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Soil and Plant Analysis - A Strategic Tool to Diagnose Micronutrient Imbalance in Lime and Sapota Orchard in Tablelands of Chambal Ravine Region of India

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ABSTRACT

Micronutrient imbalance in lime and sapota fruit crops result in unstable fruit yield, fruit shedding and degrade quality of the produce. A study was therefore conducted to evaluate micronutrient statusoflime and sapota orchard by analysing soil and plant samples. Soil samples were collected from surface (0-15cm) and sub-surface (15-30cm)depth representing whole orchard. At the same time, plant samples including 35-40 each for leaves and petiole samples each from lime and sapota field was also collected.Available micronutrients from soil samples were extracted using diethylenetriaminepenta acetic acid (DTPA) and it was in the order of manganese (Mn)> iron (Fe)> zinc (Zn)> copper (Cu) in both lime and sapota plantations. DTPA- extractable Zn and Cu showed low status, marginal status of Fe and sufficient level of Mn in soils of sapota plantations. In plant analysis, high concentration of Cu (869 mg kg^{-1}) and Zn (411mg kg^{-1}) was observed in lime leaves; however, in sapota crop Cu and Zn content was 8.25mg kg^{-1} and 16.7mg kg^{-1} respectively. Similarly, Fe and Mn content of lime leaves was 197 and 43 mg kg^{-1} which was slightly higher than sapota leaves that recorded 128 and 49mg kg^{-1} of Fe and Zn respectively. In sapota plants, higher Mn and Cu concentration in leaf resulted in Zn deficiency symptoms such as shortened internodes or rosette disorders of sapota plants. Thus, correcting micronutrient deficiency is pre-requisite for qualitative and quantitative fruit production in tablelands of India.

Keywords: Copper, Iron, Leaf analysis, Manganese, Micronutrient deficiency, Sapota, Zinc

INTRODUCTION

Ravines are typical examples of land degradation covering approximately 2.06 Mha and gully formation occurs in 8.31 Mhaarea in India (ICAR-NAAS, 2010). Generally, these ravine lands also known as badlands are situated near rivers and typically know for deep ravines cutting with extension overnearby arable lands (Pani and Carling 2013). Cultivation of crops is practised on the top slope called tablelands and adjacent undulating topography of gully eroded areas of Chambal ravines. Fruit crops like lime is of great significance in semi-arid regions of Rajasthan due to its hardy nature and low water requirement. However, sapota crop is recently introduced in the region and therefore information on area and production of sapota in Rajasthan is not readily available. Lime per unit production in Rajasthan is 4.0 t ha^{0-1} which is low against India's national average of 8.33 t ha"1 (Srivastava and Shyam, 2008). The area under sapota in India is estimated to be 1.77 lakh hectares, with an annual production of 1.74 million metric tonnes and productivity of 9.91 Mg ha^{-1} (Sharma, 2015). Major sapota growing state includes Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu, Kerala, Punjab, West Bengal, and Haryana.

In citrus crops necrosis, die back, chlorosis symptoms are commonly observed in the region due to nutrient deficiency resulting in decline of lime yield (Somasundaram *et al*., 2011). Nutrient imbalance in sapota crop is visualised by poorfruit setting,quality, shedding of fruitsand low productivity. Guvvali (2016) reported thatonly 10-12% of the total fruits set, and retains until maturity in sapota crop. Lower fruit production in north western India is mainly due to nutrient imbalance or disorders which cause considerable yield reduction with huge economic loss (Somasundaram et al., 2011; Guvvali and Shirol, 2017). Subsequently, orchards provide sub optimal fruit yield with increasing gap between the amount of nutrient added and demand of crop (Srivastava and Singh, 2006). In Rajasthan, about 57, 34, 28 and 9% soils are deficient in zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) respectively (Shukla, 2018). Micronutrients are required by plants to perform specific biochemical reactions, metabolism required for its growth and productivity. Thus in order to avoid yield and quality loss, nutrient requirements of lime and sapota crop need to be carefully monitored through soil and plant analysis for evolving nutrient management strategies. Besides soil analysis, leaf sample analysis is considered a more direct method of plant nutritional status evaluation, especially, for fruit crops as these differ from seasonal crops in nutrient requirement due to their size, population density, rate of growth and rooting pattern (Motsara and Roy, 2008). In ravine landforms, very scanty information is available on micronutrientdeficiency in fruit crops (Somasundaram *et al.,* 2011; Meena *et al.,* 2019). Therefore, the present study was conducted with the hypothesis that diagnosing micronutrient disorders of sapota crop is vital to achieve optimum fruit yield so as to improve orchard efficiency with advancing age of crop. The objective of this study was to analyse micronutrient deficiency or sufficiency level through soil and plant analysis in lime and sapota crop and its management for sustainable productivity in semi-arid regions of ravine ecosystem.

MATERIAL AND METHODS

Brief description of experimental site

The study area comprises two distinct landscapes, the agricultural tablelands and the ravenous lands adjoining Chambal river. The physiography is constituted of gently sloping (<2% slope), moderately well-drained tablelands in the immediate vicinity of ravines. The experimental orchard area is a tableland located at Research Farm, ICAR- Indian Institute of Soil and Water Conservation, Research Centre, Kota, situated at 25º 11' N latitude and 75º 51' E longitudes at an elevation of 256.9 meters above mean sea levelwith fairly levelled topography. According to Koppen's climate classification subtype, the climate of Kota is semi-arid type (Mid latitude steppe). More than 90 per cent of rainfallis received during mid-June to September with scanty showers during winter months (Nov-Dec). This region is characterized by mild and dry winters and hot summers with average rainfall of 740mm (mean of last 5 years) of which most of the rainfall is received during July month (300 mm).

Lime (Kagzi lime variety) crop planted at 4.5 x 4.5 m (row x plant) during 2001; sapota cv. 'Kalipatti' trees planted at 8 x 8 m spacing (row x plant) during 2008. The study was carried out during 2018-2019at the research farm of Indian Institute of Soil and Water Conservation, Research Centre, Kota, Rajasthan. The soils are brown to dark grey brown in colour, generally non calcareous occurring on flat gently sloping land with less than 2% slope. The soils of the region are moderately well drained fine textured soils classified as Typic Chromoustert belonging to Kota soil series. The region comprises of two diverse geology namely sandstone quartzite, silicaceous limestone and dolomite where a vast area is formed from the alluvium brought down by Chambal and its tributaries passing through the residual hillocks and gently sloping rocky plateau (Shyampura and Sehgal, 1995). The physico-chemical properties of the orchard soil are given in Table 1. The irrigation water used in sapota orchard contained bicarbonate, calcium and magnesium of 600, 66.8 and 33.5 mg l^{-1} respectively, with pH of 7.6 and electrical conductivity (EC) of 2.76 dSm^{-1}.

Orchard Management

The experimental trees were managed with uniform cultural practices as per the standard recommendations with respect to manures and fertilizers, irrigation and plant protection measures,etc. Nutrients were regularly supplied to lime crop duringcritical period of crop growth for better production and explained in Table 2. Recommended dose of nitrogen (N), phosphorus (P_2O_5), and potash (K_2O) was applied beyond a 30-cm radius from the tree trunk of lime. After ten years, fertilizer were mixed @ 750g N, 450g P and 750g K was applied to each lime plant every year. Fertilizers were applied to each tree in two or

Table 1. Soil properties under lime and sapota orchard

Soil parameters	Lime		Sapota	
Depth (cm)	**0-15**	**15-30**	**0-15**	**15-30**
pH(1:2.5)	7.74	7.51	7.81	7.62
EC (dS m^{-1})	0.57	0.62	0.55	0.59
OC (g kg^{-1})	4.7	3.6	4.5	3.4
Available nutrients (kg ha^{-1})				
Nitrogen (N)	365.7	304.4	342.3	288.7
Phosphorus (P)	17.4	13.9	15.41	11.4
Potassium (K)	436.5	412.4	386	344.5
Exchangeable cations (cmol p^+ kg^{-1})				
Na	4.9	5.7	3.2	3.5
Ca	18.2	17.9	17.7	17.8
Mg	7.6	6.1	7.5	6.4
Cation Exchange Capacity (CEC) (cmol p^+ kg^{-1})	27.6	22.5	33.4	32.8
Soil texture (%)				
Sand	27.8	29.3	27.2	29.7
Silt	42.2	41.5	44.3	42.3
Clay	30	29.2	28.5	28

three split doses when soil is moist. In sapota orchard, recommended doses of fertilizer were mixed @ 1000 g N, 500 g P and 500 g K per plant for ten-year-old sapota plants. For the application of full recommended dose of NPK,2174 g urea (1000 g N), 3125 g single super phosphate (500 g P) and 833 g murate of potash (500 g K) per plant were applied from 6^{th} year onwards. Full amount of phosphorus, potash and half dose of nitrogen in various treatments were applied as basal dose before vegetative sprouting in the month of June. Remaining half dose of nitrogen was applied after fruit set in the month of December.

Collection of plant and soil samples

A systematic survey of lime and sapota orchard was conducted to assess the micronutrient status in 15 and 10 year old plantation covering an area of 2 and 0.4 ha respectively. For leaf sample collection, uniform area was selected in the orchard and 30 trees were selected as shown in the Fig 1. In both lime and sapota orchard, recently matured leaf were collected from north, south, east, and west quarters of thetrees (Reuter *et al.,* 1997) during September and October.About 35-40 fully developed leaf samples were collected, from which petioles samples were separated.The sampling pattern is shown in figure 1 omitting the border plants. From the 35-40 leaf samples collected, petiole samples (40) separated,

Table 2. Fertilizer management in lime and sapotaorchard

Age (years)	Nitrogen (g/plant)	P_2O_5 (g/plant)	K_2O (g/plant)
		Lime	
1	75	40	75
2	150	80	150
3	225	120	225
4	300	160	300
5	375	200	375
6	450	240	450
7	525	280	525
8	600	320	600
9	675	360	675
10	750	400	750
		Sapota	
1	200	200	300
2	200	200	300
3	200	200	300
4	200	200	300
5	200	200	300
6	1000	500	500
7	1000	500	500
8	1000	1000	1500
9	1000	1000	1500
10	1000	1000	1500

shade dried and grounded to fine powder for nutrient analysis. For nutrient analysis, 1g of sample was digested with tri acid mixtures (nitric, sulphuric and perchloric acid at 9:2:1). Micronutrients were estimated by directly feeding the filtered tri acid extract of the plant sample to a calibrated atomic absorption spectrophotometer using respective hollow cathode lamps for each element (Fe, Mn, Zn and Cu). Micronutrient concentration was expressed in mg kg^{-1} on dry weight basis.

Soil samples were collected from four quadrants at two different depths (0-15cm and 15-30cm) of the lime and sapota orchard (15 composite samples from each depth). Soil samples were air dried, grounded and passed through 2mm sieve and subjected to analysis of available micronutrients, namely Fe, Mn, Zn and Cu. For the soil analysis 20g soil samples was shaken with 40ml 0.005M DTPA extractant for 2 hours (Linday and Norvell, 1978). The filtered extract was directly read on AAS (model Thermo M6 series; Thermo Scientific, Waltham, Mass.) for micronutrient analysis of iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn).

RESULTS AND DISCUSSION

Micronutrient concentration in soil samples

Micronutrient concentration of soil samples under sapota plantations are shown in Table 3. Among micronutrients, highest concentration was observed in Mn, followed by Fe, Zn and Cu. Surface soil recorded higher micronutrient concentration compared to sub-surface soil except for Mn. The micronutrient concentration in soil was crucially interpreted considering the critical limit of soil availability of DTPA extractable Zn, Cu, Mn and Fe as 0.6, 0.2, 2 and 4.5 mg kg^{-1} respectively suggested by Lindsay and Norvel (1978) and Katyal(2018).

The available Fe content in lime and sapota orchard ranged from 5.3 to 7.7 mg kg^{-1} and 3.4 to 8 mg kg^{-1} with mean value of 6.1 and 5.19 mg kg^{-1} respectively. However, sub surface mean values of DTPA Fe content in lime and sapota orchard was 5.4 and 4.59 mg kg^{-1} respectively (Table 3). Most of the soil samples showed Fe concentration below the sufficiency range (6-8 mg kg^{-1}) suggesting that Fe deficiency might arise in future in sapota plantation. Higher bicarbonate concentration of irrigation water used in fruit orchard could result in Fe deficiency. In the medium black soils of study site, Fe deficiency in lime plantations owing to increased concentration of bicarbonate ions in irrigation water was reported by Somasundaram et al. (2011). Similar report of Fe deficiency in pomegranate orchard was also reported by Gathala et al. (2004). Considering the critical concentration of soil Mn (2 mg kg^{-1}), DTPA extractable Mn concentration in both lime and sapota orchard were above sufficiency range. In lime and sapota orchard, DTPA-Mn of surface samples varied from 13.7 to 27.8 mg kg^{-1} and 8.4 to 15.2 mg kg^{-1} with mean value of 20.2 and 12.11 mg kg^{-1} respectively. In sub surface soil Mn concentration varied from 12.7 to 24.6 and 6.57 to 16.03 mg kg^{-1} with a mean value of 18.8 and 11.3 mg kg^{-1} respectively in lime and sapota orchard. In vertisol, high concentrations of both total and DTPA extractable Mn had been reported earlier by few authors (Singh *et al.,* 2006; Kumar and Babel, 2011). However, Surwase et al.(2016) also found low status of Fe and Mn in silty clay loam soils under orange crop, although soils had optimum Zn and Cu. Available Zn concentration in lime orchard was higher than that of sapota orchard. The Zn content was low to marginal level in lime orchard. The DTPA extractable Zn concentration of lime and sapota orchard varied between 0.42 to 0.97 mg kg^{-1} and 0.17 to 0.74 mg kg^{-1} respectively in surface soil. Sub surface DTPA Zn concentration varied from 0.26 to 0.81 and 0.19 to 0.72 mg kg^{-1} respectively in lime and sapota orchard. Earlier study reported Zn deficiency in fruit orchard soils of south eastern Rajasthan (Kumar and Babel, 2011; Somasundaram *et al.* 2011). Among all the four micronutrients, Cu concentration was lowest in orchard soils. The DTPA extractable Cu concentration varied between 0.082 to 0.51 mg kg^{-1} and 0.02 to 0.35 mg kg^{-1} in surface soils of lime and sapota plantations. Sub surface samples recorded lower Cu content varying from 0.05 to 0.33 mg kg^{-1} and.02 to 0.25 mg kg^{-1} in lime and sapota orchard.Soils of orchard have pH >7.5, Zn forms negatively charged ions called zincate ions (ZnO_2^{2-}) which can reduce Zn availability in soils (Katyal, 2018). Except for Mn, Fe, Zn and Cu concentration were higher in surface compared to sub surface soil. Similar results were also reported by Surwase et al. (2016) who reported higher DTPA extractable micronutrients in surface soils of orange orchards due to higher soil organic carbon and biological activity in surface layer. Thus, balanced micronutrient fertilization is necessary to correct nutrient deficiency in soils of fruits crops for doubling farmer's income.

Micronutrient concentration in plant samples (leaves and petioles)

Plant analysis is known as adiagnostic tool for managing mineral nutrition and the total nutrient concentrationin the leaf tissue provide an accurate production potential of fruit crop which mostly depends upon the supply and uptake of particular nutrient (Srivastava and Singh 2006). Leaf micronutrient concentration, like soil micronutrient content, showed wide variation (Table 4).The mean Fe content in leaves and petioles of lime trees were 196.8 and 161 mg kg^{-1} whereas, in sapota plantations it was 127 and 120 mg kg^{-1}respectively. Leaf Fe concentrations was higher than the normal Fe concentration in plant tissues. However, 12% plant samples were deficient in Fe and in case of petioles 8, 54 and 33% samples were deficient, sufficient and high in Fe concentration. Considering the optimum level of total Fe concentration in plant tissue (50-100 mg kg^{-1}), more than 62% of samples were sufficient and 18% samples recorded excess of Fe concentration. During field examination for sample collection, some trees showed interveinal chlorosis and necrotic symptoms were observed in leaves of both lime and sapota crop.(Fig. 2). Considering the normal Mn content in plant tissues (15 to 50 mg kg^{-1}), most

Table 3. Micronutrient concentration and ranges (mg kg^{-1}) in soils of lime and sapotaorchard

Soil depth (cm)	Fe	Mn	Cu	Zn
Lime				
Surface soil (0-15)				
Min	5.3	13.7	0.082	0.42
Max	7.7	27.8	0.51	0.97
Mean*	6.1±0.23	20.2±1.1	0.28±0.025	0.69±0.032
Sub surface (15-30)				
Min	3.8	12.7	0.05	0.26
Max	7.2	24.6	0.33	0.81
Mean*	5.4±0.30	18.8±0.81	0.18±0.02	0.53±0.031
Sapota				
Surface soil (0-15)				
Min	3.4	8.4	0.02	0.17
Max	8.0	15.2	0.35	0.74
Mean*	5.19 ± 0.33	12.11± 0.5	0.19 ± 0.03	0.38±0.05
Sub surface (15-30)				
Min	2.8	6.57	0.02	0.19
Max	6.5	16.03	0.25	0.72
Mean*	4.59 ± 0.29	11.3 ± 0.72	0.10 ± 0.02	0.42 ± 0.05

**Mean of 15 samples, ± Standard error of mean*

Table 4. Leaf and petiole micronutrient concentration and ranges (mg kg^{-1}) in lime andsapotaplantations

	Fe		Mn mg kg^{-1}		Cu		Zn	
	Leaf	**Petiole**	**Leaf**	**Petiole**	**Leaf**	**Petiole**	**Leaf**	**Petiole**
Lime								
Range	45 – 470.3	61.2 – 313.5	18.6 – 84.9	5.64 – 55.3	45 – 1588	63 – 941	46.3 – 650.8	68 – 473.2
Mean*	196.8 ± 22.7	161.1 ± 20.1	42.87 ± 3.58	18.6 ± 2.2	869 ± 89.6	526 ± 57.9	411 ± 39.8	293 ± 21.3
Sapota								
Range	89.41 – 231.24	33.52 – 284.51	22.2 – 97.61	11.31 – 69.26	4.35 – 19.78	2 – 18.48	0.62 – 48.12	0.54 – 36
Mean*	127.66 ± 6.56	119.8 ± 12.23	48.84 ± 3.98	33.46 ± 2.92	8.25 ± 0.77	9 ± 0.89	16.66 ± 2.25	13.01 ± 2.1

**Mean of 30 samples, ± Standard error of mean*

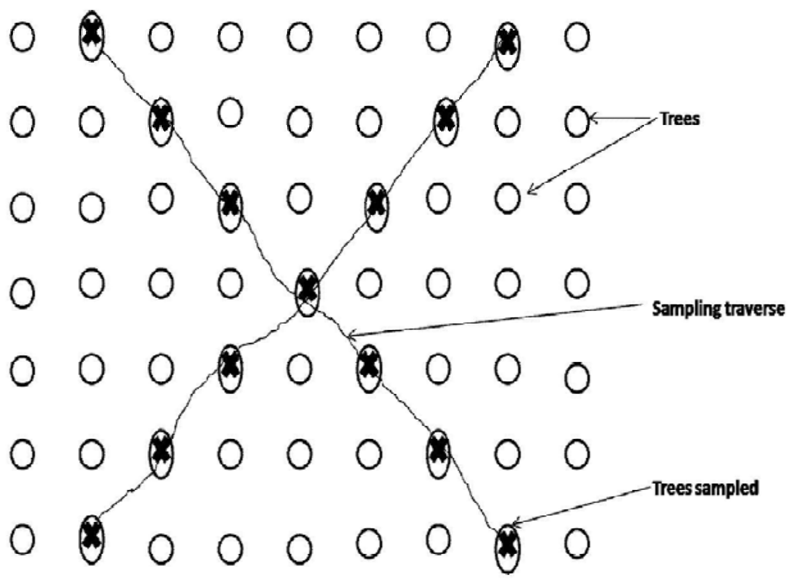

Fig. 1. Collection of representative plant samples from sapotafruit orchard

(a) (b)

Fig. 2. Iron deficiency in lime (a) and sapota (b) plants

of the leaf samples showed deficient to sufficient status. The average Mn concentration in lime varied between 43 and 19 mg kg^{-1} and in sapota was 48 and 33 mg kg^{-1} respectively for leaves and petioles samples (Table 4). Leaf samples registered 64% sufficientand 36% excess concentrationof Mn, whereas in petiole samples 8% samples were deficient. Excessive Mnconcentration in plant tissues can alter various processes such as enzyme activity, absorption, translocation and utilization of other mineral elements (Ca, Mg, Fe and P), causing oxidative stress (Ducicand Polle, 2005; Lei *et al.,* 2007). Mean Cu concentration in lime leaf samples varied between 869 and 526 mg kg^{-1} in leaf and petiole sample. In contrast, lower Cu concentration values of leaf samples were recorded in sapota plants. Copper concentration of sapota leaf samples varied from 4.35 to 19.78 mg kg^{-1} with a mean value of 8.25 mg kg^{-1}. The Cu concentration of petiole samples varied from 2 to 18.48 mg kg^{-1} with a mean value of 9 mg kg^{-1} (Table 4). The Cu concentration range in plant samples vary from 5 to 16 mg kg^{-1}. Based on the normal range of

Cu (100 mg kg^{-1}) in plants, lime plants samples showed excessive total Cu content. This was mainly attributed to the spray of Cu based fungicide to control fungal disease in orchard. Some plants with young leaves showed chlorosis symptoms due to Cu toxicity. However, in sapota crop, 13 and 21% of leaf and petiole samples were recorded as deficient and 79% were sufficient in Cu. However, Cu deficiency symptoms (dieback of apical buds) in sapota were observed during plant sampling in some sapota trees. Some common symptoms included premature defoliation and die back of twigs occurred. The tip of the twigs developed multiple buds which died soon. Zinc concentration of lime crop for leaf and petiole varied from 46.7 to 650.8 mg kg^{-1} and 68 to 473.3 mg kg^{-1} respectively with a mean value of 411 and 293 mg kg^{-1}. In sapota crop, the Zn concentration of leaf and petiole samples varied between 0.62 - 48.12 and 0.54- 36.0 mg kg^{-1} with a mean value of 16.7 and 13.0 mg kg^{-1} respectively (Table 3). Wide difference between Fe content in sapota and lime was observed in the study. Based upon the Zn concentration (<20 mg kg^{-1}), more than 73% samples were sufficient in Zn content in lime orchard. However, in sapota crop 50% of leaf samples were deficient where as 42% recorded optimum to highand 8% had excess Zn status.In petioles, 67 and 33% samples recorded deficiency and sufficiency of Zn respectively in sapota plants. High Zn concentration in lemon orchard was also reported by Somasundaram et al. (2011) where more than 88% leaf samples recorded higher Zn content. They suggested accumulation of excess of Cu in leaf resulted in greater accumulation of Zn to maintain nutrient balance.

Soil and foliar method of fertilizer application is utilized for sapota crop.Foliar application of micronutrients is considered as quickest means to correct nutrient deficiency in fruit trees. In sapota crop, Fe, Mn, Zn and Cu deficiency can be corrected by foliar spray ferrous sulfate (0.2 to 0.4%), manganese sulphate (0.3%), zinc sulphate (0.2 to 0.5%) and copper sulphate (0.1%) (Satyagopal*et al.,* 2015).Copper based fungicide (copper oxychloride with 3g l^{-1} of water) sprays will be helpful in correcting the Cu deficiency of sapota. Possibility of micronutrient response to its application in crops could be as high as 90% for very low, 60 to 90% for 'low' and 30 to 60% for 'optimum' levels of extractable micronutrients (Cooper and Abi-Ghanem, 2017). Thus,identifying the deficiencies of micronutrients timely and application of balanced fertilizers at correct time can enhance crop production and quality of fruits.

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