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Soil fertility norms for Sathgudi sweet orange (*Citrus sinensis*)

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ABSTRACT

Soil fertility norms for citrus cultivars are limited. An extensive survey was carried out in ninety five-bearing orchards of Sathgudi sweet orange (*Citrus sinensis* Osbeck) in YSR Kadapa, Nalgonda, Nellore and Anantapur districts of Andhra Pradesh to develop soil fertility norms through Diagnosis and Recommendation Integrated System (DRIS). DRIS-based analysis predicted the optimum values of available nutrients in soil as 0.70-0.92% organic carbon, 27.46-41.96 kg/ha Olsen-P, 232.51-303.11 kg/ha NH_4OAc-K, 13.13-25.80 mg/kg DTPA- Fe, 0.95-1.18 mg/kg DTPA-Zn, 18.13-29.22 mg/kg DTPA-Mn and 1.12- 2.13 mg/kg DTPA-Cu in relation to fruit yield of 21.23-39.15 tonnes/ha in Sathgudi sweet orange. These indices identified the low levels of organic carbon (41% orchards), Olsen-P (45% orchards) and DTPA-Zn (32% orchards). While optimum levels of K, Fe, Cu, and Mn were observed in sweet orange growing orchards of Andhra Pradesh. The new DRIS norms for yield showed that the yield level should be considered as 'low' when it is less than 21.22 tonnes/ha.

Key words: Andhra Pradesh, DRIS indices, Sathgudi, Soil fertility norms

Andhra Pradesh stands first in sweet orange (*Citrus sinensis* Osbeck) and acid lime (*Citrus aurantifolia* Swingle) production contributing as much as 87% and 29%, respectively to the country's production (Srivastava 2014). Sweet orange are considered more nutrient sensitive and nutrient forager compared to mandarins or acid lime (Srivastava and Kohli 1997, Srivastava and Singh 2003a). Most of the Sathgudi sweet orange growers of Andhra Pradesh are suffering from multiple nutrient deficiencies (Srivastava and Singh 2003a), thereby, orchards are nutritionally neglected, and hence suffer from early decline in productivity (Srivastava and Singh 2008a). The problem is further aggravated due to absence of soil fertility diagnostics for Sathgudi sweet orange, with the result,orchards continue producing sub-optimum yield (Srivastava and Singh 2002).

Most of the fertilizer recommendations emanating in India are based on soil test ratings of Muhr *et al*. (1965), which hardly suit to any of the important commercial citrus cultivars (Srivastava and Singh 2001c). The currently available diagnostic methods are applicable only to narrowly specify developmental stage of crop (Srivastava and Singh 1997, 2001a, 2001b, 2005; Srivastava *et al*. 1999) and accordingly, soil fertility evaluation is performed (Srivastava and Singh 2001c, 2002), since nutrient supply acts in tandem through soil-plant continum.

The Diagnosis and Recommendation Integrated System (DRIS) is a method to evaluate plant nutrition through indices, which provide a reliable mean of simultaneously identifying imbalances, deficiencies and excesses in plant nutrients and ranking them in order of importance (Walworth and Sumner 1986). Using DRIS, new norms as ratings for soil fertility are developed as a new five-tier system of fertilizer recommendation. 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 2001a, 2008a, 2008b). In this background, the studies were carried out with two objectives, viz. establishing soil fertility analysis-based DRIS norms for sweet orange growing soils of Andhra Pradesh and diagnosing the nutrient constraints and their frequency distribution.

MATERIALS AND METHODS

The above research was conducted under AICRP on Fruits (Citrus), Citrus Research Station, Dr Y S R Horticultural University, Tirupati, Andhra Pradesh, India from 2009-14. A total of 95 sweet orange orchards were surveyed in Andhra Pradesh, comprising areas of YSR Kadapa district, Nalgonda, Nellore and Anantapur districts. The soil samples were collected at 0-15 cm depth representing the zone of major feeder root concentration from beneath the perimeter of trees. The collected soil samples were air dried ground and passed through 2 mm sieve. The sets of these soil samples were processed and analyzed in the laboratory for soil characteristics. The soil

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pH and electrical conductivity were determined in 1:2.5 soil:water suspension (Jackson 1973) respectively. Soil fertility analyses consisted of alkaline potassium permangate ($KMnO_4$) distillation for available N (Subbaiah and Asiza 1956), sodium bicarbonate ($NaHCO_3$) (pH 8.3) extractable P as Olsen-P, 1 N neutral ammonium acetate (NH_4OAc)-extractable-K, and diethylenetriaminepentaacetic acid (DTPA)-calcium chloride ($CaCl_2$) extractable Fe, Mn, Cu and Zn (Lindsay and Norvell 1978).

The whole population, i.e. total number of orchards were divided into two groups based on yield, viz. less than 25 t/ha as low yielding and rest as high yielding subpopulation as per principle of third quartile method (Nageshwara Rao 1983). From selected 95 orchards, 69 orchards were classified as low yielding, whereas 26 orchards were classified as high yielding. The procedure of DRIS norms initially developed by Beaufils (1973) and modified by Bhargava (2002) was used through a PC based program. DRIS norms for soils were calculated as per procedure developed by Filho (2004). The norms for classification of nutrients in soils 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, Srivastava and Singh 2007, 2008a, 2008b). As such, new five-tier system of classification of soil characteristics has been established as new ratings for soil fertility, viz. deficient, low, optimum, high and excess for each soil parameter.

RESULTS AND DISCUSSION

Soil fertility norms

The ranges of soil parameters, fruit yield and quality parameters for low and high yielding orchards of sweet orange with mean and coefficient of variation of high yielding orchards (Table 1) showed significant differences. The range of values for different soil parameters of high yielding orchards were observed as 7.4–8.6 pH (mean: 7.76 and CV: 3.74%), 0.1-1.1 dS/m EC: (mean: 0.52 and CV 67.31%) and 0.4- 1.5% organic carbon (mean: 0.78 and CV: 34.62 %).The soils were moderately alkaline and EC of soils showed non-saline nature with wide range of organic carbon content. Wider range of primary available nutrients 18-55 kg/ha Olsen-P (mean: 34.08 mg/kg and CV: 31.31%) and 185-625 K_2O (mean: 384.58 kg/ha and CV: 28.92%) were observed. Regarding soil available micronutrients, 12-33 DTPA- Fe (mean: 24.02 mg/kg and CV: 21.57%),1.5-2.2 mg/kg Mn (mean: 1.84 mg/k and CV: 9.78%),18-34 mg/kg Cu (mean: 24.44 mg/kg and CV: 16.16%) and 1.5-2.3 mg/kg Zn (mean: 1.86 mg/kg and CV: 11.29%) were recorded. The ranges of fruit yield and quality parameters for high yielding orchards of sweet orange were obtained as 140-220 g fruit weight (mean: 181.69 g and CV: 11.72%), 32-45% juice (mean: 38.08 % and CV: 8.04%), 8-14^0 Brix TSS (mean: 10.70 and CV: 12.99%), 0.58-1.2 % acidity (mean: 0.86 and CV: 19.74%) and 25-37 t/ha fruit yield (mean: 29.04 and CV: 12.36%). The components of these means were weighted by the reciprocals of the CVs of the high to low yielding orchards (variance ratio) which indicated a significant difference with reference to all the nutrients (Table 1).These differences are indicative of importance

Table 1 Mean soil fertility, fruit yield and fruit quality parameters between low and high-yielding sweet orange orchards

Parameter	Low yielding orchards (n=69)				High yielding orchards (n=26)				
	Range	Mean	CV (%)	V_L	Range	Mean	CV (%)	V_H	V_L/V_H
pH	7.4- 8.8	8.09	4.08	0.11	7.4-8.6	7.76	3.74	0.09	1.22
EC (dS/m)	0.1-1.6	0.6	70.00	0.18	0.1-1.1	0.52	67.31	0.12	1.50
OC (%)	0.1-1.0	0.59	32.20	0.04	0.4-1.5	0.78	34.62	0.07	0.57
Olsen-P (kg/ha)	2.01-50.0	24.39	34.85	72.25	18.0-55.0	34.08	31.31	113.75	0.64
NH_4OAc-K (kg/ha)	31.0-75.0	265.39	44.65	140-40	185-625	384.58	28.92	123-72	1.13
DTPA-Fe (mg/kg)	4.5-31.0	12.34	51.38	40.15	12.00-33.00	24.02	21.57	26.81	1.50
DTPA-Mn (mg/kg)	0.3-3.60	1.39	59.71	0.68	1.5-2.2	1.84	9.78	0.03	22.67
DTPA-Cu (mg/kg)	1.9-3.00	1.92	26.25	2.55	1.8-3.4	2.44	16.16	1.56	1.64
DTPA-Zn (mg/kg)	1.2-3.60	2.09	27.75	0.34	1.5-2.3	1.86	11.29	0.04	8.50
Fruit weight (g)	140.0-220.0	176.57	10.0-35.0	333.0-66.0	140.0-220.0	181.0-69.0	11.0-72.0	453.0-26.0	0.74
Juice (%)	29.0-45.0	36.0-96.0	9.0-12.0	11.0-34.0	32-45	38.08	8.04	9.35	1.21
TSS (^{0} Brix)	8-12.2	10.39	9.91	1.07	8-14	10.70	12.99	1.94	0.55
Acidity (%)	0.6-1.6	1.06	18.87	0.04	0.58-1.2	0.861	19.74	0.03	1.33
Fruit yield (tonnes/ha)	7.5-24	15.39	27.09	17.40	25-37	29.04	12.36	12.91	1.35

V_L, Variance of low yielding orchards; V_H, Variance of high yielding orchards of soil nutrient concentration in influencing the fruit yield (Srivastava and Singh 2003a, 2003b).

Use of DRIS with soil data provides an advantage of taking into account, the nutrient balance and ranking nutrients in terms of abundance relative to optimal levels. The concept of an optimum soil nutrient balance is promoted as the basic cation saturation ratio (McLean 1977, Srivastava and Singh 2002) advocating the use of specific fractional level of nutrient saturation of cation exchange capacity rather than nutrient ratios. Optimizing soil fertility has recently emerged as a new field of investigation which ensures maximum yield under a wide range of soil conditions (Srivastava and Singh 2001c). 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). DRIS-based soil fertility norms predicted the optimum values of 0.70-0.92% OC, 27.46-41.96 kg/ha Olsen-P, 232.51-303.11 kg/ha NH_4OAc-K, 13.13-25.80 mg/kg DTPA-Fe, 0.95-1.18 mg/kg DTPA-Zn, 18.13-29.22 mg/kg DTPA-Mn and 1.12- 2.13 mg/kg DTPA-Cu in relation to optimum fruit yield of 21.23-39.15 tonnes/ha. These values in order to obtain fruit yield of 39.16-58.29 tonnes/ha as high yield, a different soil test values would be required to be maintained. These values comprises 0.93-1.18% OC, 41.97-54.10 kg/ha P_2O_5, 301.12-457.10 kg/ha K_2O, 25.81-41.32 mg/kg DTPA-Fe, 1.19-2.11 mg/kg DTPA-Zn, 29.23-41.45 mg/kg Mn and 2.14-3.16 mg/kg DTPA-Cu (Table 2). The earlier studies from Marathwada region of Maharashtra reported the optimum soil available nutrients as 142 mg/kg $KMnO_4$-N, 11.4 mg/kg Olsen- P, 210.3 mg/kg NH_4OAc-K, 13.2 mg/kg DTPA-Fe, 14.6 mg/kg, 2.16 mg/kg DTPA-Cu DTPA- Mn, DTPA-Zn 0.98 mg/kg DTPA-Cu for an optimum yield of 24.1 tonnes/han Mosambi sweet orange (Srivastava and Singh 2003a, 2008a,). A soil testing program, thus, can identify areas which are either under-or over-fertilized to enable more efficient use of fertilizers (Srivastava *et al*. 2007).

Distribution of nutrient constraints

The evaluation and classification of the total (95) orchards (Table 3) showed that, organic carbon was one of the limiting factors for the lower yield, as fruit (41%) orchards were in low range of soil organic carbon. As many 39 orchards were under low class of organic carbon which contributed towards low fruit yield. Low availability of plant available P as Olsen-P was observed in 45% orchards, another yield limiting soil fertility constraint in these orchards. The most of orchards (30%) comes under optimum category of available NH_4OAc-K. From the data regarding soil available micronutrients, it was observed that most of the soils were in optimum range of DRIS norms, except Zn, which was in high range in 50% orchards. On the other hand, 72.63% orchards displayed optimum level of DTPA-Cu followed by 64.21% orchards optimum in

Table 2 Soil fertility norms (derived from DRIS based analysis) developed for Sathgudi sweet orange orchards of Andhra Pradesh

Parameter	DRIS norms				
	Deficient	Low	Optimum	High	Excess
OC (%)	< 0.42	0.42-0.69	0.70-0.92	0.93-1.18	> 1.18
Olsen- P (kg/ha)	< 16.12	16.12-27.45	27.46-41.96	41.97-54.10	> 54.10
NH_4OAc-K (kg/ha)	< 181.10	181.10-232.50	232.51-303.11	301.12-457.10	> 457.10
DTPA-Fe (mg/kg)	< 6.02	6.02-13.12	13.13-25.80	25.81-41.32	> 41.32
DTPA-Zn (mg/kg)	< 0.68	0.68-0.94	0.95-1.18	1.19-2.11	> 2.11
DTPA-Mn (mg/kg)	< 11.02	11.02-18.12	18.13-29.22	29.23-41.45	> 41.45
DTPA-Cu (mg/kg)	< 0.89	0.89-1.11	1.12-2.13	2.14-3.16	> 3.16
Fruit yield (tonnes/ha)	< 11.10	11.10-21.22	21.23-39.15	39.16-58.29	> 58.29

Table 3 Frequency distribution of soil fertility constraints in Sathgudi sweet orange orchards of Andhra Pradesh

Parameter	Percentage frequency distribution				
	Deficient	Low	Optimum	High	Excess
OC (%)	17 (17.90)	39 (41.05)	31 (32.64)	5(5.26)	3 (3.15)
Olsen-P (kg/ha)	11 (11.58)	43 (45.26)	32 (33.69)	8(8.42)	1 (1.05)
NH_4OAc-K (kg/ha)	18 (18.95)	9 (9.47)	29 (30.53)	30(31.58)	9 (9.47)
DTPA-Fe (mg/kg)	19 (20.00)	23 (24.21)	43 (45.26)	10(10.53)	0 (0.00)
DTPA-Mn (mg/kg)	2 (2.10)	29 (30.53)	61 (64.21)	03(3.16)	0 (0.00)
DTPA-Cu (mg/kg)	0 (0.00)	0 (0.00)	69 (72.63)	21(22.11)	5 (5.26)
DTPA-Zn (mg/kg)	21 (22.11)	11 (11.58)	2 (2.10)	48(50.53)	13 (13.68)
Fruit yield (tonnes/ha)	13 (13.68)	49 (51.58)	33 (34.74)	0(0.00)	0 (0.00)

*Figures in the parenthesis indicate percentage

DTPA-Mn and 45.26% orchards in DTPA-Fe. Srivastava *et al.* (2007) reported shortages of soil nutrients like C, N, Zn, P, Mn, and K in decreasing order in Mosambi sweet orange in Maharashtra region of Maharashtra. Such soil fertility indexing would serve as a ready reckoner with regard to fruit yield based soil fertility evaluation and establishing the fertilizer doses.

In present investigation, DRIS has established the new categorization of yield levels through DRIS norms. The new DRIS norms for yield showed that the fruit yield level should be considered as 'low' when it is less than 21.22 tonnes/ha. With the above level of nutrients being maintained, an optimum yield level ranging from 21.23-39.15 tonnes/ha was possible. The yield was low in 51.58 %, low in 13.68% and optimum in 33.74% orchards. Thus, these new DRIS norms for soil fertility evaluation can be used for rationalizing the quantity of manures and fertilizers to be applied for getting optimum yield of Sathgudi sweet orange, instead of conventional method of fertilization using blanket fertilizer application. It can be concluded that, DRIS not only identifies the yield limiting nutrients, but also prioritize them helping to correct the most required nutrients, and thereby, aid in harvesting increased yield of sweet orange.

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