Original Research Article

Effect of soil nutrient status on yield and quality of Sweet orange (*Citrus sinensis* (L.) Osbeck) in YSR district of Andhra Pradesh

Abstract

The present study was conducted to determine the effect of soil nutrient status on fruit yield and quality of sweet orange (*Citrus sinensis* (L.) Osbeck) in YSR district of Andhra Pradesh, India. To carry out this investigation fifty sweet orange orchards aged between 12 to 13 years were selected and soil samples were collected from these orchards at 0-30 cm and 30-60 cm depth. Majority of the soils of the study area were deficit in available nutrients such as Zn, Fe, N, P and Mn, but Ca, Mg, S, K and Cu were in optimum to high range.

The soil mineral nutrients like N, P and K influenced the fruit weight significantly and positively (r = 0.469**, r = 0.446** and r = 0.415**, respectively), but fruit yield and fruit juice per cent had significant positive relation with soil N (r = 0.519** and r = 0.353*) and P (r = 0.409** and r = 0.364**) only. Soil P had a significant positive correlation with TSS (r = 0.438**). Soil Fe and Mn had a significant negative correlation with titrable acidity (r = -0.371** and r = -0.292*, respectively). Soil Mn had a significant negative correlation with fruit TSS (r = -0.311*).

Key words: Sweet orange, soil macro nutrients, soil micro nutrients, fruit yield, fruit quality, YSR District.

Introduction

Sweet orange (*Citrus sinensis* (L.) Osbeck) occupies a prominent position in the fruit industry of the world, as well as in India. The area under sweet orange in India during 2015 was 2.78 lakh hectares with production of 45.26 lakh tones (Horticultural Statistics at a Glance, 2015).

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 (Horticultural Statistics at a Glance, 2015). In YSR district, area under sweet orange is 0.11 lakh ha with production of 1.54 lakh Mt (CPO, YSR district, 2015).

At present, among various citrus cultivars being grown in India, the sweet orange is the leading citrus cultivar with 70% share of the total citrus production. Productivity of sweet orange depends on many abiotic (climate, site, soil, nutrition & irrigation management) and biotic (rootstock, cultivar, insect pest & disease management) factors. Among them adequate supply of plant nutrients is a very important factor to produce the good quality fruits.

The application of macro-nutrients particularly nitrogen (N), phosphorus (P) and potassium (K) plays important role in yield, as well as fruit quality (Srivastava and Singh, 2009). The fruit size, weight, yield and quality (TSS, juice percent, acidity and ascorbic acid) are directly related to nutritional status of plant and soil of the orchard. (Huchche, 1999).

Sweet oranges, when used in combination with rough lemon (*Citrus jambhiri* Lush) rootstock, may be more prone to various nutritional disorders than mandarins (*Citrus reticulata* Blanco), especially for micronutrients. Studies addressing the contribution of different soil fertility and plant nutritional factors are comparatively limited. Absence of a suitable soil and plant test norm in relation to optimum fruit yield further jeopardized the timely diagnosis of causes for malnutrition of premier *Citrus sinensis* cultivar Mosambi in India. Such conditions are highly conducive to gradual improvisation in orchard efficiency, especially with advancing orchard age (Srivastava and Singh, 1999).

Therefore, the present study was conducted to investigate the relationship of soil nutrient status with fruit yield and quality of sweet orange in YSR district of Andhra Pradesh, India.

Materials and Methods

For studying the effect of soil nutrient status on fruit yield and quality of sweet orange in the YSR district, during 2014, fifty sweet orange orchards aged between 12 to 13 years were selected (Figure 1) in different mandals and in each orchard, two pits were dug at random and composite soil samples were separately collected at two depths *viz*., 0 – 30 and 30 – 60 cm with geo reference by taking location co-ordinates and collected samples were processed for laboratory analysis. Available nitrogen in soil was determined by alkaline permanganate method as described by Subbiah and Asija, (1956). Available phosphorus was extracted from soil with 0.5 M sodium bi-carbonate (Olsen *et al*., 1954) as an extracting agent and determined using double beam US-VIS spectrophotometer. The available 'K' was extracted with the neutral normal ammonium acetate determined using Flame photometer (Jackson, 1973). Calcium and magnesium were determined by versanate titration method (Vogel, 1978), available S was estimated by extracting the soil sample with 0.15% calcium chloride (Williams and Steinbergs, 1959) and S content in the extract was determined by turbidimetric method (Chesnin and Yien, 1951), available micronutrients *viz*., iron, manganese, zinc and copper in soil were extracted with 0.005 M DTPA extractant (1 : 2 ratio) developed by Lindsay and Norvell (1978) and contents were estimated by using Atomic Absorption spectrophotometer (Agilent, 200 Series AA).

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 Ranganna (1986).

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}.

Statistical analysis

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

Results and Discussion

Nutrient status of the sweet orange orchards

Major nutrients (N, P and K)

The soil available N content ranged from 125.26 to 307.33 kg ha^{-1}, with a mean value of 224.31 kg ha^{-1} at 0-30 cm and at 30 to 60 cm it ranged from 82.72 to 220.69 kg ha^{-1}, with a mean value of 150.79 kg ha^{-1} (Table 1 and Figure 2).

The available P content of soil showed a variation of 5.26 to 39.54 kg ha^{-1} and 2.13 to 25.07 kg ha^{-1} with a mean values of 17.79 kg ha^{-1} and 11.16 kg ha^{-1} in surface and sub-surface soils, respectively (Table 1 and Figure 2).

The available K content of the surface soils was differed from 116.14 to 955.92 kg ha^{-1}, with a mean value of 365.00 kg ha^{-1}. In the sub-surface soils of sweet orange orchards in study area, the available K content was varied from 69.66 to 554.51 kg ha^{-1}, with a mean value of 258.54 kg ha^{-1} (Table 1 and Figure 2).

As per the ratings given by Muhr *et al*. (1965), out of all the soils of sweet orange orchards studied, 82% were deficit in N and 18% were medium in N, 20% were deficient in P, 60% were medium in P and 20% were high in P, but in case of available K, 32% were in medium range and 68% were in high range (Table 2 and Figure 3). Similar results with regard to soil N, P and K was reported by Ranjha *et al*. (2002).

Secondary nutrients (Ca, Mg and S)

The exchangeable calcium (Ca) content of surface soils was ranged from 8.50 to 45.25 cmol(p$^+$)kg^{-1} with a mean value of 27.13 cmol(p$^+$)kg^{-1} and in sub-surface soils the exchangeable calcium content ranging from 6.00 to 46.50 cmol(p$^+$)kg^{-1} with a mean value of 29.52 cmol(p$^+$)kg^{-1} in sweet orange growing orchards of the study area (Table 1 and Figure 2).

The exchangeable magnesium (Mg) content of soil showed a variation of 2.25 to 41.50 cmol(p$^+$)kg^{-1} and 2.75 to 22.50 cmol(p$^+$)kg^{-1} with mean values of 13.48 cmol(p$^+$)kg^{-1} and 10.51 cmol(p$^+$)kg^{-1} in surface and sub-surface soils, respectively (Table 1 and Figure 2).

The available sulphur (S) content of surface soils was differed from 14.37 to 73.41 mg kg^{-1}, with a mean value of 30.12 mg kg^{-1}. In sub-surface soils of sweet orange orchards of study area, the available S content was varied from 8.35 to 29.16 mg kg^{-1}, with a mean value of 16.58 mg kg^{-1} (Table 1 and Figure 2).

The higher exchangeable calcium status observed in all the orchards both in the surface and subsurface soils and were above critical limit of <1.50 cmol(p$^+$)kg^{-1} as established by Tandon (1989). Similar trend was observed with respect to exchangeable magnesium status as that of exchangeable calcium. As per the critical limit of Mg <1.00 cmol(p$^+$)kg^{-1} developed by Tandon (1989).

The available S content was higher in surface soils than sub-surface soils of the study area. It might be due to application of organic manures and sulphur containing fertilizers on surface layers. As per the S critical limit (<10 mg kg^{-1}) prescribed by Tandon (1991), all the surface soils of the study area were sufficient in S content. Similar results were reported by Chaudhari *et al*. (2016).

Micronutrients (Fe, Cu, Mn and Zn)

The available Fe, Zn, Mn and Cu content of surface soils was ranged from 1.05 to 5.12, 0.08 to 1.23, 0.52 to 9.73 and 0.37 to 2.87 mg kg^{-1}, with mean values of 2.67, 0.37, 4.05 and 1.33 mg kg^{-1}, respectively in the sweet orange growing orchards of the study area (Table 1 and Figure 2).

In the sub-surface soils of study area, the available Fe, Zn, Mn and Cu content was varied from 0.67 to 3.95, 0.01 to 1.19, 0.59 to 9.00 and 0.42 to 2.60 mg kg^{-1}, with a mean value of 1.58, 0.26, 2.93 and 0.92 mg kg^{-1} , respectively (Table 1 and Figure 2).

Out of all the soils of sweet orange orchards studied, 24% and 78% samples were very low in available Fe and Zn, respectively. Low in available Fe, Zn and Mn contents to an extent of 68%, 18% and 8%, respectively. Medium in available Fe, Zn Mn and Cu were 8%, 4%, 38% and 18%, respectively. High in available Mn (36%) and Cu (82%), but very high in available Mn (18%) (Table 2 and Figure 3). Chaudhari *et al*. (2016) also reported that maximum soil samples were deficient in Fe and Zn irrespective of soil depth.

The variation in the available micronutrient contents of soils might be due to variation in organic carbon content of the soils and micronutrient containing minerals. Similar results were also reported by Khokhar *et al*. (2012), Noor *et al*. (2013) and Surwase *et al*. (2016) with regard to available micronutrient concentration and distribution in different soils.

Fruit yield

From the table 3, 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 Srivastava *et al*., (2007), accordingly, 52% of the orchards were poor yielders, 32% low yielders and 16% optimum yielders.

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 3.

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 100ml^{-1} with an average value of 180.11 g, 31.62%, 3.62, 0.87%, 10.77 ^{o}Brix and 32.08 mg 100ml^{-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 Satyanarayana and Ramasubba Reddy (1994). 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 (Kazi *et al.,* 2012).

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 Satyanarayana and Ramasubba Reddy (1994).

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 Satyanarayana and Ramasubba Reddy (1994).

Correlation of soil nutrient status with fruit yield and fruit quality

As per the correlation matrix presented in the table 4, the soil mineral nutrients like N, P and K influenced the fruit weight significantly and positively (r = 0.469**, r = 0.446** and r = 0.415**, respectively), showing their importance in regulating the quantum of fruit weight, but fruit yield and fruit juice per cent had significant positive relation with soil N (r = 0.519** and r = 0.353*) and P (r = 0.409** and r = 0.364**) only. Earlier studies demonstrated the similar positive correlation of soil available N and P with fruit yields of Nagpur mandarin (Srivastava and Singh 2001) and *Kinnow* mandarin (Dhillon and Dhatt 1988). Soil P had a significant positive correlation with TSS (r = 0.438**).

Soil Fe and Mn had a significant negative correlation with titrable acidity (r = -0.371** and r = -0.292*, respectively). Soil Mn had a significant negative correlation with fruit TSS (r = -0.311*).

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

Conclusions

Majority of the soils of the study area were deficit in available nutrients such as Zn, Fe, N, P and Mn, but Ca, Mg, S, K and Cu were in optimum to high range. Fruit yield and fruit weight was positively and significantly influenced by soil organic carbon content, N and P. Fruit juice per cent had significant positive relation with soil N and P. Soil P had a significant positive correlation with TSS. Soil Fe and Mn had a significant negative correlation with titrable acidity. Soil Mn had a significant negative correlation with fruit TSS.

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Table 1. Soil mineral nutrient content of the sweet orange growing soils of YSR district.

Parameter	Total samples	0 – 30 cm			30 – 60 cm		
		Range	**Mean**	**SD**	**Range**	**Mean**	**SD**
Available N (kg ha^{-1})	50	125.26- 307.33	224.31	51.05	82.72 - 220.69	150.79	40.04
Available P (kg ha^{-1})	50	5.26 - 39.54	17.79	9.095	2.13 - 25.07	11.16	6.08
Available K (kg ha^{-1})	50	116.14 - 955.92	365.00	169.34	69.66 - 554.51	258.54	95.59
Ex. Ca (cmol(p^+)kg^{-1})	50	8.50 - 45.25	27.13	8.47	6.00 - 46.50	29.52	8.83
Ex. Mg (cmol(p^+)kg^{-1})	50	2.25 - 41.50	13.48	8.97	2.75 - 22.50	10.51	4.86
Available S (mg kg^{-1})	50	14.37 - 73.41	30.12	13.19	8.35 - 29.16	16.58	4.51
DTPA-Fe (mg kg^{-1})	50	1.05 - 5.12	2.67	0.92	0.67 - 3.95	1.58	0.72
DTPA-Zn (mg kg^{-1})	50	0.08 - 1.23	0.37	0.25	0.01 - 1.19	0.26	0.20
DTPA-Mn (mg kg^{-1})	50	0.52 - 9.73	4.05	1.98	0.59 - 9.00	2.93	2.03
DTPA-Cu (mg kg^{-1})	50	0.37 - 2.87	1.33	0.53	0.42 - 2.60	0.92	0.41

(Ex. = Exchangeable)

Table 2. Distribution of the mineral nutrients in the sweet orange orchards soils of YSR district.

Parameter	Total samples	Very low		Low		Medium		High		Very high	
		Number of Samples	%	Number of Samples	%	Number of Samples	%	Number of Samples	%	Number of Samples	%
Available N (kg ha^{-1})	50	–	–	41	82.00	9	18.00	–	–	–	–
Available P (kg ha^{-1})	50	–	–	10	20.00	30	60.00	10	20.00	–	–
Available K (kg ha^{-1})	50	–	–	–	–	16	32.00	34	68.00	–	–
DTPA-Fe (mg kg^{-1})	50	12	24.00	34	68.00	4	8.00	–	–	–	–
DTPA-Zn (mg kg^{-1})	50	39	78.00	9	18.00	2	4.00	–	–	–	–
DTPA-Mn (mg kg^{-1})	50	–	–	4	8.00	19	38.00	18	36.00	9	18.00
DTPA-Cu (mg kg^{-1})	50	–	–	–	–	9	18.00	41	82.00	–	–

* Soil nutrient indices were referred to the Muhr *et al*. (1965) and Lindsay and Norvell (1978).

Table 3. Mean fruit yield and fruit quality parameters of the study area

Parameter	Total samples	Range	Mean	SD
Fruit weight (g)	50	155.20 - 218.38	180.11	19.52
Juice %	50	24.34 - 38.20	31.62	3.48
Juice pH	50	3.30 - 4.10	3.62	0.18
Titrable Acidity (%)	50	0.70 - 1.14	0.87	0.10
TSS (^{o}Brix)	50	7.40 - 13.60	10.77	1.70
Vit.-C (mg $100ml^{-1}$)	50	26.24 - 40.16	32.08	3.82
Yield (t ha^{-1})	50	6.00 - 25.50	12.32	4.98

Table 4. Correlation coefficient matrix between soil mineral nutrients and fruit yield, fruit quality parameters

	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn
Fruit weight	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	-0.090	-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.

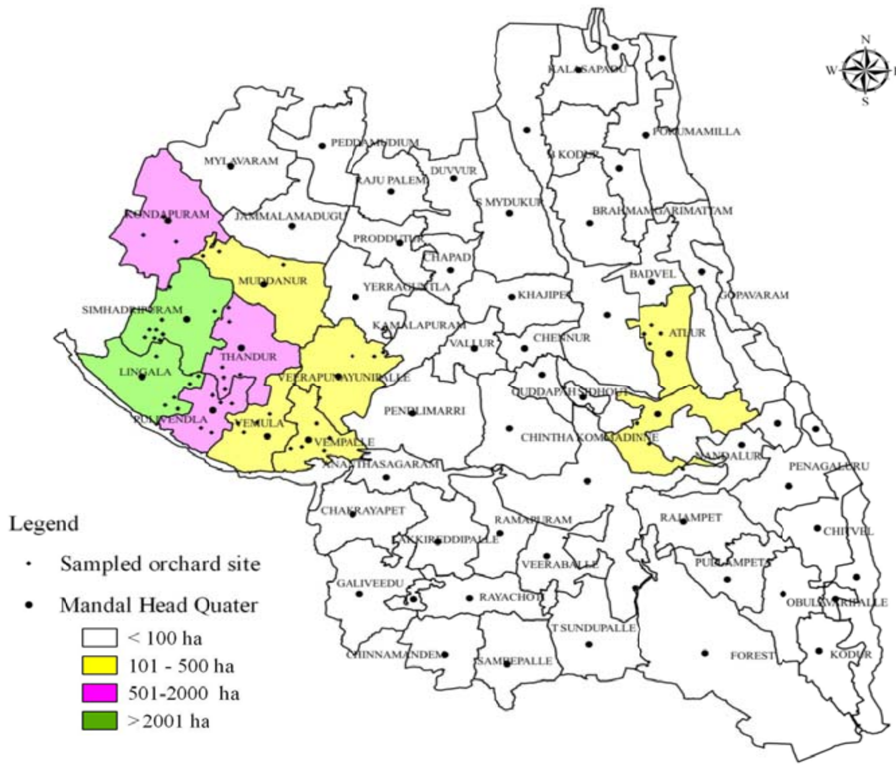

Figure 1. Map showing area wise distribution of Sweet orange and sampled sites in different mandals of YSR district

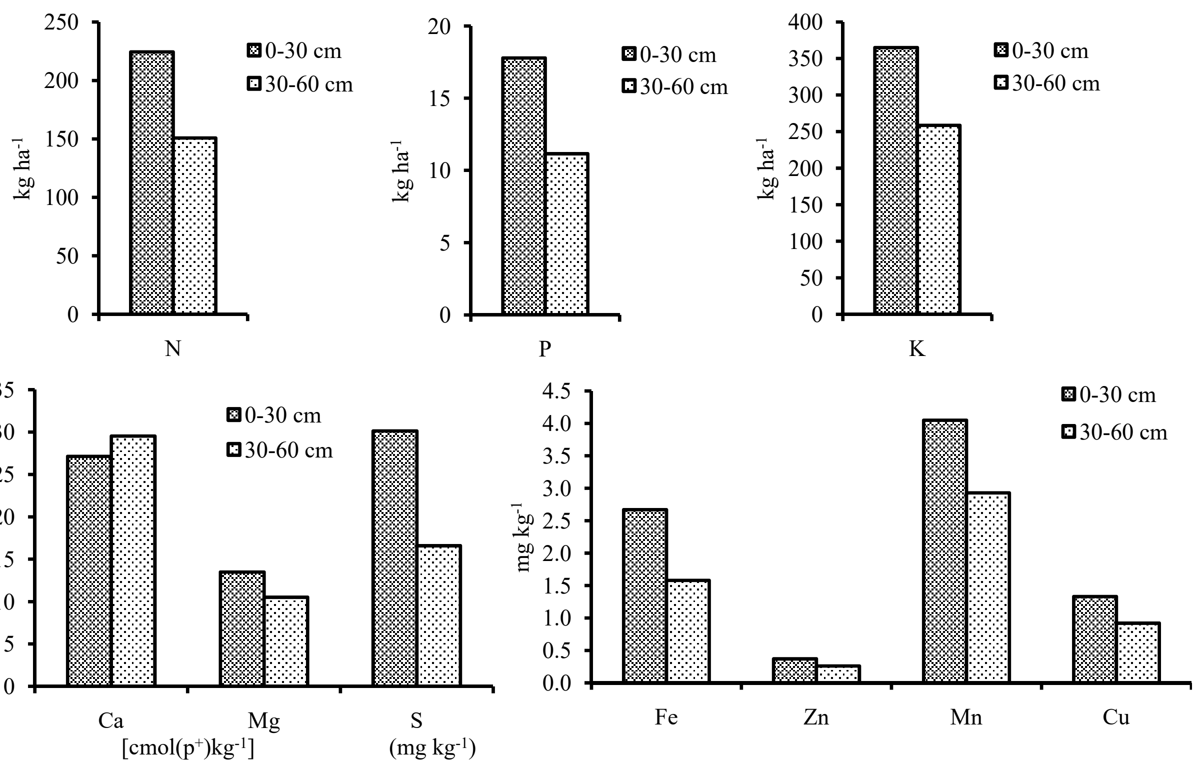

Figure 2. Mean soil nutrients content of the sweet orange growing soils in YSR district

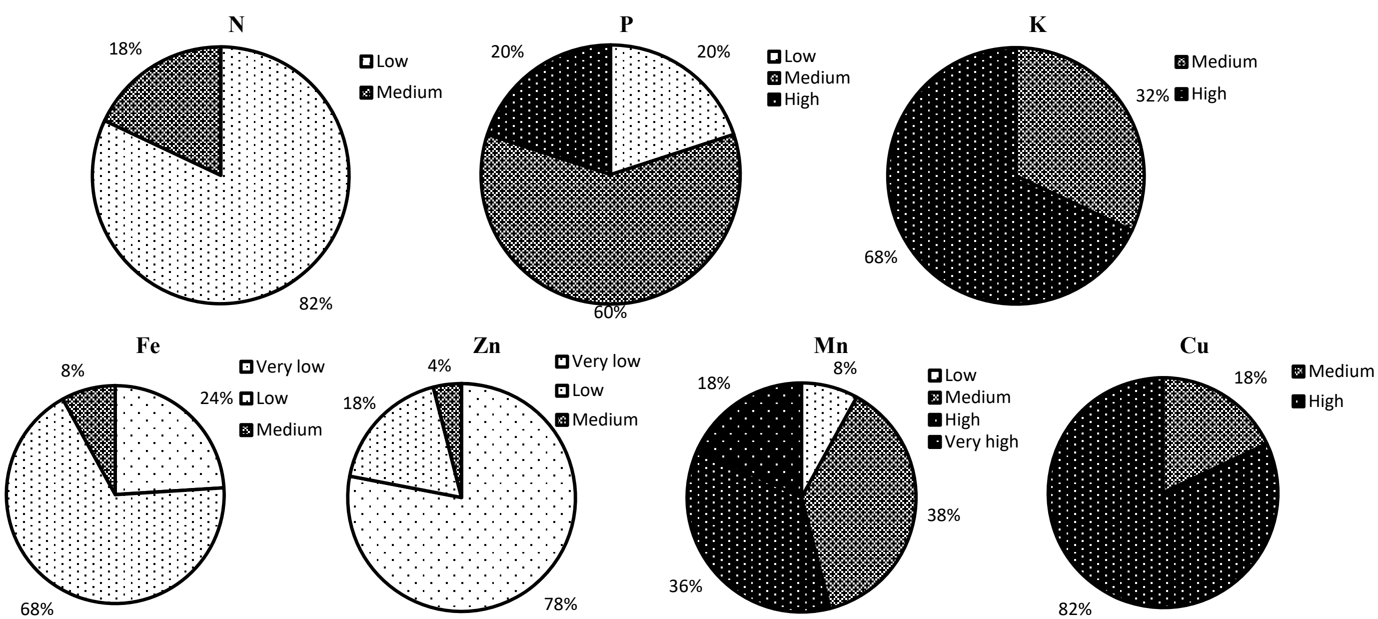

Figure 3. Nutrients distribution in the soils of sweet orange orchards of YSR district