1

Nutrient constraints and their frequency distribution

Nutrient deficiencies of N, Zn, Mn, P, and K due to their negative values in decreasing order (148 40) was observed (Table 2) through soil analysis-based DRIS indices. While, other nutrients viz., Fe, Cu, Ca and Mg with increasing positive indices (76 222) 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 N is corrected by its supply, the next nutrient that will limit the yield is Zn. Further, if N and Zn are satisfied, the next limiting nutrient is Mn followed by P and K. Hence, various nutrients in the order of decreasing influence on fruit yield were rated as: N < Zn < Mn < P< K < Fe < Cu < Ca < Mg.

Table 2: Soil fertility constraints in acid lime orchards of western Maharashtra

Acid lime (n = 25)	**Nutrients found deficient and low (n = 15)**					**Nutrients found high and excess (n = 10)**			
	N	**Zn**	**Mn**	**P**	**K**	**Fe**	**Cu**	**Ca**	**Mg**
Concentration(mg kg^{-1})	101.6	0.52	1.21	4.6	92.7	16.3	1.96	334.6	116.9
DRIS indices	-148	-148	-110	-90	-40	76	108	178	222

Higher is the value of DRIS indices, high is the magnitude of nutrient deficiency and vice-versa

The frequency distribution of soil fertility constraints were diagnosed (Table 3) which revealed 69.8% orchards were deficient $KMnO_4$-N, followed by 61.2% in DTPA-Zn, 58.2% orchards deficient in DTPA-Mn, 56.2% orchards deficient in Olsen-P, and 40.3% orchards deficient in NH_4OAc-K. On the other hand, 39.3% orchards displayed optimum level of NH_4OAc-K followed by 37.6% orchards optimum in Olsen-P, 28.6% orchards optimum in DTPA-Zn, 22.3% orchards optimum in DTPA-Mn, 19.2% orchards optimum in NH_4OAc-Mg, and 15.0% orchards optimum in $KMnO_4$-N. Earlier studies by Huchche *et al*. (1996) on black clay soils of central India showed a significant response of both N (600 g tree^{-1} year^{-1}) and K (300 g tree^{-1} year^{-1}).Such soil fertility indexing would serve as a ready reckoner with regard to soil fertility evaluation and establishing the fertilizer doses.

Table 3: Frequency distribution of soil fertility constraints in acid lime orchards of western Maharashtra

Nutrients	**Percentage frequency distribution**				
	Deficient	**Low**	**Optimum**	**High**	**Excess**
$KMnO_4$-N (mg kg^{-1})	69.8	15.2	15.0	-	-
Olsen-P (mg kg^{-1})	56.2	6.2	37.6	-	-
NH_4OAc-K (mg kg^{-1})	40.3	10.2	39.3	10.2	-
NH_4OAc-Ca (mg kg^{-1})	-	-	10.2	51.2	38.6
NH_4OAc-Mg(mg kg^{-1})	-	-	19.2	61.4	19.4
DTPA-Fe(mg kg^{-1})	10.2	10.2	10.2	50.0	19.4
DTPA-Mn(mg kg^{-1})	58.2	8.3	22.3	11.2	-
DTPA-Cu(mg kg^{-1})	-	10.2	39.2	40.4	10.2
DTPA-Zn(mg kg^{-1})	61.2	10.2	28.6	-	-

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