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Leaf Nutrient Status Vis-à-vis Fruit Yield and Quality of Sweet Orange (*Citrus sinensis* (L.) Osbeck)

A. Ramanjaneya Reddy[1*], V. Munaswamy[1], P. Venkataram Muni Reddy[1], B. Ravindra Reddy[2] and P. Sudhakar[3]

[1]Department of Soil Science and Agricultural Chemistry, S. V. Agricultural College, Tirupati, Andhra Pradesh-517502, India.
[2]Department of Statistics and Mathematics, S.V. Agricultural College, Tirupati, Andhra Pradesh-517502, India.
[3]Department of Crop Physiology, S. V. Agricultural College, Tirupati, Andhra Pradesh-517502, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author ARR designed and executed the study by collecting and analyzing soil and plant samples, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BRR assisted in statistical analysis. Authors VM and PVMR provided required laboratory facilities and helped in draft preparation. Authors PS managed the literature searches and subsequent draft proofing. All authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted to know the effect of leaf nutrient status on fruit yield and quality of sweet orange (*Citrus sinensis* (L.) Osbeck) in YSR district of Andhra Pradesh, India. In this investigation fifty sweet orange orchards aged between 12 to 13 years were selected and plant samples such as index leaves and matured fruits were collected from 10 per cent of plants in each orchard. Leaf Zn deficiency (62%) was the most severe among the 10 mineral elements tested and followed by Fe (54%), Mn (52%) and Cu (26%). Fruit yield showed significant positive correlation with leaf N (r =0.519**) and P (r =0.409**). Fruit weight had significant positive correlation with leaf Nitrogen (r = 0.469**), Phosphorus (r = 0.446**) and Potassium (r = 0.415**). Fruit juice percent was significantly and positively correlated with leaf N (r =0.353**) and P (r =0.364**). Titrable acidity had significant negative correlation with leaf Fe (r = -0.371**) and leaf Mn (r = -0.292*). Total

**Corresponding author: E-mail: arnreddy.2000@gmail.com;*

Soluble Solids (TSS) showed a significant positive relation with leaf P (r = 0.438**) and significant negative correlation with leaf Mn (r = -0.311*). Vitamin C content of the sweet orange fruit had significant positive correlation with leaf N (r = 0.437**), P (r = 0.516**) and K (r = 0.398**).

Keywords: Sweet orange; leaf macronutrients; leaf micronutrients; fruit yield; fruit quality.

1. INTRODUCTION

Sweet orange (*Citrus sinensis* (L.) Osbeck) is one of the most important commercial citrus cultivars of India having significant nutritional source for human health as they contain more of minerals and vitamins [1,2]. Most of the fruits are consumed as fresh, while some portion is used in the form of squashes, juices and drinks. Sweet orange fruits form an essential commercial commodity for several agroindustries and possess immense economic value.

In India, sweet oranges are grown mainly in the states of Maharashtra, Andhra Pradesh, Punjab, Karnataka and parts of North – East region with an area of 2.78 lakh hectares and 45.26 lakh tones [3].

In Andhra Pradesh, the chief sweet orange production areas are Prakasam, YSR, Ananthapur and SPSR Nellore districts with an area of nearly 0.94 lakh ha and production of 13.16 lakh tonnes during 2014–15 [3]. In YSR district, area under sweet orange is 0.11 lakh ha with production of 1.54 lakh Mt [4]. In YSR district sweet orange is cultivating in a variety of soils ranging from red loamy sands/sandy loams to black clay loams/sandy clay loams under semi-arid monsoonic climate with distinct summer, winter and rainy seasons with mean annual temperature of 27-35°C and rainfall of 700-800 mm.

Fruit crop like sweet orange, leaves have been found to be practically sensitive and convenient index of the nutrient status of the plant and also leaf nutrient composition is considered to be a basic tool for the investigation of soil fertility problems. Lot of research is being done on influence of soil fertility status on fruit yield and quality of sweet orange, but information on leaf nutrient status and its correlation with fruit yield and quality parameters is lacking. Hence, the present investigation was carried out to find out leaf nutrient status and its possible effects on fruit yield and quality of sweet orange.

2. MATERIALS AND METHODS

To study the correlation between leaf nutrient status, fruit yield and quality of sweet orange (*Citrus sinensis* (L.) Osbeck) in YSR district of Andhra Pradesh, during 2014, fifty sweet orange orchards aged between 12 to 13 years were selected (Figure 1) in different mandals and in each orchard, plant samples such as index leaves and matured fruits were collected, and collected samples were processed for laboratory analysis.

2.1 Leaf Sample Collection and Preparation for Analysis

Fifty leaf samples were collected from 5 to 7 months old non-fruiting terminals of spring flush (February flush) at random covering 10 per cent of trees in an orchard to represent the nutrients. The leaves from trees were collected covering all four directions *viz*., North, South, East and West preferably at 1.5 to 2.0 m from ground level [5].

The collected leaf samples were kept under running tap water, then washed with 0.2 per cent liquid detergent to remove the adhering material and again washed with running tap water to get rid of the detergent. Then the samples were rinsed with 0.1 N hydrochloric acid and then three successive rinsings were made with single distilled water followed by three more rinsings with double distilled water. After washing and rinsing, the leaves were blotted with filter paper, then placed in paper bags and dried in an oven at 70°C till constant weight. Later the plant samples were ground in a plant material grinder to 40 mesh for analysis. The ground samples were thoroughly mixed and stored in butter paper bags for further analysis.

2.2 Leaf Analysis

The processed leaf samples were analyzed for total N, P, K, Ca, Mg, S, Zn, Fe, Cu and Mn following standard procedures.

2.3 Total Nitrogen (N)

The total nitrogen content of leaf sample was estimated by Micro-kjeldahl method [6] and expressed in percentage.

2.4 Di-acid Digestion of Leaf Samples for Estimation of P, K, Ca, Mg, S, Fe, Mn, Cu and Zn

One gram of oven dry leaf sample was digested with 10 ml of di-acid mixture (Nitric acid and Perchloric acid in 10:4 ratio). The digested leaf samples were diluted to known volume with double distilled water and filtered [7]. This filtrate was used for the estimation of P, K, Ca, Mg, S, Fe, Mn, Cu and Zn adopting the standard procedures mentioned below.

The phosphorus concentration in di-acid extract was determined by Vanadomolybdo phosphoric yellow colour method by using spectrophotometer (Jasco V-530 UV visible spectrophotometer) at 470 nm wavelength [7] and expressed in percentage.

The concentration of potassium in di-acid extract was determined using the flame photometer [7] and expressed as a percentage.

The calcium content of the leaf samples was estimated by titrating the di-acid extract with 0.01 N EDTA using mureoxide as an indicator in the presence of 16% sodium hydroxide buffer [8] and expressed in percentage. The magnesium content of the leaf samples was estimated by titrating the di-acid extract with 0.01 N EDTA using ammonium hydroxide and ammonium chloride buffer and Eriochrome black-T as indicator. Magnesium titer value was obtained by subtracting the calcium titer value from the combined estimation of calcium and magnesium [8] and expressed in percentage.

Sulphur concentration in di-acid extract was determined by turbidometric method using spectrophotometer at a wave length of 420 nm [8] and expressed in percentage.

The di-acid extract was fed to Atomic absorption spectrophotometer (Agilent, 200 Series AA) and the concentration of iron, manganese, copper and zinc were determined [9] and expressed in mg kg^{-1}.

2.5 Fruit Yield and Quality Parameters Determination

Fruit yield was estimated by weighing total number of fruits harvested per plant and expressed as yield per tree (kg). Fruit yield per hectare for season was estimated depending upon the spacing adopted in the orchard and expressed in t ha^{-1}.

Fully ripened and matured fruits were selected and harvested for fruit quality analysis. Fruit quality parameters such as, total soluble solids were estimated by using digital hand refractometer (ATAGO Co. Ltd., Japan), Juice percentage, Acidity percentage, Ascorbic acid contents were determined by following the procedures given by [10].

2.6 Statistical Analysis

Results were analyzed in SPSS 20.0 using Pearson correlation coefficient matrix to know the significant variations between the leaf nutrient status with fruit yield and fruit quality parameters of sweet orange. Descriptive statistics were calculated using Microsoft Excel (Microsoft, WA, USA) spread sheet.

3. RESULTS AND DISCUSSION

Leaf nutrient analysis carried out for macro and micronutrients such as, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulpur (S), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu). The results pertaining to leaf nutrient analysis presented (Table 1), discussed and interpreted hereunder.

3.1 Leaf Macronutrients

From the results presented in Table 1, was observed that the leaf total nitrogen, phosphorus and potassium content ranged from 1.23 to 2.74, 0.03 to 0.24 and 0.88 to 3.59 per cent with a mean of 2.03, 0.16 and 1.96 per cent, respectively in the sweet orange orchards of the study area. Similar leaf nutrient contents in Nagpur mandarin orchards of Nagpur district were reported by [11]. Similar findings with respect to leaf N was reported by [12].

Leaf secondary nutrients such as calcium, magnesium and sulphur varied from 1.64 to 4.92, 0.28 to 2.80 and 0.14 to 1.54 per cent with a mean of 0.74, 0.44 and 0.30 per cent, respectively (Table 1).

As per the results presented in the Table 1, the distribution of macronutrients in the leaf samples as per rating chart suggested by [13], the per cent deficit of N, P and K in leaf samples were 2%, 8% and 4%, respectively. Per cent samples

low in N, P, K, Ca and Mg were 42%, 12%, 14%, 2% and 12%, respectively. Per cent samples optimum in N, P, K, Ca and Mg were 46%, 20%, 14%, 68% and 10%, respectively. High in N, P, K, Ca and Mg were found in 4%, 50%, 16%, 18% and 18% samples, respectively. Excess in N, P, K, Ca and Mg were noticed in 6%, 10%, 52%, 12% and 70% samples, respectively.

3.2 Leaf Micronutrients

Micronutrients such as, iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) analyzed for their status in the index leaves of the sweet orange and mean values are presented in the Table 1.

The Fe, Zn, Mn and Cu content of the leaves ranged from 17.16 to 99.82, 2.15 to 31.71, 5.96 to 86.50 and 0.92 to 50.08 mg kg^{-1}, respectively with mean values of 36.08, 9.18, 30.90 and 8.29 mg kg^{-1}, respectively.

The distribution of micronutrients in the leaf samples was categorized as suggested by [13]. About 54%, 62%, 52% and 26% samples were deficit in Fe, Zn, Mn and Cu, respectively. Low in Fe, Zn, Mn and Cu were to an extent of 28%, 16%, 14% and 24%, respectively. Optimum in Fe (18%), Zn (18%), Mn (34%) and Cu (38%). High in Zn and Cu were 4% and 6% samples, respectively. Excess in Cu (6%) (Table 1).

Leaf Zn deficiency (62%) was the most severe among the 10 mineral elements tested and followed by Fe (54%), Mn (52%) and Cu (26%). However, the average leaf content of N, P Ca and Cu was 2.03, 0.16, 2.66 and 8.29, which was much more than the optimum range, respectively. Similar findings with regard to leaf nutrient content of sweet orange growing in Anantapur district of Andhra Pradesh was reported by [14]. [15] and [16] reported that Zn, and Fe deficiencies were widespread in citrus growing soils of China. Low micronutrients status in citrus leaves of sub-tropical zone of Jammu region was reported by [17].

3.3 Fruit Yield

From the Table 2, it could be noticed that the fruit yield of the sweet orange ranged from 6.00 to 25.50 t ha^{-1} with a mean yield of 12.32 t ha^{-1}. The yield of sweet orange orchards of the study area was classified based on the ratings suggested by [13], accordingly, 52% of the orchards were poor yielders, 32% low yielders and 16% optimum yielders.

3.4 Fruit Quality

Fruit quality parameters like fruit weight, juice per cent, juice pH, titrable Acidity (%), total soluble solids (TSS) and vitamin C (ascorbic acid) were analyzed and the mean values are presented in Table 2.

The fruit weight, fruit juice per cent, juice pH, titrable acidity, TSS and vitamin C of the sweet orange fruits were ranged from 155.20 to 218.38 g, 24.34 to 38.20%, 3.30 to 4.10, 0.70 to 1.14%, 7.40 to 13.60 ^{o}Brix and 26.24 to 40.16 mg 100 ml^{-1} with an average value of 180.11 g, 31.62%, 3.62, 0.87%, 10.77 ^{o}Brix and 32.08 mg 100 ml^{-1}, respectively.

The juice per cent of sweet orange orchards obtained from all the orchards in the study was lower when compared with the standards (>42% juice) prescribed by [18]. The variation in the fruit juice per cent in all the orchards studied might be due to increased mobilization of sugars by manganese and potassium and probably due to more accumulation of sugars in fruits [19].

The results indicated that titrable acidity of the sweet orange fruits was more (0.7 to 1.14%) in all the orchards studied as per the standards (0.4 to 0.7 % acidity) given by [18].

Most of the vitamin C (ascorbic acid) values registered in the study were below the level of standards (44 mg 100 ml^{-1}) suggested by [18].

3.5 Correlation of the Leaf Nutrient Content with Fruit Yield and Fruit Quality

From the data presented in Table 3, it could be noticed that the fruit yield showed significant positive correlation with leaf N (r =0.519**) and P (r =0.409**). [20] also reported that the fruit yield was more significantly and positively correlated with leaf N content. [21] observed a positive correlation of leaf P status with fruit yield. [22] also reported that the correlation coefficient values of fruit yield was significantly and positively correlated with all the major nutrients in leaf. Similar findings were also reported by [23] while determining the relationship of orchard location, soil and tree nutrient status with fruit quality of 'Kinnow' mandarin (*Citrus reticulata* Blanco) in Sargodha district, Pakistan and reported that the fruit weight exhibited positive correlation with leaf N. The lesser relation of other foliar nutrients with fruit yield might be due

to the fact that their lower values in the foliar nutrient content.

Fruit weight had significant positive correlation with leaf N (r = 0.469**), P (r = 0.446**) and K (r = 0.415**). Similar results were reported by [24] with respect to leaf N and fruit weight.

Fruit juice percent was significantly and positively correlated with leaf N (r =0.353**) and P (r =0.364**). [23] also reported that the N content in the leaf was directly related to per cent juice content in the fruits. [22] also reported similar results in sweet orange grown on *Udic Haplustert* of Maharashtara.

Titrable acidity had significant negative correlation with leaf Fe (r = -0.371**) and leaf Mn (r = -0.292*). TSS showed a significant positive relation with leaf P (r = 0.438**) and significant negative correlation with leaf Mn (r = -0.311*).

Vitamin C content of the sweet orange fruit had significant positive correlation with leaf N (r = 0.437**), P (r = 0.516**) and K (r = 0.398**). Similar results were also observed by [23] while determining the relationship of orchard location, soil and tree nutrient status with fruit quality of 'Kinnow' mandarin (*Citrus reticulata* Blanco) in Sargodha district, Pakistan and reported that the Ascorbic acid (*r* = 0.25) positively correlated with soil P contents.

The leaf Ca, Mg, S, Zn and Cu content showed no significant correlation with either fruit yield or any of the fruit quality parameters.

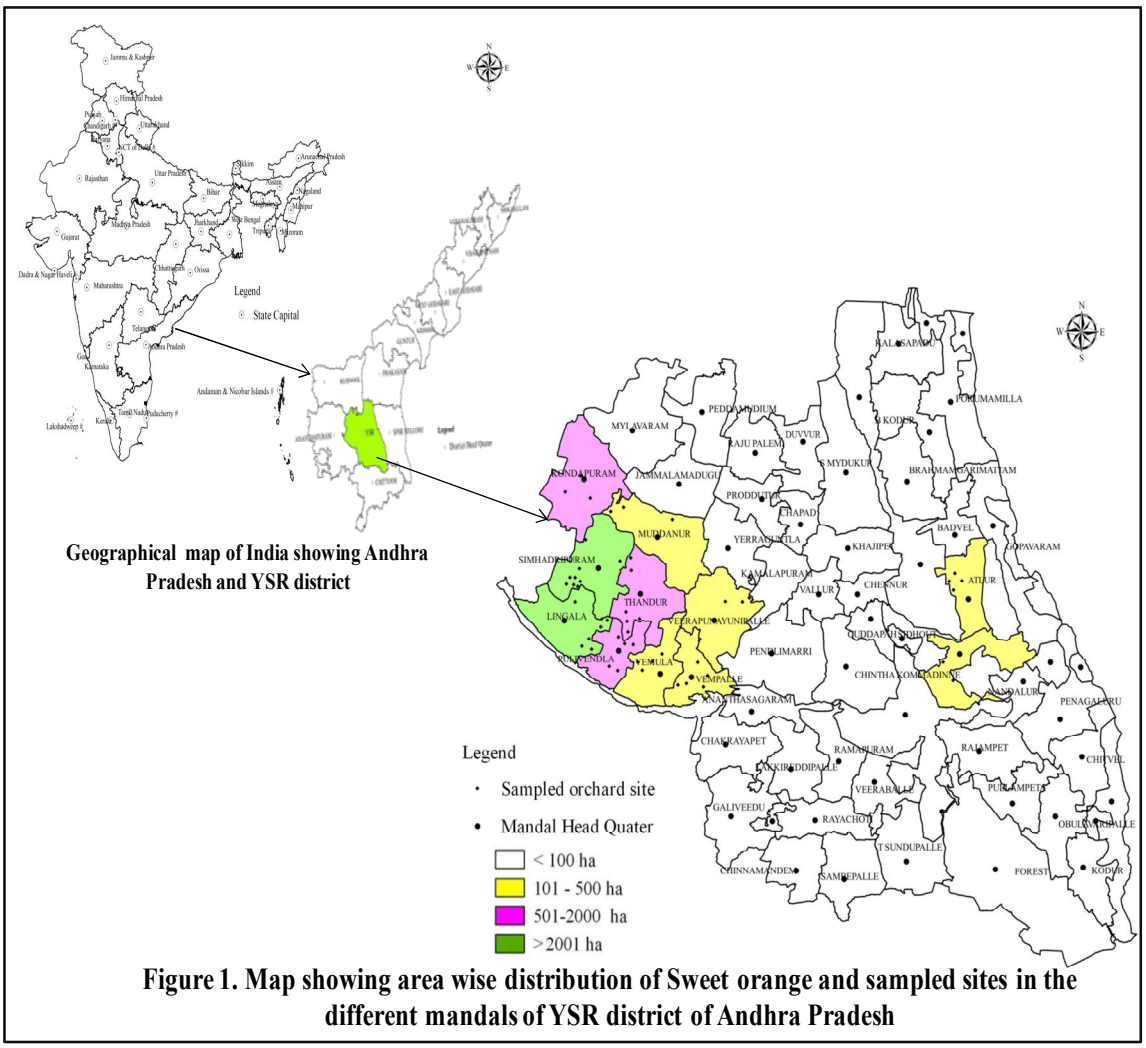

Figure 1. Map showing area wise distribution of Sweet orange and sampled sites in the different mandals of YSR district of Andhra Pradesh

Table 1. Mean mineral nutrient content of leaves of the sweet orange and the distribution of the leaf samples nutrient indices

Parameter	Mean	SD	Deficient		Low		Optimum		High		Excess	
			Samples	%	Samples	%	Samples	%	Samples	%	Samples	%
N (%)	2.03	0.44	1	2.00	21	42.00	23	46.00	2	4.00	3	6.00
P (%)	0.16	0.06	4	8.00	6	12.00	10	20.00	25	50.00	5	10.00
K (%)	1.96	0.61	2	4.00	7	14.00	7	14.00	8	16.00	26	52.00
Ca (%)	2.66	0.74	0	0.00	1	2.00	34	68.00	9	18.00	6	12.00
Mg (%)	1.11	0.44	0	0.00	1	2.00	5	10.00	9	18.00	35	70.00
*S (%)	0.40	0.30	0	0.00	7	14.00	23	46.00	9	18.00	11	22.00
Fe (mg kg^{-1})	36.08	23.68	27	54.00	14	28.00	9	18.00	0	0.00	0	0.00
Zn (mg kg^{-1})	9.18	7.15	31	62.00	8	16.00	9	18.00	2	4.00	0	0.00
Mn (mg kg^{-1})	30.90	20.18	26	52.00	7	14.00	17	34.00	0	0.00	0	0.00
Cu (mg kg^{-1})	8.29	8.57	13	26.00	12	24.00	19	38.00	3	6.00	3	6.00

*Nutrient ratings of Sweet orange leaves by [13] and *[25]*

Table 2. Mean fruit yield and fruit quality parameters of the study area

Parameter	Mean	SD
Fruit weight (g)	180.11	19.52
Juice %	31.62	3.48
Juice pH	3.62	0.18
Titrable Acidity (%)	0.87	0.10
TSS (^{o}Brix)	10.77	1.70
Vit.-C (mg $100ml^{-1}$)	32.08	3.82
Yield (t ha^{-1})	12.32	4.98

Table 3. Pearson correlation coefficient matrix of leaf mineral nutrients with fruit yield and fruit quality parameters

	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn
Fruit Wt.	0.469**	0.446**	0.415**	0.155	0.019	-0.204	-0.004	-0.134	-0.179	-0.117
% juice	0.353*	0.364**	0.147	-0.023	-0.068	-0.077	-0.028	-0.035	-0.008	-0.110
Juice pH	0.090	0.054	0.097	-0.067	0.212	0.024	-0.196	0.043	-0.024	-0.259
Titrable acidity	0.012	0.042	0.028	-0.262	-0.09	-0.093	-0.371**	-0.058	0.098	-0.292*
TSS %	0.267	0.438**	0.192	0.037	0.068	-0.032	-0.193	-0.199	-0.047	-0.311*
Vit.-C	0.437**	0.516**	0.398**	0.018	-0.042	-0.052	-0.058	-0.052	-0.178	-0.113
Yield	0.519**	0.409**	0.249	0.136	-0.043	-0.067	-0.049	-0.048	-0.168	-0.104

** and ** indicate a significant difference at P < 0.05 and P < 0.01, respectively*

4. CONCLUSION

Leaf Zn deficiency (62%) was the most severe among the 10 mineral elements tested and followed by Fe (54%), Mn (52%) and Cu (26%). The correlation coefficient values indicated that fruit weight and vitamin C was significantly correlated with all the major primary leaf nutrients. The lesser relation of foliar micro nutrients with fruit yield and quality might be due to the fact that their lower values in the foliar nutrient content.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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