

**DRIS NORMS FOR IDENTIFICATION OF YIELD
LIMITING NUTRIENTS IN LIME (*Citrus aurantifolia*)
ORCHARDS OF VIJAYAPURA DISTRICT,
KARNATAKA**

AMBAREESH NEMU JADHAV

**DEPARTMENT OF SOIL SCIENCE AND
AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, VIJAYAPURA
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005**

NOVEMBER, 2019

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By

AMBAREESH NEMU JADHAV

**DEPARTMENT OF SOIL SCIENCE AND
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CERTIFICATE

This is to certify that the thesis entitled "**DRIS NORMS FOR IDENTIFICATION OF YIELD LIMITING NUTRIENTS IN LIME (*Citrus aurantifolia*) ORCHARDS OF VIJAYAPURA DISTRICT, KARNATAKA**" submitted by **Mr. AMBAREESH NEMU JADHAV** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

VIJAYAPUR

NOVEMBER, 2019

**(SAVITA B.)
CHAIRMAN**

Approved by:

Chairman:

(SAVITA B.)

Members: 1.

(VIDYAVATHI G.YADAHALLI)

2.

(V. S. SURKOD)

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LIST OF ABBREVIATIONS

%	Per cent
±	Plus or minus
°C	Degree Celsius
<i>et al.</i>	Et alia (and others)
viz.	namely
ha	Hectare
i.e.	That is
kg	Kilogram
g	Gram
@	At the rate
cm	centimetre
m	Meter
N	Nitrogen
P	Phosphorous
K	Potassium
Ca	Calcium
Mg	Magnesium
S	Sulphur
Fe	Iron
Zn	Zinc
Mn	Manganese
Cu	Copper
B	Boron
Mo	Molybdenum
DRIS	Diagnosis and Recommendation Integrated System
PASS	Plant Analysis with Standard Scorer
CND	Compositional Nutrient Diagnosis
SRA	Sufficiency Range Approach

CVA	Critical Value Approach
DOP	Deviation from Optimum Percentage
MT	Metric Tonne
NII	Nutrient imbalance index
INM	Integrated Nutrient Management
RDF	Recommended Dose of Fertilizer
TSS	Total Soluble Sugar
VAM	Vesicular ArbuscularMycorrhiza
ppm	Parts Per Million
CV	Coefficients of Variation
SD	Standard Deviation
IND	Independent Nutrient Indices
DNI	Dependent Nutrient Indices
GIS	Geographical Information System

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1. INTRODUCTION

Acid lime (*Citrus arantifolia*) is the vital important fruit producing crop of India, it ranks third important fruit after mandarin and sweet orange. After banana and mango, citrus stands greatest industrial fruit crop in India. India is the largest producer of lime and lemons ranks fifth position in the world. Citrus is grown in most of the states like, Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, Gujarat, Bihar and Himachal Pradesh. Some of the known important species of citrus group are Kagzi lime (*Citrus arantifolia*), Pummelo (*Citrus grandis*), Sweet orange (*Citrus sinensis*) and Mandarin (*Citrus reticulate*). These are most widespread and common fruit in India because their availability is throughout the year with moderate prices.

Among the popular citrus species, acid lime (*Citrus aurantifolia*) is one of the important horticulture fruit crop in India. Kagzi lime (Spur lime, Acid lime, Pati lime, Mexican lime) which belongs to Rutaceae family, in Gujarati, it is known as 'limbu', whereas in Hindi it is called as 'Nimbu or Neebu'. Lime has high demand for its consumption in India because of its nutritional value and availability at lower price. Lime is the most popular for its useful in soft drinks, pickles, excellent food qualities, beautiful appearance and pleasing flavour, citric acid is used for manufacturing pharmaceuticals and cosmetics.

In India acid lime is cultivated in an area of 2,75,000 hectare by the total producing 27,63,570 tonnes and overall productivity of 10.05 tonnes per hectare (Anonymous, 2014). In India, Karnataka state ranks 5th in acid lime production with 2,83,470 tonnes accounting to 12,150 hectare of area (Anonymous, 2014). In India Karnataka ranks 7th in production of citrus and accounts for production of citrus only 3.4% of total in the country, whereas lime contributes about 9.0% to the total production of Karnataka in the country. State produces 0.27 m MT of lime with a productivity of 23.4 t/ha (Anon., 2014a). Major lime producing areas in the Karnataka are Vijayapura, Kalburgi, Bagalkot, Koppal, Ballari, Chitradurga and Gadag.

Vijayapura district lies in the Northern Dry Zone of Karnataka possessing congenial climatic condition for cultivation of lime. The district comes under semi-arid climate with low rain fall, exhibits cold winter and high temperature during summer. In

Vijayapura district, it is unique remunerative fruit crop grown as a commercial scale in an area of 6,499 hectare, by the production of 1,62,475 tonnes and productivity 25 tonnes per hectare (Anonymous, 2014b). According to district statistical department of Vijayapura during 2015-16 the lime area of Vijayapura, Indi, Sindagi, Muddebihal and Basavana Bagewadi taluk were 975, 4059, 1023, 18 and 740 ha respectively with production 24375, 101475, 25575, 450 and 18500 tonnes and productivity 25 tonnes per hectare for all taluks of Vijayapura district. Indi having major area of 4,059 ha, with a production 1,01,475 tonnes and productivity 25 tonnes per hectare of lime. Majorly grown in Indi, Sindagi and Vijayapura taluks, followed by Basavan Bagewadi and in small area at Muddebihal taluks of Vijayapura district (Anon., 2015).

The production, quality and productivity of lime need to be improved in order to make this enterprise more remunerative and sustainable for the years to come. However, this is an uphill task in the back drop of prevailing problems like inherent low fertility of soil, poor soil physicochemical properties, uncertain rains, extreme temperatures, pests and diseases, poor quality irrigation water besides inefficient nutrient management practices. One of the prerequisites of successful cultivation and higher production of any horticultural crop is scientific nutrient management. Further, nutrient management needs to be developed on sound principles of chemistry by considering the inherent soil fertility status, soil physic-chemical properties and plant response to the mode of nutrition. Soil analysis gives a crude idea about actual status of nutrient availability amenable for uptake by the plant, while leaf analysis reveals the virtual assimilation of nutrients.

The nutrient requirement of lime must be examined through soil and leaf analysis to overcome any yield loss. Approaches to nutrient management are the main theme for enhancing the net return of sensible fertilization practices. To accomplish this goal, the proper definition of the impact of known yield limiting nutrient is needed. Similarly, the assessment of fruit crops leaf is evaluated as a more accurate practice for evaluating plant nutrient status than soil assessment (Hallmark and Beverly, 1991) owing to fruit plants that are vary seasonal in their dietary need due to their canopy extent, plant population, growth rate, root density and rooting system. The fundamental concept engaged in leaf assessment is that nutrient content is a mixed value of all the

aspects at any precise point within the plant that have affected nutrient concentration up to the sampling period.

Further, in simple term plant analysis is the study of association of nutrient content in plant to its growth and is a straight tactic to report nutritional problems of plants (Chapman and Brown, 1950). For nutritional diagnosis of fruit crop several approaches have been adapted based on leaf analysis which includes the SRA (Sufficiency Range Approach), CVA (Critical Value Approach), DRIS (Diagnosis and Recommendation Integration System) (Beaufils, 1973; Walworth and Sumner, 1987) and Multivariate CND(Compositional Nutrient Diagnosis) (Parent and Dafir, 1992). Among these approaches, DRIS and CND are the two recent concepts that could be implemented to diagnose nutritional imbalances from tissue analyses.

DRIS is the dual ratio concept and which uses ratios of nutrient concentration rather than single nutrient concentration for tissue analysis interpretation. DRIS use the dual relation and solve the dilution or concentration problem of plant nutrient. According to the statement of Beaufils (1973) and Walworth and Sumner (1987) as the tissue ageing concentration of nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) decreases while concentration of Calcium (Ca) and Magnesium (Mg) increases. To overcome these problems DRIS came into existence as it uses the concept of dual ratios and remain constant values simultaneously reduce the impact of biomass build-up. Thus, this method postulated that is more accurate in finding of nutrient deficiency and excess.

DRIS can recognize the causes of reduced crop yield due to nutrient unevenness, even though none of the nutrients are smaller than critical over an index of imbalances (Baldock and Schulte, 1996). The DRIS indices are used for yield limiting factors categorization and ranked them in their order of significance. Walworth and Sumner (1987) have indicated several advantages of this method over traditional techniques such as CVA (Critical Value Approach). These include detecting the most yield limiting nutrient and also other nutrients would probable to become limiting. Compare critical level approach with DRIS method have ability to diagnose the necessary crop nutrient

much prior to plant life cycle thus, one can take corrective actions as early as possible. DRIS provides relatively more accuracy in diagnosis and suggestions free of consequences such as geographic position and tissue age etc.

This methodology was effectively used to interpret foliar analytical outcomes from plant tissue such as grapes (Bhargava and Raghupathi, 1995), mango (Raghupathi and Bhargava, 1999), papaya (Anjaneyulu, 2007), sapota (Savita and Anjaneyulu, 2008), Coorg mandarin (Raghupathi *et al.*, 2013) and litchi (Savita *et al.*, 2017).

Hence, the present study aims at measuring the mineral nutrient concentration both in soil and plant using standard procedures and assessing its relation with crop yield with following objectives are,

1. To investigate the nutritional status of soil and plants in lime orchards
2. To develop leaf nutrient norms/guides using Diagnosis and Recommendation Integration System (DRIS) in lime.
3. To identify yield limiting nutrients and order of nutrient imbalances in low yielding orchards of lime through DRIS indices.

2 REVIEW OF LITERATURE

The fertilizer and manurial practices differ widely from species-to species and area-to-area. The nutritional content of fruit crops like lime varies from those of seasonal crop species in various aspects like their canopy size, plant population, growth rate, root density and rooting pattern and their perennial nature. Many lime growers apply fertilizers based on assumption or age old practice. More than this, the prevalent rate of yield decides to larger level of fertilizer usage. Therefore, to make ensure high economic returns and productivity, correct doses of fertilizer and manures using reliable diagnostic tool applying to evade nutrient excesses and shortage. In this path, a more direct method of assessing plant nutritional status is evaluated in plant analysis than soil analysis, particularly for fruit plants. Diagnosis and Recommendation Integrated System (DRIS) practice is relatively a new methodology to enhance diagnostic accuracy and effectiveness of nutrient management to achieve greater productivity. In this sense, the DRIS is an excellent statistical tool for ensuring balanced plant nutrition by discovering the most yield-limiting nutrients, further ordering their requirements, and taking steps towards remedial action. Therefore, this study is focused on “DRIS Norms for Identification of Yield Limiting Nutrients in Lime (*Citrus aurantifolia*) Orchards of Vijayapura District, Karnataka. This section presents the associated review of work on this issue.

2.1 Nutritional studies on lime

2.2 Diagnosis and Recommendation Integrated System (DRIS)

2.2.1 Development of DRIS ratio norm

2.2.2 Interpretation of the DRIS nutritional indices

2.2.3 Nutrient imbalance index (NII)

2.2.4 DRIS norms in crop plants

2.2.5 Comparison of DRIS with other diagnostic technologies

2.1 Nutritional studies on lime

Lime is a highly nutrient responsive crop. Occurrence of multi-nutrient deficiencies upon taking remedies of such deficiencies of nutrients is the more difficult exercise. Site specific nutrient management studies find more efficiency than traditional method but standard advanced fertilization response studies required when specific constraint fertilization. At the same time use of integrated strategies viz., soil application of macronutrients, foliar application of micronutrients and integrated nutrient management (INM) using rationale of organic manures encouraged with microbial association. But, there is vast variation generated by fertilizer necessity experiments in their recommendations depending upon soil type, tree age and climatic features also there are very less evidences on micronutrients requirement. Worldwide studies have suggested that establishment of nutrient diagnosis for optimal range of nutrients based on soil and leaf analysis. Establishment of morphological descriptors and nutrient norms have more helped in defining the nutrient limitation highly accurate. Such studies powerfully deserve decontaminating diagnostics at regional and quite finer at orchard level, so that one-time accurate diagnosis of limiting nutrient is made, managing becomes a comparatively easier job (Srivastava, 2013).

Panchbhai *et al.* (2006) collected soil samples from acid lime orchards (n=70) and assessed the soil nutrient status in Maharashtra. Orchards were classified as high and low yielding population and mean content of soil N, P, K and S was 398.57 and 270.12 kg ha⁻¹, 43.47 and 35.98 kg ha⁻¹, 328.30 and 227.92 kg ha⁻¹ and 17.32 and 15.77 kg ha⁻¹ respectively. Whereas mean of high and low yielding orchards Ca (23.50 and 21.58 cmol(p+) kg⁻¹), Mg (12.94 and 10.43 cmol(p+) kg⁻¹) respectively. Mean micronutrient Fe, Mn, Zn and Cu in high yield orchards were 8.49, 20.79 1.19, 9.78 ppm respectively whereas micronutrient Fe, Mn, Zn and Cu in low yielding orchards were 7.86, 19.26, 0.87, 7.31ppm respectively.

Shah *et al.*,(2012) identified deficiency of leaf micronutrient like Zn, Cu, Fe, Mn and B in citrus orchard of Swat valley, North Western Pakistan The result showed that Zn, Mn, B and Cu were deficient 100, 96, 42 and 16 per cent respectively. The soil sample analysis showed that deficient in 10-44% in Zn, 12-18% in Fe, 4-

14%. Diagnosing micronutrient deficiencies in soil and plant were poorly correlated in citrus orchards.

Shirgure and Srivastava (2013) applied different form of potassium (K) fertilizers through fertigation in 14-16 years Nagpur mandarin orchards. Trial treatments included ; T₁-potassium chloride fertigation [KCl], T₂- potassium nitrate fertigation [KNO₃], T₃- potassium sulphate fertigation [K₂SO₄] and T₄- mono-potassium phosphate fertigation [KH₂PO₄] @ 150 g K₂O/plant. The result showed that T₄ gives highest fruit yield (31.13 t/ha) followed by treatment T₂ (29.4 t/ha) was observed. The leaf nutrient status and uptake was high in treatment T₄ (150 g K₂O/plant).

Kuchanwar *et al.* (2017) carried out research to study the consequence of fertigation on leaf nutrient status and fruit quality on 6 years old Nagpur mandarin having spacing of 6 x 3 m. The treatments were soil application of NPK fertilizers and five fertigation treatments i.e. 80, 100, 120, 140, and 160 per cent of the recommended dose of NPK fertilizers (1200:400:600 g NPK plant⁻¹). The leaf nutrient content increased with increase in levels of NPK and highest content of N (2.63 %) and P (0.18 %) were recorded for 160 % of RDF through fertigation. The fruit quality parameters such as juice content (52.32 %), TSS (11.06° Brix) and acidity (0.81%) were recorded under 120 % of RDF through fertigation.

Bhandari *et al.* (2018) reported that application of different doses of inorganic sources and organic source through FYM out of which treatment T-11 with 75 % RDF + 3 kg vermicompost + 10 kg FYM + 150 g VAM + 25 g Azotobactor (T11) significantly influenced the quality parameters and vegetative growth of acid lime.

2.2 Diagnosis and Recommendation Integrated System (DRIS)

Foliar assessment can only be useful implement to evaluate plant nutrient concentration if appropriate processes can be assessed for diagnosis from analytical information. Because of the dynamic nature of the foliar arrangement, this strongly influences plant age and affects nutrient interaction, absorption and supply. Foliar analysis can become a difficult exercise (Walworth and Sumner, 1987). The tissue analysis has been taken into account is an important method of evaluation and needed a specified plant part usually leaf or petiole (Malavolta, 2006; Mourao, 2004; Hallmark

and Beverly, 1991; Beaufils, 1973). The leaf is regarded the most significant part of the plant because where the physiological activities are occur and this tissue easily exhibits nutritional disturbances. In addition, there is a need for leaf sampling to understand the dietary status. The composition of the leaf tissue is extremely affected by leaf area, phase of plant maturation and nutrient interaction. Various techniques can be used to interpret the concentration of nutrients in leaf analyzes.

The techniques of critical level sufficiency range and DRIS are used more frequently to derive outcomes from traditional chemical analysis of plant tissue (Beaufils, 1973 ; Walworth and Sumner, 1987 ; Mourao, 2004 ; Camacho *et al.*, 2012 ; Serra *et al.*, 2012).

Beaufils (1973) proposed the concept of DRIS, which involved the use of dual ratio concept rather than using single nutrient concentration for tissue analysis interpretation.

Beaufils (1973) defined DRIS as a comprehensive system that fully recognizes nutritional aspects that limit crop production and thus enhances the likelihood of higher yield by enhancing fertilizer recommendation doses. DRIS indices are specific for leaf or plant nutrient and how far it is away from the optimal range.

The DRIS indices are the used in standardizing the yield factor in the order of their restricting demands. Various benefits of this technique over standard critical-level approach methods (Walworth and Sumner, 1987). These comprise the usage of the data in evaluating plant tissue nutrient balance, detecting the most yield limiting nutrient and also arrange them in their order of requirement even other nutrients which are going to be limiting, another most importance advance is the capacity to diagnose the crop nutrient requirement well before the crop's life cycle and allows one to take corrective action sooner.

The DRIS offers relatively more liberty from the effect of some of the sampling factors such as the geographic place and age of the plant portion etc. in diagnosis and recommendations (Walworth and Sumner, 1987).

The DRIS was therefore been effectively applied to several crops viz., Nagapur mandarin (Srivastava and Shyam, 2007), Arabian coffee (Partelli *et al.*, 2007), Ber

(Singh *et al.*, 2010), Passion fruit (Carvalho *et al.*, 2011), Aonla (Nayak *et al.*, 2011), Pineapple (Agbangba *et al.*, 2011), Plum (Disha *et al.*, 2012), Coorg mandarin (Raghupathi *et al.*, 2013), Sorghum (Dagbenonbakin *et al.*, 2013), Banana (Raghupathi and Srinivas, 2014), Pera orange (Hernandes *et al.*, 2014), Tomato (Scucuglia and Creste, 2014), Khasi mandarin (Srivastava *et al.*, 2014), Tempranillo grape (Martin *et al.*, 2016), Kinnow Mandarin (Srivastava and Patil, 2016), Apple (Sofi *et al.*, 2017), Mango (Naika and Bhatt, 2017), Pomegranate (Gosavi *et al.*, 2017), Oil palm (Matos *et al.*, 2017), Litchi (Savita *et al.*, 2017), Teak (Chanan *et al.*, 2019).

2.2.1 Development of DRIS norm

The initial step to implementing DRIS is to develop standards or norm values. For developing norm values, the DRIS utilizes a survey methodology (Beaufils, 1971, 1973) based on crop response model (Sumner and Farina, 1986).

In DRIS, the whole population of observations is separated into high and low yields based on average cut-off yields, then mean content of the high yield sub-group obtained for estimation of optimum tissue parameter. Furthermore, the coefficients of variation (CVs) from the high yield population were taken to measure the relative spread of yield response at the upper yield levels (Sumner and Farina, 1986).

The use of average cut-off value to separate high and low yielding population was not critical as long as high yielding data remained normally distributed. Davee *et al.* (1986) well-defined high yield groups as a population with more than average output of one standard deviation (SD) and low yield groups less than average yield as population with yield one standard deviation (SD). When the cut-off value for separating high and low maize yields ranged from 7 to 9 kg ha⁻¹ the average tissue values for N/P=6.7 %, N/K=4.8 %, and P/K=2.4 % ratios determined by Letzsch and Sumner, 1984.

There are three forms of expression may possibly considered for each pair of nutrients. Nitrogen and phosphorus can be associated with the N/P ratio, its reverse P/N or the N-P product. In DRIS computation, only one expression of nutrients is used to relate each pair of nutrients. The selection is made by comparing low yield population variation with high yield population variation. The most important variation ratios are

form the expression (N/P, P/N or N_xP) used in the calculation of DRIS indices (Beaufils, 1973 and Walworth and Sumner, 1987).

The DRIS chart, in which three selected nutrient element norms, can be used to relate to each other (Beaufils, 1973 and Sumner, 1981). The three-axis intersection point corresponds to the mean value of each type of expression from the high yielding group.

This content is chosen to enhance the probability of achieving high yield. The circle diameter is set to 4/3 SD (Beaufils, 1971) where the high yielding group standard deviation (SD) is set. A plant content that falls within the innermost circle would be regarded as a balanced area. Increase the degree imbalance between nutrients if any one passes away from central zone. This imbalance area is split into two sub-zones, the first of which is recognized as a slight to mild imbalance area with an 8/3 SD diameter. The area of labeled imbalance is beyond this.

2.2.2 Interpretation of the DRIS nutritional indices

Using the DRIS chart enables three components to be diagnosed. The DRIS also provides a mathematical way to organize a vast amount of nutrient ratios into nutrient indices that can be readily interpreted. A nutrient index is an average function of all nutrient ratios (Beaufils, 1973 and Sumner, 1981). DRIS calculation is provided in detail in material and methods.

Since each ratio values and their function are added to one subtotal nutrient index and from another before averaging, all nutrient indices of an individual sample are balanced close to zero (Beaufils, 1973). The more negative an index, the more nutrient deficient it indicates in the diagnosis as compared to other nutrient use. On the other hand, a more positive nutrient index indicates that the respective nutrient is present in relatively excessive amounts (Walworth and Sumner, 1987).

All indexes equal to zero will be shown in a plant sample with adequate nutritional balance. However, the nutrient index is intended to be equivalent to zero and not due to sufficient concentration (Walworth and Sumner, 1987). A result of diagnosis follows:

Nutrients	:	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
Index	:	-24	0	+8	+8	+8	+2	+4	-6	-10	+5	+5

One might say that the nitrogen index shows the most deficient nutrient relative to others, and perhaps the most nutrient-limiting yield if the yields were entirely nutritionally linked. And the index of phosphorus equals zero, it means P is sufficient in plant tissue but less ample than potassium and calcium or magnesium and in this diagnosis, it would be the second most limiting nutrient. Though, in this situation, it may be due to addition of nutrient but not removed from the soil, at least under normal situations, according to these diagnosis recommendations for addition of nitrogen and phosphorous in lower quantity, in spite of the P index is equivalent to zero.

2.2.3 Nutrient imbalance index (NII)

The goal of evaluating the nutritional status nutritional balance of plants cannot be reached nutritional diagnosis by the traditional methods, such as the technique of sufficiency range and the critical level approach, since both take into account only single nutrient concentration in the plant, without any connection among these nutrients.

In plant total nutritional imbalance in particularly sample may be recognized by the sum total of nutrient indices irrespective of sign called the Nutrient Imbalance Index (NII). If the sums of the DRIS indices are bigger, one or more of the measured variables will limit yield. Greater the nutrient imbalance index more would be the nutrient imbalance and lower yield, however smaller the NII lesser the nutrient imbalance and higher yield, even low yields may occur if other factors are limited, (Beaufils, 1973; Walworth and Sumner, 1987).

2.2.4 DRIS norms in crop plants

Hundal and Arora (1995) established preliminary DRIS norms for N, P and K in litchi (*Litchi chinensis* Sonn.) leaves for the diagnosis and ranking of the most limiting and excessive elements. The DRIS approach was applied to leaf samples collected after bimonthly interval in ten years old litchi tree. The concentration of N, P and K in leaf fluctuated with time of sampling. Higher amounts of nitrogen, phosphorous, and potassium were recorded in April and June due to fertilization of litchi trees in month of

March. The DRIS indices showed that for these three nutrients were in the following limiting order $P > K > N$. After application of fertiliser in March, the requirement order has altered to $P > N > K$. Regardless of position of leaf and variety, the DRIS indices diagnosed the order of necessity as $N > K > P$ despite significant modifications in their leaf concentrations. Thus, DRIS system can therefore be used regardless of the position of the leaf samples, variety and the sampling time in litchi and yields can be enhanced by formulating suitable combination of required nutrients.

Coleman *et al.* (2003) studied DRIS on fast-growing sweetgum. Established foliar nutrient ratios for N, P, K, Ca and Mg and DRIS indices were calculated for the same studies. Potassium shown more negative imbalance whereas magnesium shown strong positive imbalances, this is due to leaching and low soil availability of potassium. While nitrogen was identified as insufficiencies in all tested stands but no imbalances of phosphorous is occurred. Remediation super optimal levels of Magnesium and calcium are predicted to be an indirect outcome of satisfying insufficient nitrogen and potassium. Improving nitrogen and potassium inequity will results in improved growth, taking benefit of those nutrients previously contained in super optimal concentration.

Hundal *et al.* (2005) collected leaf samples from mango fruit tree (*Dashaheri* cv.) bimonthly interval for 6 times from same plant grown in an orchard to know the impact of sampling time on the composition of the leaf using DRIS. Computed DRIS indices and shown decreasing order of yield limiting nutrients were P followed by N, K, Ca, Mg, S and Mn followed by B, Zn, Fe and Cu both macro and micronutrient followed same pattern of requirement irrespective of sampling time. DRIS approach recommended that the foliar application of Mn with phosphatic fertilizer could boost the output, strength and quality of mango fruit at a specific site.

Raj and Rao (2006) revealed that DRIS indices sensitivity to the long-term fertilization with N, P and K practice for 15 years old mango tree (cv. Baneshan) using DRIS norms. N doses are 405g, 1000g, 1595g and 2000g N tree⁻¹. P doses are 405g, 1000g, 1595g and 2000g P₂O₅ tree⁻¹. K doses are 405g, 1000g, 1595g and 2000g K₂O tree⁻¹. According to DRIS indices the treatment T7 (N:P:K 405:1595:1595) with highest fruit yield 694 (kg tree⁻¹) showed no deficiency of N, P and K whereas treatment T3 (N:P:K 405:1595:405) recorded second highest fruit yield 490.0 (kg tree⁻¹) where there

is deficiency K was placed at fourth position. All the treatment fertilization with K dose @ 405 g tree⁻¹ showed lower yield of fruit. The order of nutrient requirement were, Ca followed by Fe, Mg, Zn, S and Cu and Mg followed by Ca, Zn, K, S and Fe for both treatment T7 and T8 respectively.

In Punjab, DRIS norms were developed for guava trees by Hundal *et al.* (2007). Their result showed that the DRIS diagnosis was not affected by the position of the sampled leaf tissue. The nutrient showed inconsistency for K, Ca, Zn and Cu, while relative consistency for P, Mg, Mn and Fe. Nutrient sufficiency ranges obtained from DRIS norms were 1.41-1.65 per cent N, 0.10-0.17 per cent P, 0.51-0.97 per cent K, 1.16-2.12 per cent Ca, 0.31-0.51 per cent Mg, 0.18-0.28 per cent S, 105-153 mg Fe, 58-110 mg Mn, 15-29 mg Zn and 6-16 mg Cu kg⁻¹. The identified relative deficiencies of nutrients were N followed by P, K, Ca, S, Mn, Zn and Cu associated comparative excesses at multiple locations for Fe in guava trees.

Singh *et al.* (2010) established DRIS norms for multiple nutrient ratios acquired from the high-yield population in ber (*Zizyphus mauritiana*) and used those to compute DRIS indices. Nutrient sufficiency ranges obtained from DRIS norms were 0.68 to 1.64 per cent N, 0.18 to 0.34 per cent P, 1.18 to 1.86 per cent K, 1.06 to 1.77 per cent Ca, 0.23 to 0.39 per cent Mg, 0.12 to 0.18 per cent S, 55 to 205 mg/kg Fe, 26 to 80 mg/kg Mn, 17 to 33 mg/kg Zn, and 5 to 11 mg/kg Cu. According to these sufficiency ranges derived from DRIS: 79, 76, 76, 75, 84, and 72 per cent of the specimens were sufficient, while 13, 15, 21, 14, 7, and 18 per cent of the complete specimens were low in N, P, K, Ca, Mg, and S, respectively. The 84, 85, 77 and 86 per cent of samples were sufficient for micronutrients and 6, 3, 8 and 2 per cent were low in Fe, Mn, Zn, and Cu, respectively.

Dagbenonbakin *et al.* (2010) carried out study on cotton leaf nutrient concentration and fiber yield data from organic and inorganic field trial used to derived DRIS norms were N/P (9.65), K/N (0.59), N/Mg (10.55), S/N (0.08), P/K (0.19), Ca/P (5.79), Mg/P (0.96), Zn/P (0.01), Ca/K (0.18), Zn/K (0.001), Ca/Mg (5.77), S/Ca (0.14) and Mg/Zn (143.84) respectively. Concluded that this preliminary DRIS model is best tool for diagnosing N, P, K, Mg, S, Ca and Zn status of cotton crop.

Carvalho *et al.* (2011) studied the DRIS technique on yellow passion fruit to assess the plant's nutritional status with diverse phonological stages. The average productivity (16.9 t/ha/year) of 54 passion fruit orchards were selected and evaluated for N, P, K, Ca, Mg, S, Cl, Fe, Zn, Mn and B. In general, in both phonological stages, the average nutrient content did not vary two productivity levels. There was a change between different phonological stages. K in May, P in October and Fe in January were the nutrient with the most negative DRIS indexes and the Mean Nutritional Equilibrium Index was greater in absolute value.

Nayak *et al.* (2011) conducted experiment on aonla orchards and calculated DRIS norms and computed DRIS indices. Based on DRIS principles nutrient sufficiency ranges derived on aonla were 1.30 – 1.64, 0.054 – 0.092, 0.40 – 0.64 per cent and 32.4 – 45.9 ppm respectively for N, P, K and Zn. In most age groups, deficiencies of N, P, K and Zn were observed in aonla orchards. When compared to among age group of aonla relative deficit of N, P, and K were indicated whereas relative adequacy of Zn was obtained. If consider younger plant (5 years old) a comparative deficiency of N, Zn and K was found to be relatively adequate for P. N was showed to be more yield limiting nutrient in most age group of aonla orchards.

Agbangba *et al.* (2011) conducted experiment on DRIS in pineapple ‘Smooth Cayenne’ for increase fruit yield and quality through efficient fertilizer management. DRIS norms have been created based on leaf nutrient concentration (N, P, K, Ca, Mg, S and Zn). The nutrient ratios selected are 0.3, 2.2, 0.6, 0.1, 0.0013, 0.0046, 1.5, 3.6, 0.0007 and 0.4 for P/N, K/N, Mg/N, S/N, Zn/N, Zn/P, K/Ca, K/Mg, Zn/K and Mg/Ca, respectively.

Disha *et al.* (2012) surveyed in plum orchards in the Kullu district of Himachal Pradesh, India. Forty-four DRIS norms were created from the database of 1000 observations of yield and composition of leaf nutrient. Nutrient expressions such as N/P, N/K, N/Ca, N/Mg, K/P, Ca/P, Mg/P, Ca/K, Mg/K, Ca/Mg, Fe/N, Mn/N, Fe/P, Mn/P, Cu/P, B/P, Fe/K, Mn/K, Cu/K, Fe/Ca, Ca/Zn, Ca/Mn, Cu/Ca, B/Ca, Fe/Mg, Zn/Mg, Mg/Mn, B/Mg, Fe/Zn, Fe/Mn, Zn/Mn, Cu/Zn, B/Zn, Cu/Mn and B/Mn had the highest variance ratio indicating significant contribution of these expression for determining the yields in plum orchards. Their study concluded that N, Fe and Cu

deficiencies in 4 per cent orchards, while N, Fe and Cu surpluses were analysed in 8, 36 and 12 per cent orchards, respectively. The P, K, Mg, Zn, Mn and B deficiencies have been diagnosed in 12, 20, 12, 24, 8 and 32 per cent orchards, respectively. Only 52 per cent orchards had excess of Mg. Nutrient B was the most yield-limiting nutrient stated in various orchards and 32 per cent orchards showed B deficiency, while Zn deficiency was found in 24 per cent orchards.

Raghupathi *et al.* (2013) studied in Coorg mandarin to create the nutrient concentration and yield database in the Kodagu region of Karnataka, India. Twenty-eight nutrient expressions were derived. Among several nutrient ratios, some are chosen as standard diagnostic norms such as N/P, N/K and P/Zn and the norm values for seedling crops were 6.427, 1.703 and 0.013, respectively, with the highest physiological rationale. The ratio of N/P, N/K, Zn/P and Ca/Mg and the norms values were 7.17, 1.395, 77.80 and 5.92 respectively identified in budded plants. Most yield limiting nutrient identified by DRIS were Zn and Mg in Coorg mandarin.

Dagbenonbakin *et al.* (2013) established DRIS norms on grain and leaf nutrient composition of sorghum for N, P, K, Ca, S and Zn from organic and inorganic trials. The DRIS norms providing by this experiment were (N/P), (K/N), (N/Ca), (S/N), (N/Zn), (P/Ca), (S/P), (Zn/P), (K/Ca), (K/Zn), (S/Zn), (Ca/Zn), and (S/Ca) is 6.5, 0.7, 4.6, 0.1, 712.2, 4.7, 0.7, 0.4, 0.01, 3.3, 0.1, 510.1, 39.0, 164.0 and 0.30 respectively. For higher plants within the predictable narrow ranges, giving reliability to both the database and DRIS system. This preliminary sorghum DRIS system provides a useful diagnostic tool for evaluating sorghum plant status (N), (P), (K), (Ca), and (S) and (Zn).

Elferjani *et al.* (2013) studied DRIS on hybrid poplars, on fertilizer application growth response of 4 clones were tested in 2 plantations. There are 1st two fertilizer treatments based on DRIS recommendation as DRIS- I and DRIS- II, on previously established norms and DRIS norms established from hybrid poplars respectively. Another two treatments compared under trees under standard (STD) fertilizer and unfertilized trees treatment (40 N, 20 P, 20 K). Plant nutrients content and DRIS indices indicated that fertilizer treatments, and DRIS- I rectified nitrogen deficiencies but fail to rectify phosphorous deficiencies. Based on DRIS indices treatment (DRIS- I and DRIS- II) at the forest site enhances the growth rate (6.67 per cent) marginally high compare to

standard treatment (5.80 per cent). Growth rate increased by fertilization were 7.51, 4.76 and 13.25 per cent on average for DRIS- I, DRIS- II and STD treatments respectively in fertilization site, compared to un-fertilization. In general DRIS based fertilizer treatment increase growth rate, they were identical to or less effective compare to STD treatment and may not be as practical as using a standard fertilizer method.

Raghupathi and Srinivas (2014) revealed that using DRIS and geographic information service (GIS) tool to identification of nutrient imbalances on banana. Most foliar nutrients displayed a greater nugget/sill ratio showed miss match between the concentration of plant nutrients and available soil nutrients. DRIS indices have recognized higher diagnostic sensitivity for N, P, K, Ca and Fe. While medium to low diagnostic sensitivity at the initial stage With regard to Mg, Mn and Zn were found. When sampled at flowering stage diagnostic sensitivity showed with Ca, Fe and Zn by DRIS indices. DRIS with application of GIS for mapping in plant and soil was helpful for identification nutrient limiting yield for establishing nutrient management strategies.

Scucuglia and Creste (2014) establish DRIS norms and nutrient imbalance index (NII) for industry tomato plants, the level leaf nutrient concentrations evaluated for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B in 25 genotype of industrial tomato. The genotype differs in their nutrient absorption efficiency. The order of nutrient requirement for high yielding (>48 t/ha) group plants were P followed by Mn, Ca, K, B, Zn, Cu, N, Mg and S whereas for low yielding (<48 t/ha) groups were S followed by Fe, Cu, Zn, K, N, P, Mn, Mg, Ca and B. The plants which produce less than 6 kg⁻¹ plant, showed deficiencies of K and B and excess in Mg. the study showed that DRIS norms developed for greenhouse potatoes need less amount of N, Fe and Mn nutrients.

Leaf nutrient concentration of micronutrient cations from 78 commercial mulberry gardens at West Bengal analyzed to compute DRIS indices (Kar *et al.* 2014). Model relating DRIS indices and foliar micronutrient concentration under analysis of regression was fitted. Optimum foliar concentrations of micronutrient cations for mulberry garden are 16.56 mg/kg for Zn, 6.37 mg/kg for Cu, 163.84 mg/kg for Fe and 45.24 mg/kg for Mn respectively. Can help to use micronutrient fertilizer efficiently by using single straight fertilizer instead of fertilizer mixtures or compounds that contain

more than one elements. Evaluated DRIS norms are helpful for correcting nutritional imbalances and further improve the yield of mulberry.

Behera *et al.* (2015) conducted survey for assessment of leaf nutrient status in 64 oil palm plantation, developed leaf nutrient standard norms using DRIS and computed DRIS indices. According to DRIS indices order of limiting nutrients were detected as $P > Mg > K > N > B$. As per DRIS indices optimum leaf nutrient ranges from 1.64-2.79%, 0.36-0.52%, 0.37-0.75%, 0.89-1.97%, 0.35-0.63%, 0.89-1.50%, 3.10-13.9 mg/kg, 7.50-32.2 mg/kg, 35.0 - 91.1 mg/kg, 206 - 948 mg/kg, and 895 - 2075 mg/kg respectively for N, P, K, Ca, Mg, S, B, Cu, Zn, Mn and Fe. With this approach judiciously use of right quantity of fertilizer results in increase input use efficiency also.

Srivastava and Patil (2016) revealed that nutrient index through DRIS on Kinnow' mandarin using plant analysis data showed optimum value of leaf nutrient concentration is 2.22-2.32% nitrogen, 0.11-0.15% phosphorus, 1.10-1.41% potassium, 2.32-2.79% calcium, 0.38-0.61% magnesium, 22.4-58.3 ppm iron, 26.3-56.2 ppm manganese, 4.2-7.2 ppm copper and 21.3-26.9 ppm zinc via fruit yield of 32.4-56.1 kg tree⁻¹. Using these nutrient index standards, Zn was observed as most deficient (64.7%) followed by Fe (61.5%), Mn (57.6%), N (96.1%), and P (38.5%) using percentage of orchards as basis.

Savita *et al.* (2017) noted the nutrient imbalances by diagnosing DRIS. Indices showed that the most yield limiting nutrients were in decreasing order $S > Zn > Mo > B$ in fruiting terminals of litchi. In non-fruited terminals also S is the most limiting nutrient followed by Mo, B and Zn suggested in low yielding orchards of litchi.

Chanan *et al.* (2019) investigated the macronutrient status using by means of DRIS approach on 17 years old teak plantations. Index analysis on teak has bring out in macronutrient index N, P, K, Ca and Mg is - 8.40, - 1.70, - 4.17, 4.98 and 9.28 respectively. The order of nutrient requirement from lowermost to highest were (Mg > Ca > P > K > N). Mg and Ca have showed positive index values, this suggest sufficiency's of nutrients. Whereas N, K and P showed negative index values, this suggests less availability of nutrients, thus limiting growth of teak. Current study recommended that superior silvicultural nutrient input treatments, to be specific nitrogen, phosphorus and potassium to attain maximum growth of teak.

2.2.5 Comparison of DRIS with other diagnostic techniques

Baldock *et al.* (1996) represent two challenging approaches are Sufficiency Range (SR) independent nutrient indices (IND) system and the DRIS dependent nutrient indices (DNI) to show complementary and to introduce a new approach using both IND and DNI called Plant Analysis with Standardized Scores (PASS). In which both IND and DNI indices are on the appropriate DRIS scale. When compared the capacity to analyze sufficiencies and deficiencies in twenty-four maize (*Zea mays* L.) grain yield and dry matter comparisons, PASS had greater effectiveness rating (82 per cent) than the SR (41 per cent) and DRIS (33 per cent). The PASS approach had significantly greater amount of accurate diagnosis of nutrient deficiency than DRIS and SR.

Partelli *et al.* (2007) compared DRIS norms with the sufficiency range approach on Arabian coffee. DRIS norms and Sufficiency ranges were developed. The differences between DRIS norms and sufficiency ranges were verified using “t” test. In summer foliar concentration of N, P and S were higher and in winter Fe and Mn. For the season of the year values were specific. Between the sufficiency range and DRIS method there changes in foliar concentration of nutrients. Samples analyzed during summer with sufficiency range method Mn, S, K and Ca were most limiting nutrient and Cu, S, K and Zn when DRIS was used.

Foliar diagnosis and interpretation of plant nutrient analysis using DRIS and CND, to conclude in the order of limit nutrients and response to potential fertilization corn (Gott *et al.*, 2012). Similar range was found by CND and DRIS approaches. The ideal ranges of amplitudes were smaller sufficiency range found when matched.

Johnn *et al.* (2013) conducted study to establish and valid at norms for cut roses (*Rosa* spp. L.) including 1914 foliar analyses growing within greenhouses. The nutrient diagnosis approaches like DRIS and compositional nutrient diagnosis (CND) indicated that very significant effects on productivity and the nutritional balance relation associated with particularly N, P, Mg, Mn and B.

Min *et al.* (2015) conducted study and compared norms among DRIS, DOP and CND diagnosis method in apple. The regression relating DRIS, CND and DOP indices

were significant linear. The study indicated that the changes in DRIS, DOP and CND method did not showed much differences in identifying deficiencies.

Martin *et al.* (2016) studied DOP-Deviation from Optimum Percentage and DRIS approaches for diagnosis of leaf nutrient interpretation on ‘Tempranillo’ (*Vitis Vinifera* L.). At both flowering phase (n=684) and veraison phase (n=801) with an average yield situation (3,800 to 10,000 kg per hectare), DRIS and DOP were diagnosed with N, P, K, Ca and Mg. Significant variation between DOP and DRIS were indicated while a same database used to P and Mg were diagnosed with leaf blades and petioles and K was diagnosed with leaf blades.

Sofi *et al.* (2017) used several methodologies employed for DRIS indices, such as Beaufils, Elawali and Gascho (E&G) and Jones. According to the Beaufil DRIS indices approach in apple tree at the initial stage the were order of nutrient requirements were $Mg > N > S > P > Cu > Zn > Fe > Mn > B > Ca > K$ and 40 – 50 years The order of nutrient requirements were $S > Cu > Mg > Fe > P > N > Ca > Mn > K > Zn > B$, the requirement for foliar implementation of magnesium salt and urea in the initial stage, however yield reduction in the later stage is not due to the nutrient deficiencies but rather genetic character of tree. DRIS norms derived nutrient sufficiency ranges for apple were 1.91 to 2.24, 0.18 to 0.26, 1.11 to 1.61, 1.74 to 1.88, 0.30 to 0.33 and 0.28 to 0.30 per cent respectively for N, P, K, Ca, Mg and S.

3 MATERIAL AND METHODS

Lime orchards in Indi and Sindagi taluks of Vijayapura districts of Karnataka were surveyed during 2018-19 to develop DRIS norms and indices for nutrient management of lime orchards. The Kagzi lime production techniques in brief and the methodology used in the development of leaf nutrient norms using DRIS are described in this chapter.

3.1 Lime production techniques

3.1.1 Climate, soil requirement, propagation and varieties

3.1.2 Planting season, aftercare and harvest

3.2 Establishment of data bank through survey approach

3.2.1 Area of survey

3.2.2 Leaf sampling

3.2.3 Soil sampling

3.2.4 Yield data and other information

3.3 Processing of leaf samples for analysis

3.4 Processing of soil samples for analysis

3.5 Analytical methods

3.5.1 Analytical methods for leaf samples

3.5.2 Analytical methods for soil samples

3.5.4 Categorization soil nutrient status and nutrient index value for lime orchards

3.6 Steps involved in development of DRIS norms

3.6.1 DRIS ratio norms in lime

- 3.7 Computations of DRIS norms
- 3.8 Computation of DRIS indices and Nutritional Imbalance Index (NII)
- 3.9 Leaf nutrient guides/ranges
- 3.10 Statistical analysis

3.1 Lime production techniques

3.1.1 Climate, soil requirement, propagation and varieties

Acid lime is tropical in its climatic requirements. The areas, which are warm, moderately humid, free from strong winds and frost, are ideally suited for its cultivation. It grows successfully even up to 1,000m above mean sea-level, provided humidity is low and favorable. Acid lime adopts well to a variety of soils and it grows fairly well in black and light loamy soils. A loamy soil of uniform texture well drained and rich in organic matter and fertility is ideal for lime. It is highly sensitive to waterlogged conditions. A well-drained soil with a pH of 6.5 to 7.5 is ideal for better growth and yield. Kalaburgi, Vijayapura, Bagalakot, Koppal, Ballari, Chitradurga and Gadag districts of Karnataka state are suitable for lime cultivation. Acid lime is propagated commercially through seeds. It can be propagated by cuttings, layering and budding owing to high intensity of polyembryony. Besides, seed propagation is the cheapest and easiest method. The seeds should be bold, well-developed, true-to-shape and size of the variety. Freshly extracted seeds are used for propagation. Though lime has been in cultivation for several centuries, there are not improved varieties. Commonly grown lime is the acid lime called kagzi lime.

3.1.2 Planting season, aftercare and harvest

Planting can be done at the onset of the rainy season (June-August) where rainfall is less, so that they can get the full benefit of the ensuring rainfall. For which pits of 75 × 75 × 75 cm at the distance of 6 × 6 m accommodating around 277 plants per hectare and filling the pits with well-decomposed manure. Necessary protective measures are required to avoid wind damage. Pruning of bearing lime trees though differs with the variety, chiefly consists of removal of dead, dried, diseased and broken, cries-cross

branches, whose existence is detrimental to the health of the tree. Pruning may be done just after harvesting. The fertilizer and manurial practices differ widely from species to species and area-to-area. The plant nutrients must be supplied through organic and inorganic manures. A fully grown plant of acid lime should be given 50kg farmyard manure, 900g N, 250g P_2O_5 and 500g K_2O per year. Manures and fertilizers are also broadcast in the tree basin, 60 to 70cm away from the tree trunk and incorporated by digging with spades. It is necessary to provide adequate irrigation, especially during the fruiting and dry periods of the year. Among the different methods of irrigation, generally basin system and drip irrigation are followed in India.

Further, summer is the most critical period in lime growers. Mulching of tree basins is very necessary to check weed growth, conserve soil moisture, hinder soil temperature fluctuations and activate the biological properties of soil. Generally lime is harvested with a pole harvester, having an iron hook and a net at one end. Lime fruits come to harvest 6 month after flowering, two times in a year July to September and March to June. A good acid lime plant (7 year-old) may yield 1,000 to 1,200(25 t/ha/year) fruits annually, the average yield being 3,000 to 3,500 fruits/tree/year.

3.2 Establishment of data bank through survey approach

The first step in the development of leaf nutrient norms is collection of leaf samples from lime orchards through survey. The DRIS utilizes the survey approach for development of DRIS norms and identification of yield limiting nutrients.

3.2.1 Area of survey

During the period 2018-19, a survey was carried out in Indi and Sindagi taluks of Vijayapura districts of Karnataka state where lime cv. Khazi lime is being grown extensively.

3.2.2 Leaf sampling

Leaf samples were collected by selecting 4 months shoot of new growth 1st leaf in June month as outlined by Bhargava and Raghupathi (2005). It is essential to select a specific part of the same physiological age at a definite location on the plant at definite stage of growth for comparison. From each lime orchard, 25 to 30 trees were selected

and 50 leaves were collected randomly to form a composite and representative sample. Total 85 leaf samples from 85 orchards were collected. Based on cut-off yield 54 orchards considered as high yielding population and 31 orchards considered as low yielding lime orchards. The samples were taken to the laboratory on the same day for further processing and analysis.

3.2.3 Soil sampling

Four composite soil samples representing each orchard was collected from 0 –22 cm depth in between four plants from each orchard during the survey to study the general fertility status of the soils of the lime growing orchards. Each sample was formed from six random samples of an orchard and pooled together to form one representative sample for analysis (Jackson, 1973).

3.2.4 Yield data and other information

The information on variety, crop age, soil type, irrigation methods and sources of irrigation, nutrient management practices and expected and actual crop yield was collected from each lime grower during the survey.

3.3 Processing of leaf samples for analysis

The leaf samples of lime were decontaminated by washing in sequence with tap water to remove the dirt or soil, then in 0.2% detergent solution and in $\frac{N}{10}$ HCl solution to remove residues of chemical spray materials on the leaf followed by washing in single and double distilled water. Excess water will be removed by pressing between the folds of blotting paper and leaf samples were dried in an oven at 75°C for 72 hours. After complete drying, the samples were powdered in Mixer grinder and stored in polycarbyl containers for analysis.

3.4 Processing of soil samples for analysis

The soil samples were dried in shade at ambient temperature, passed through 2mm sieve and stored for further analysis of pH, EC, Alkaline KMnO_4 hydrolysable N, Olsen's P, Neutral $1N$ NH_4OAc K, Neutral $1N$ NH_4OAc Ca, Neutral $1N$ NH_4OAc Mg, 0.15% CaCl_2 extractable S, DTPA extractable Fe, Mn, Zn and Cu and Hot water soluble B. An aliquot of 2 mm sieved soil was ground using agate pestle and mortar to pass through 0.2 mm sieve for determination of organic carbon of soil.



Plate 1. A view of soil sampling of lime orchard



Plate 2. A view of leaf sampling of lime orchard



Plate 3. A view of high yielding lime tree



Plate 4. General view of high yielding lime orchard

3.5 Analytical methods

3.5.1 Analytical methods for leaf samples

The leaf samples will be analysed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B. The samples were analysed (except N) by taking one-gram materials digesting in di-acid mixture (9:4 ratio of nitric and perchloric acids) by using standard analytical methods (Jackson, 1973). Nitrogen was estimated by micro-kjeldhal method, whereas P, K and S were analysed by vanado-molybdate, flame-photometer and turbiditometric methods respectively. Calcium and magnesium by versenate method and micronutrients viz. Fe, Mn, Cu and Zn will be analysed by using atomic absorption spectrophotometer. Boron was estimated by ashing one-gram of leaf sample in a muffle furnace and extracting using dilute HCl. The analysis was carried out by azomithine -H method. The analytical procedures adopted and references are given in Table 1.

3.5.2 Analytical methods for soil samples

The soil samples were analyzed for pH, EC, Alkaline KMnO_4 hydrolysable N, Olsen's P, Neutral 1N NH_4OAc K, Neutral 1N NH_4OAc Ca, Neutral 1N NH_4OAc Mg, 0.15% CaCl_2 extractable S, DTPA extractable Fe, Mn, Zn and Cu and Hot water soluble B. The soil organic carbon was estimated by following Walkley and Black's method. Alkaline KMnO_4 hydrolysable N was estimated by alkaline permanganate method. Olsen's P, was extracted using Olsen's reagent and estimated through spectrophotometer (Systronics Spectrophotometer 106) after developing blue colour by ascorbic method. Neutral 1N NH_4OAc K was extracted with neutral 1N ammonium acetate and estimated by flame photometer (Model name). The Neutral 1N NH_4OAc Ca, and Neutral 1N NH_4OAc Mg, were estimated by using titrimetric method after extraction with neutral normal ammonium acetate further 0.15% CaCl_2 extractable S was estimated by turbidity method. The DTPA extractable Fe, Mn, Zn and Cu were estimated by using atomic absorption spectrophotometer. Hot water soluble B was estimated through azomithine -H method by using spectrophotometer at 540 nm wavelength. The analytical procedures adopted and their references are given in Table-2 for soil.

Table 1. Details of the analytical methods followed in leaf analysis

Sl. No	Nutrient	Unit	Method employed	Reference
1	Nitrogen	(%)	Microkjeldhal method	Jackson (1973)
2	Phosphorus	(%)	Vanadomolybdate phosphoric acid yellow colour method	Jackson (1973)
3	Potassium	(%)	Flame photometer method	Jackson (1973)
4	Calcium	(%)	Titrimetric method	Jackson (1973)
5	Magnesium	(%)	Titrimetric method	Jackson (1973)
6	Sulphur	(%)	Turbiditic method	Chesnin and Yien (1951)
7	Iron, Mn, Zn and Cu	($\mu\text{g g}^{-1}$)	Atomic absorption spectrophotometric method	Jackson (1973)
8	Boron	($\mu\text{g g}^{-1}$)	Azomithine-H	Jackson (1973)

Table 2: Details of the analytical methods followed in soil analysis

Sl. No.	Soil characteristics	Unit	Method of estimation	Reference
1	pH	(1: 2.5 soil : water)	pH meter	Jackson (1973)
2	Electrical conductivity	dS m ⁻¹	EC bridge	Jackson (1973)
3	Organic carbon	%	Walkley and Black's wet oxidation method.	Jackson (1973)
4	Alkaline KMnO ₄ hydrolysable N	kg ha ⁻¹	Alkaline potassium permanganate method	Jones <i>et al.</i> (1991)
5	Olsen's P	kg ha ⁻¹	Spectrophotometric method using Olsen's reagent.	Jackson (1973)
6	Neutral 1N NH ₄ OAc K	kg ha ⁻¹	Flame photometric method using neutral normal ammonium acetate as extractant	Jackson (1973)
7	Neutral 1N NH ₄ OAc Ca	cmol(P ⁺) kg ⁻¹	Titrimetric method using neutral normal ammonium acetate as extractant	Jackson (1973)
8	Neutral 1N NH ₄ OAc Mg	cmol(P ⁺) kg ⁻¹	Titrimetric method using neutral normal ammonium acetate as extractant	Jackson (1973)
9	0.15% CaCl ₂ extractable S	mg kg ⁻¹	Turbidimetric method	Chesnin and Yien (1951)
10	DTPA extractable Fe, Mn, Zn and Cu	mg kg ⁻¹	Atomic absorption spectrophotometric (AAS) using DTPA as extractant.	Lindsay and Norvell (1978)
11	Hot water soluble B	mg kg ⁻¹	Azomithine-H method	Jackson (1973)

3.5.3 Categorization of soil nutrient status and nutrient index value for lime orchards

The soils were classified in low, medium and high categories of nutrient status using standard soil nutrient rating values for each nutrient. Nutrient index value calculated from the proportion of soils under low, medium and high available nutrient categories for soil samples.

The following equation was used to calculate Nutrient Index Value:-

$$\text{Nutrient Index Value} = (Nl \times 1) + (Nm \times 2) + (Nh \times 3)/Nt$$

Where, Nl = Number of samples falling in low category of nutrient status.

Nm = Number of samples falling in medium category of nutrient status.

Nh = Number of samples falling in high category of nutrient status.

Nt = Total number of samples analysed for a nutrient in any given area.

Parker *et al.* (1951) had classified the nutrient index values less than 1.5 as the indicative of low nutrient status and between 1.5 to 2.5 as medium while higher than 2.5 as high nutrient status. Ramamoorthy and Bajaj (1969) had categorized these values as less than 1.67 being indicative of low fertility status, between 1.67 to 2.33 as medium and more than 2.33 to classify as high. Soil samples of each taluk were classified based on nutrient index values as per the criteria of Ramamoorthy and Bajaj (1969).

3.6 Steps involved in development of DRIS norms

1. A data bank of nutrient concentration vs. yield data was established from survey.
2. Nutrient concentrations were expressed in as many forms as possible.
3. The whole population was divided into two subgroups based on yield performance as high and low yielding, the cut off being 1500 fruits/plant/year.

4. The mean of each subpopulation was calculated for various forms of expressions.
5. The variance ratios between yields of sub population for all the forms of expressions were calculated together with the coefficient of variance.
6. The forms of expressions for which significant variance ratios are obtained were selected as ratio norms.

For development of DRIS norms for lime, the whole population was divided into two populations namely high yielding and low yielding groups (Beaufils, 1973). The orchard that yielded more than 1500 fruits/plant/year of lime was considered as high yielding orchard and less than that constituted low yielding group.

3.6.1 DRIS ratio norms in lime

The DRIS technique utilizes nutrient ratios rather than absolute or individual levels of nutrients. Three priorities were used for the choice of nutrient expression: the first was to guarantee that the norms were based on ordinary Gaussian yield distribution versus nutrient expression values, as otherwise calculated means (norms) for nutrient phrases could vary from the real values at peak output; The second priority was to pick those nutrient expressions for which the variance ratios (Low yield variance / High yield variance) were comparatively big, thereby maximizing the potential for differentiation between healthy and unhealthy crops; and the third priority was to pick equivalent expressions for each of the 11 elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B) to fulfill the absolute (orthogonal) mathematical model requirement (Walworth and Sumner, 1987).

3.7 Computations of DRIS norms

The DRIS approach uses nutrient ratios rather than the nutrient concentrations themselves. All possible combination of nutrient ratios involving two nutrients and their inverses were worked out. DRIS norms were calculated as described by Beaufils (1973); Walworth and Sumner (1987).

The computer programme developed at Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bengaluru for DRIS was used for developing norms. After computing these ratios for each sample in the low and high yielding population, their means for the two groups were determined. The nutrient ratios whose variance ratios (variance of low yielding/variance of high yielding population) for the two subpopulations varied significantly were selected for developing DRIS norms. In case a nutrient ratio and its inverse yielded significant variance ratios, the form that had the higher variance ratio and lower coefficient values was selected for the purpose.

The individual nutrients were also considered for the computation of DRIS norm in the same way as the nutrient ratios. The means of the nutrient ratios or individual nutrients from the high yielding population formed the diagnostics norms. The eleven nutrients are N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B.

3.8 Computation of DRIS indices and Nutritional Imbalance Index (NII)

DRIS provides a means of ordering nutrient ratios into meaningful expressions in the form of indices. The DRIS indices were calculated as described by Walworth and Sumner (1987) by using the following formula, as an example for one nutrient is given below.

For example, in case of N the indices are

$$N = 1/10[f(N/P) - f(K/N) + f(N/Ca) + f(N/Mg) + f(N/S) - f(Fe/N) + f(N/Mn) - f(Zn/N) + f(N/Cu) - f(B/N)]$$

Where, when N/P is larger or equal to n/p,

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

When N/P is smaller than n/p,

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

In which N/P is the actual value of the ratio of N and P in the plant under diagnosis and n/p is the value of the norm (mean of the high yielding population) and CV is the co-efficient of variation for the population of n/p for the high yielding orchards. Similarly, the indices for other nutrients have been calculated using appropriate formulae. The absolute sum values of the nutrient indices generate an additional index called 'Nutritional Imbalance Index' (NII). This was worked out by taking the actual sum of the DRIS indices irrespective of sign.

3.9 Leaf nutrient guides/ranges

The norms for classification of nutrient status in plants were derived as outlined by Bhargava and Chadha (1993) and Raghupathi and Bhargava (1999a). Five leaf nutrient guide/ ranges have been derived using mean and standard deviation (SD) as deficient, low, optimum, high and excess for each nutrient. The 'optimum' nutrient range is the value derived from "mean – $4/3$ SD to mean + $4/3$ SD". The range 'low' was obtained by calculating "mean – $4/3$ SD to mean – $8/3$ SD" and the value below "mean – $8/3$ SD" was considered as 'deficient'. The value from "mean + $4/3$ SD to mean + $8/3$ SD" was taken as 'high' and the value above "mean + $8/3$ SD" was taken as 'excessive'.

3.10 Statistical analysis

The data were tabulated and subjected to simple correlation. The test of significance was conducted at 5 and 1% level of significance. The selection of high and low yielding population, cutoff yield and categorization of soils based on soil fertility status and nutrient index value for lime orchards was carried out using Microsoft Office Excel- 2010.

4. EXPERIMENTAL RESULTS

The result of present studied entitled “DRIS Norms for Identification of Yield Limiting Nutrients in Lime (*Citrus aurantifolia*) Orchards of Vijayapura District, Karnataka” is presented in this chapter. The aim of this research was to create leaf nutrient standards/guides and recognize most yield-limiting nutrients and nutrient imbalances through DRIS indices in low yielding lime orchards.

4.1 Soil nutrient status of lime orchards

4.1.1 Range and mean of soil properties and nutrient status

4.1.2 Categorization of soils based on soil fertility status and nutrient index value for lime orchards

4.1.3 Relationship between soil properties and soil extractable nutrients

4.1.4 Relationship between soil properties and fruit yields of lime

4.1.5 Relationship between extractable soil nutrients and fruit yields of lime

4.2 Leaf nutrient status in lime orchards

4.2.1 Range and mean of leaf nutrients concentration of the entire population of lime orchards

4.2.2 Range and mean of leaf nutrients concentration of high yielding lime orchards (n=54)

4.2.3: Range and mean of leaf nutrients concentration of low yielding orchards of lime (n=31)

4.2.3 Relationship between leaf nutrient concentration of lime and fruit yields

4.3 DRIS ratio norms in lime

4.4 DRIS indices and nutrient imbalance index (NII) in lime

4.5 Leaf nutrient standards for lime

4.6 Classification of low-yielding orchards based on leaf nutrient norms in lime

4.1 Soil nutrient status of lime orchards

The soil properties and nutrient status of lime orchards situated in the district of Vijayapura are described in individual soil samples.

4.1.1 Range and mean of soil properties and nutrient status

The range and mean values of soil properties and nutrient status of lime orchards (n=85) are presented in Table 3. Soil pH (1:2.5 suspensions of soil and water) varies from 7.20 to 8.52 with an average value of 8.01. These soils electrical conductivity ranged in 1:2.5 soil and water suspensions from 0.13 to 1.87 dSm⁻¹. The organic carbon content ranged from 0.50 to 1.13% with an average value of 0.81%. Alkaline KMnO₄ hydrolysable N, Olsen's P and Neutral 1N ammonium acetate (NH₄OAc) K ranged from 75.44 to 589.74, 4.38 to 54.43 and 148.39 to 356.91 kg ha⁻¹ respectively with mean values of 315.60, 14.89 and 246.46 kg ha⁻¹.

Neutral 1N ammonium acetate (NH₄OAc) Ca and Mg ranged from 15.53 to 28.58 and from 3.18 to 16.60 cmol(P⁺)kg⁻¹ with mean concentration 21.77 and 9.40 cmol (P⁺) kg⁻¹ soil respectively. The CaCl₂ (0.01%) extractable S content of soil varies from 11.33 to 74.00 mg kg⁻¹ with mean value of 40.42 mg kg⁻¹. Extractable DTPA Fe in soils ranged from 4.64 to 14.27 mg kg⁻¹ with a 7.35 mg kg⁻¹ is average value and soil Mn ranged from 7.5 to 40 mg kg⁻¹ with a 23.66 mg kg⁻¹ is average value. The soil DTPA extractable Zn and Cu status ranged from 0.71 to 2.20 mg kg⁻¹ and 3.02 to 8.80 mg kg⁻¹ respectively with mean values of 1.33 and 5.39 mg kg⁻¹. Hot water soluble B in soils ranged from 0.18 to 1.66 mg kg⁻¹ with a mean value of 0.70 mg kg⁻¹.

4.1.2 Categorization of soils based on soil fertility status and nutrient index value for lime orchards

Based on the extractable soil nutrient content, soils were classified as low, medium and high category using standard soil rating values for each nutrient. The nutrient index value for the percentage of soils in the low, medium and high categories of nutrients available was calculated.

For Indi taluk the proportion of soil samples falling in low, medium and high categories for different nutrients and the calculated values of nutrient index are

Table 3: Range and mean of soil properties and soil nutrient status in different lime orchards of Vijayapura District

(n= 85)

Property	Unit	Range	Mean
pH	(1:2.5 soil:water suspension)	7.20 - 8.52	8.01
EC	dSm ⁻¹	0.13 - 1.87	0.36
Organic carbon	%	0.50 - 1.13	0.81
Alkaline KMnO ₄ hydrolysable N	kg ha ⁻¹	75.44 - 589.74	315.60
Olsen's P	kg ha ⁻¹	4.38 - 54.43	14.89
Neutral 1N NH ₄ OAc K	kg ha ⁻¹	148.39 - 356.91	246.46
Neutral 1N NH ₄ OAc Ca	cmol (P ⁺) kg ⁻¹	15.53 - 28.58	21.77
Neutral 1N NH ₄ OAc Mg	cmol (P ⁺) kg ⁻¹	3.18 - 16.60	9.40
0.15% CaCl ₂ extract S	mg kg ⁻¹	11.33 - 74.00	40.42
DTPA extractable Fe	mg kg ⁻¹	4.64 - 14.27	7.35
DTPA extractable Mn	mg kg ⁻¹	7.50 - 40.00	23.66
DTPA extractable Zn	mg kg ⁻¹	0.71 - 2.20	1.33
DTPA extractable Cu	mg kg ⁻¹	3.02 - 8.80	5.39
Hot water soluble B	mg kg ⁻¹	0.18 - 1.66	0.70

presented in the Table 4. For N, samples were 50, 48, and 2 per cent respectively in low, medium, and high categories. In P, 45, 33 and 22 per cent samples were in low, medium and high categories, respectively, whereas in medium and high categories for K 70 and 30 per cent samples were respectively. For S, samples in medium and high categories were 13 and 87 per cent respectively. It is apparent from the data that all (100%) soil samples were high in Mn and Cu. For Fe, 68 and 32 per cent samples were medium and high categories, respectively. For Zn, samples in medium and high categories were 43 and 57 per cent, while for B, samples in medium and high categories were 8 and 92 per cent, respectively. As per the calculated values of nutrient index, soils of lime orchards of Indi taluk of Vijayapura were low in N, whereas medium in P, K and Fe and high in S, Mn, Cu, Zn, and B.

The percentage of soil samples falling in low, medium and high categories for different nutrients and the calculated values of nutrient index for Sindagi taluk is presented in Table 5. It is apparent from the data that all 36 and 64 per cent soil samples were low and high for N. For P, 60, 32 and 8 per cent samples were in low, medium and high categories, respectively. In case of K, 68 and 32 per cent samples were in medium and high categories, respectively. For S, 100 per cent samples were in high categories. Among the micronutrients, 92 and 8 per cent samples were in medium and high categories, respectively for Fe. In case of Mn and Cu all (100%) soil samples were falling under high category. For Zn, 36 and 64 per cent samples were in medium and high categories, respectively while 8, 32 and 60 per cent samples were in low, medium and high categories, respectively for B. As per the calculated values of nutrient index, soils of lime orchards of Sindagi taluk were low in N and P, medium in K and Fe and high in S, Mn, Cu, Zn and B.

4.1.3 Relationship between soil properties and soil extractable nutrients

Simple correlation assessment between soil properties and extractable nutrients content in soil samples is shown in Table 6. The pH of the soil was significant and negative correlation with Olsen's P, DTPA (pH 7.3) extractable Fe, hot water soluble (significant at $p = 0.05$) and highly significant and negative correlation with neutral $1\text{N NH}_4\text{OAc}$ exchangeable Ca (significant at $p = 0.01$). Soil organic carbon content had a significant and highly negative correlation with Neutral $1\text{N NH}_4\text{OAc}$ extractable K

Table 4: Percent samples falling in low, medium and high categories of essential nutrients and nutrient index value for lime orchards of Indi taluk

(n=60)

Nutrient	Low	Medium	High	Nutrient Index Value (NIV)
N	30 (50)	29 (48)	1 (2)	1.52 (L)
P	27 (45)	20 (33)	13 (22)	1.77 (M)
K	0	42 (70)	18 (30)	2.3 (M)
S	0	8 (13)	52 (87)	2.87 (H)
Fe	0	41 (68)	19 (32)	2.32 (M)
Mn	0	0	60 (100)	3 (H)
Zn	0	26 (43)	34 (57)	2.57 (H)
Cu	0	0	60 (100)	3 (H)
B	0	5 (8)	55 (92)	2.92 (H)

Table 5: Percent samples falling in low, medium and high categories of essential nutrients and nutrient index value for lime orchards of Sindagi

(n=25)

Nutrient	Low	Medium	High	Nutrient Index Value (NIV)
N	9 (36)	16 (64)	0	1.64 (L)
P	15 (60)	8 (32)	2 (8)	1.48 (L)
K	0	17 (68)	8 (32)	2.32 (M)
S	0	0	25 (100)	3 (H)
Fe	0	23 (92)	2 (8)	2.08 (M)
Mn	0	0	25 (100)	3 (H)
Zn	0	9 (36)	16 (64)	2.64 (H)
Cu	0	0	25 (100)	3 (H)
B	2 (8)	8 (32)	15 (60)	2.52 (H)

Table 6: Simple correlation coefficients (r) between soil properties and soil extractable nutrients

Extractable Nutrients	Unit	pH (1:2.5 soil water suspension)	EC (dSm ⁻¹)	OC (%)
Alkaline KMnO ₄ hydrolysable N	kg ha ⁻¹	-0.059	-0.094	0.129
Olsen's P	kg ha ⁻¹	-0.215*	-0.038	-0.005
Neutral 1N NH ₄ OAc K	kg ha ⁻¹	-0.097	0.169	-0.360**
Neutral 1N NH ₄ OAc Ca	cmol(P ⁺) kg ⁻¹	-.319**	0.095	0.048
Neutral 1N NH ₄ OAc Mg	cmol(P ⁺) kg ⁻¹	-0.027	0.074	-0.217*
0.15% CaCl ₂ extract S	mg kg ⁻¹	-0.154	-0.045	0.11
DTPA extract Fe	mg kg ⁻¹	-0.254*	-0.014	-0.186
DTPA extract Mn	mg kg ⁻¹	-0.114	-0.008	-0.044
DTPA extract Zn	mg kg ⁻¹	-0.081	-0.197	0.099
DTPA extract Cu	mg kg ⁻¹	-0.115	-0.032	0.142
Hot water soluble B	mg kg ⁻¹	-0.227*	0.084	0.112

**Significant at p≤0.01, *Significant at p≤0.05.

(significant at $p = 0.01$) whereas significant and negative correlation with Neutral 1N NH_4OAc extractable Mg (significant at $p = 0.05$).

4.1.4 Relationship between soil properties and fruit yields of lime

Simple correlation analysis was performed between lime fruit yields and soil properties and the values of simple correlation coefficients are presented in Table 7. Lime fruit yield showed non-significant correlation between soil properties and fruit yields of lime.

4.1.5 Relationship between extractable soil nutrients and fruit yields of lime

Simple correlation analysis was performed between extractable soil nutrients and lime fruit yields and the values of simple correlation coefficients are presented in Table 8. Fruit yields of lime showed a significant and positive correlation with Neutral 1N NH_4OAc K, Hot water soluble B (significant at $p = 0.05$) and highly significant and positive correlation with 0.15% CaCl_2 extractable S (significant at $p = 0.01$).

4.2 Leaf nutrient status in lime orchards

4.2.1 Leaf nutrients status of the entire population of lime orchards

The range and mean values of levels of leaf nutrients in the entire population are presented in Table 9. In leaf N ranged from 0.71 to 1.74 per cent with a mean value of 1.29 per cent. However, the N content generally did not differ greatly among orchards; it low in some low yielding orchards compared to the mean value. Leaf P varied from 0.22 to 1.42 per cent with an average value of 0.74 per cent content of leaf K ranged from 0.53 to 1.89 per cent with a mean of 1.04 per cent. Compared to P and K, the variation observed in concentration of leaf N was comparatively large.

Calcium concentration in leaves of lime ranged from 0.70 to 2.0 per cent with a mean value of 1.26 per cent. Magnesium concentration varied from 0.10 to 1.26 per cent with a mean of 0.42 per cent. The content of the leaf S ranged from 0.13 to 0.95 per cent with an average of 0.33 per cent. Ca and Mg showed comparatively greater variations in their levels among the secondary nutrients.

Table 7: Simple correlation between soil properties and fruit yields of lime

Soil properties	Unit	Yield (Fruits/tree/year)
pH	(1:2 soil water suspension)	-0.136
EC	dSm ⁻¹	0.03
Organic carbon	%	0.037

**Significant at $p \leq 0.01$, *Significant at $p \leq 0.05$

Table 8: Simple correlations between extractable soil nutrients and fruit yields of lime

Soil extractable nutrients	Unit	Yield (Fruits/tree/year)
Alkaline KMnO_4 hydrolysable N	kg ha^{-1}	0.00
Olsen's P	kg ha^{-1}	0.21
Neutral 1N NH_4OAc K	kg ha^{-1}	0.222*
Neutral 1N NH_4OAc Ca	$\text{cmol(P}^+) \text{ kg}^{-1}$	0.021
Neutral 1N NH_4OAc Mg	$\text{cmol(P}^+) \text{ kg}^{-1}$	0.076
0.15% CaCl_2 extractable S	mg kg^{-1}	0.309**
DTPA extractable Fe	mg kg^{-1}	0.083
DTPA extractable Mn	mg kg^{-1}	0.205
DTPA extractable Zn	mg kg^{-1}	0.173
DTPA extractable Cu	mg kg^{-1}	-0.01
Hot water soluble B	mg kg^{-1}	0.220*

**Significant at $p \leq 0.01$, *Significant at $p \leq 0.05$

Table 9: Range and mean of leaf nutrient concentrations entire population of lime orchards

(n=85)

Nutrient	Unit	Range	Mean
N	%	0.71 - 1.74	1.29
P	%	0.22 - 1.42	0.74
K	%	0.53 - 1.89	1.04
Ca	%	0.70 – 2.00	1.26
Mg	%	0.10 - 1.26	0.42
S	%	0.13 - 0.95	0.33
Fe	µg/g	6.79 - 120.21	32.35
Mn	µg/g	0.37 - 4.91	2.16
Zn	µg/g	7.08 - 39.66	28.4
Cu	µg/g	2.31 - 13.74	5.66
B	µg/g	44.93 - 146.95	98.55

Among the micronutrients, Fe concentration ranged from 6.79 to 120.21 $\mu\text{g/g}$ in lime leaves with a mean value of 32.35 $\mu\text{g/g}$. The leaf Mn ranged from 0.37 to 4.91 $\mu\text{g/g}$ with a value of 2.16 $\mu\text{g/g}$. The leaf Zn content ranged from 7.08 to 39.66 $\mu\text{g/g}$ with an average value of 28.4 $\mu\text{g/g}$. Leaf Cu content ranged from 2.31 to 13.74 $\mu\text{g/g}$ with a 5.66 $\mu\text{g/g}$ mean value. The concentration of boron in the leaves ranged from 44.93 to 146.95 $\mu\text{g/g}$ with a mean value is 98.55 $\mu\text{g/g}$ mean.

4.2.2 Leaf nutrients status of high yielding lime orchards (n=54)

The range and mean of leaf nutrients in high yielding lime orchards presented in Table 10. The concentration of N ranged from 0.97 to 1.74 per cent with an average value of 1.30per cent. The concentration of Leaf P varied from 0.30 to 1.27per cent with an average value of 0.78per cent and the concentration of Leaf K ranged from 0.53 to 1.89per cent with an average of 1.02per cent. The concentration of calcium in leaves ranged from 0.70 to 2.0 per cent with an average value of 1.21 per cent. Magnesium concentration in leaves ranged from 0.35 to 1.12 per cent with a mean of 0.64 per cent. The concentration of the leaf S ranged from 0.20 to 0.75per cent with an average of 0.36per cent.

The level of leaf Fe varied from 18 to 51 $\mu\text{g/g}$ with a mean of 31.94 $\mu\text{g/g}$ and the concentration of leaf Mn ranged from 7.08 to 44 $\mu\text{g/g}$ with a mean of 27.49 $\mu\text{g/g}$. Zinc concentration in leaves ranged from 3.82 to 29.6 $\mu\text{g/g}$ with a mean value of 19.65 $\mu\text{g/g}$ and Cu concentration in leaves ranged from 3.91 to 7.10 $\mu\text{g/g}$ with a mean of 5.53 $\mu\text{g/g}$. Boron concentration in leaves ranged from 44.93 to 135.52 $\mu\text{g/g}$ with a mean value of 95.51 $\mu\text{g/g}$.

4.2.3 Range and mean of leaf nutrients concentration of low yielding orchards of lime (n=31)

The range and mean of nutrients in low yielding orchards of lime are presented in Table 11. Nitrogen concentration ranged from 0.71 to 1.41 per cent with a mean value of 1.17 per cent, while P and K concentrations ranged from 0.22 to 1.36 per cent and 0.54 to 1.70 per cent with mean values of 0.63 and 1.01 per cent, respectively. Calcium, Mg and S concentration in the leaves ranged from 0.70 to 1.80, 0.10 to 0.94 and 0.16 to 0.71 per cent with mean values of 1.33, 0.32 and 0.31 per cent, respectively.

Table 10: Range and mean of leaf nutrients concentration of high yielding orchards of lime

(n=54)

Nutrient	Unit	Range	Mean
N	%	0.97 - 1.74	1.30
P	%	0.30 - 1.27	0.78
K	%	0.53 - 1.89	1.02
Ca	%	0.70 – 2.00	1.21
Mg	%	0.35 - 1.12	0.64
S	%	0.20 - 0.75	0.36
Fe	µg/g	18.00– 51.0	31.94
Mn	µg/g	7.08 – 44.0	27.49
Zn	µg/g	3.82 - 29.6	19.65
Cu	µg/g	3.91 - 7.10	5.53
B	µg/g	44.93 - 135.52	95.51

The range and mean values for Fe, Mn, Zn, Cu and B concentrations in low yielding orchards of lime were 12.29 to 67.45, 12.92 to 34, 6.16 to 10.51, 4.06 to 6.17, and 40 to 92.19 $\mu\text{g/g}$ with the mean values of 32.47, 27.68, 7.89, 5.13, and 76.71 $\mu\text{g/g}$ respectively.

4.2.3 Relationship between leaf nutrient concentration of lime and fruit yields

Simple correlation analysis was performed between plant nutrient content of lime and fruit yields are presented in Table 12. Fruit yield showed a significant and positive correlation with P and Mg concentration in lime.

4.3 DRIS ratio norms in lime

In Table 13, together with their coefficient of variation in lime, a total of fifty-five nutrient ratio expressions used as diagnostic norms from high yielding population are provided. Ideally, it was noted that for greater diagnostic accuracy, a specific nutrient ratio to be selected as a standard should have a high variance ratio and a low coefficient of variation between high and low yielding groups.

The important nutrient ratio expressions were : K/N (0.79), Ca/N (0.94), N/S (3.28), Fe/N (24.66), Mn/N (21.22), Cu/N (4.29), Ca/K (1.25), K/S (2.94), K/Cu (0.19), Ca/S (3.52), Ca/Cu (0.23), S/Mg (0.59), Cu/Mg (9.21), S/Fe (0.01), Mn/Fe (0.89), Fe/Cu (5.81), and Mn/Cu (5.07) etc. Showed lower co-efficient of variation when compared to others. Important expressions of nutrients with N were: Ca/N (0.94), N/Mg (2.22), N/S (3.82), Fe/N (24.66), Mn/N (21.22), and Cu/N (4.29).

The other important expressions of nutrients with K were: Ca/K (1.25), K/Mg (1.71), K/S (2.94), Fe/K (32.99) K/Cu (0.19) and B/K (99.57). The ratios of important ratios involving Ca were: Ca/S (3.52), Ca/Cu (0.23), Ca/B (0.01), for magnesium S/Mg (0.59), Cu/Mg (9.21), for sulphur S/Fe (0.01), Mn/s (80.29), Cu/S (16.11), for iron Mn/Fe (0.89), Fe/Cu (5.81), Fe/B (0.35), and Mn/Cu (5.07), Mn/B (0.30) and Cu/B (0.06) were also from a physiological point of perspective equally significant. The coefficient of variation (CV) ranged from the smallest 18% for Cu/N to the largest 73% for B/Zn, showing greater variation in their absolute concentrations in the high producing population.

Table 11: Range and mean of leaf nutrients of low yielding lime orchards
(n=31)

Nutrient	Unit	Range	Mean
N	%	0.71 - 1.41	1.17
P	%	0.22 - 1.36	0.63
K	%	0.54 - 1.70	1.01
Ca	%	0.70 - 1.80	1.33
Mg	%	0.10 - 0.94	0.32
S	%	0.16 - 0.71	0.31
Fe	µg/g	12.29 - 67.45	32.47
Mn	µg/g	12.92 - 34	27.68
Zn	µg/g	6.16 - 10.51	7.89
Cu	µg/g	4.06 - 6.17	5.13
B	µg/g	40 - 92.19	76.71

Table 12: Simple correlation coefficient between leaf nutrient concentration and fruit yield of lime

Nutrient	Unit	Fruit yield
N	%	0.085
P	%	0.241*
K	%	0.198
Ca	%	-0.15
Mg	%	0.272*
S	%	0.11
Fe	µg/g	0.034
Mn	µg/g	-0.043
Zn	µg/g	0.152
Cu	µg/g	0.195
B	µg/g	-0.208

**Significant at $p \leq 0.01$, *Significant at $p \leq 0.05$

Table 13: DRIS ratio norms in lime

Sl. No.	Selected Ratio	DRIS norms	CV (%)	Sl. No.	Selected Ratio	DRIS norms	CV (%)
1	N/P	1.88	38	29	Ca/S	3.52	28
2	K/N	0.79	26	30	Ca/Fe	0.04	36
3	Ca/N	0.94	25	31	Mn/Ca	24.17	37
4	N/Mg	2.22	32	32	Ca/Zn	0.07	70
5	N/S	3.82	25	33	Ca/Cu	0.23	30
6	Fe/N	24.66	23	34	Ca/B	0.01	31
7	Mn/N	21.22	24	35	S/Mg	0.59	29
8	N/Zn	0.08	58	36	Fe/Mg	53.20	35
9	Cu/N	4.29	18	37	Mn/Mg	45.77	34
10	N/B	0.01	32	38	Zn/Mg	31.82	32
11	P/K	0.81	43	39	Cu/Mg	9.21	25
12	Ca/P	1.83	59	40	B/Mg	162.91	37
13	P/Mg	1.28	38	41	S/Fe	0.01	28
14	S/P	0.51	41	42	Mn/S	80.29	33
15	Fe/P	45.18	38	43	S/Zn	0.02	59
16	Mn/P	38.36	34	44	Cu/S	16.11	24
17	P/Zn	0.04	46	45	B/S	279.85	33
18	P/Cu	0.14	34	46	Mn/Fe	0.89	32
19	P/B	0.01	40	47	Fe/Zn	1.84	64
20	Ca/K	1.25	31	48	Fe/Cu	5.81	22
21	K/Mg	1.71	34	49	Fe/B	0.35	36
22	K/S	2.94	28	50	Mn/Zn	1.54	48
23	Fe/K	32.99	32	51	Mn/Cu	5.07	28
24	Mn/K	28.49	34	52	Mn/B	0.30	35
25	K/Zn	0.06	65	53	Cu/Zn	0.33	66
26	K/Cu	0.19	26	54	B/Zn	5.72	73
27	B/K	99.57	34	55	Cu/B	0.06	37
28	Ca/Mg	2.09	41				

CV is co-efficient of variation expressed in percent

4.4 DRIS indices and nutrient imbalance index (NII) in lime

The DRIS norms established from high yielding lime orchards were used to calculate DRIS indices from the foliar mineral composition of lime grown at various sites to identify the most needed nutrient elements as well as their order of requirement. The plant's nutrient imbalance is diagnosed by indices of DRIS. The DRIS offers a mathematical means of readily interpretable ordering a big amount of nutrient ratios into nutrient indices. Table 14 presents the DRIS indices along with the nutrient imbalance index (NII), yield and nutrient requirement order of low yielding lime trees.

Depending on the magnitude of the indices, the order in which distinct nutrients restrict returns may also be stated. In sl. No. 1 orchard No.2 for instance, there NII were 174 in N (-25), S (-17), Fe (-15), Zn (-14) P (-9), and B (-6) had negative signs, while others had positive signs. The No.56 orchard, with the smallest NII of 76, had an index of B (-11), Mg (-8), Zn (-8), P (-8) and N (-3) the order yield limiting nutrients were B>P>Mg>Zn>N. The orchard no. 64, showed the highest NII of 340 had an index of Mg (-156), Zn (-8), P (-4) and N (-2) the order yield limiting nutrients were Mg>Zn>P>N. In general consider whole population among macronutrient Mg was the most yield limiting nutrient followed by P and S. N and K also showing as yield limiting nutrient only in few orchards. Among micronutrient Zn was the most yield limiting nutrient followed by B and Fe.

The orchard no. 40 showed nutrient indices zero for sulfur indicated the optimum level, in the present investigation, the sum of indices ranged from 76 to 340 regardless of the sign. Among the 31 low yielding orchards, the orchard 64, 67, and 75 reported high NII as 340, 292 and 270, suggesting that these orchards were more imbalanced than those of the orchard 76, 5, and 56 which recorded low NII as 110, 88, and 76. Simple correlations were established for the low yielding orchards between NII and fruit yield per tree. A weak correlation between yield and NII was stated by the linear correlation coefficient ($r = -0.260$).

Table 14: DRIS indices, nutrient imbalance index (NII), yields and order of nutrient requirement for low yielding lime orchards

Sl. No.	Orchard no	N index	P index	K index	Ca index	Mg index	S index	Fe index	Mn index	Zn index	Cu index	B index	NII	Fruits/ tree/year	Order of limiting nutrients
1	2	-25	-9	22	6	36	-17	-15	15	-14	8	-7	174	1200	N>S>Fe>Zn>P>B
2	5	-1	-1	40	-7	-11	-4	-1	3	-18	-1	1	88	980	Zn>Mg>Ca>S>Cu>Fe
3	10	-1	7	37	9	-61	5	13	15	-25	10	-9	192	500	Mg>Zn>B>>N
4	11	1	7	18	8	-13	-1	-13	17	-15	5	-14	112	400	Zn>B>Mg>Fe>S
5	13	-5	14	-8	16	-9	-12	-4	6	-19	11	10	114	1100	Zn>S>Mg>K>N>Fe
6	19	3	18	0	9	-23	-5	31	9	-32	-1	-9	140	400	Zn>Mg>B>S>Cu
7	21	2	15	-13	8	11	5	13	5	-33	-10	-3	118	1200	Zn>K>Cu>B
8	23	0	30	-4	10	3	3	8	-26	-18	7	-13	122	400	Mn>Zn>B>K>N
9	28	3	21	0	-15	30	-2	8	2	-33	-9	-5	128	1250	Zn>Ca>Cu>B>S>K
10	35	6	37	-28	5	14	-8	57	-3	-30	-13	-37	199	300	B>Zn>K>Cu>S>Mn
11	40	9	2	-5	16	-40	0	13	9	-14	8	2	118	1000	Mg>Zn>K>S
12	41	-15	-51	53	7	-27	-7	26	15	-9	6	2	166	1000	P>Mg>N>Zn>S
13	45	7	11	12	15	-50	-3	11	11	-15	7	-6	148	800	Mg>Zn>B>S
14	55	-5	-5	5	20	-60	1	50	8	-14	13	-13	194	700	Mg>Zn>B>P>N
15	56	-3	-8	6	3	-8	4	16	3	-8	6	-11	76	700	B>Mg>Zn>P>N
16	57	1	-16	4	15	-31	2	34	10	-18	-3	2	136	600	Mg>Zn>P>Cu
17	58	9	1	8	21	-97	-4	17	27	-7	14	11	216	400	Mg>Zn>S>P
18	59	1	-4	23	16	-71	3	12	5	-13	19	9	176	400	Mg>Zn>P>N
19	62	10	12	-13	6	-8	-28	2	12	-14	12	9	126	1400	S>Zn>K>Mg

Sl. No.	Orchard no	N index	P index	K index	Ca index	Mg index	S index	Fe index	Mn index	Zn index	Cu index	B index	NII	Fruit/ tree/year	Order of limiting nutrients
20	63	-17	-2	6	11	-56	16	27	6	-16	20	5	182	700	Mg>N>Zn>P
21	64	-2	-4	29	19	-156	26	26	29	-8	29	12	340	1000	Mg>Zn>P>N
22	65	-20	-18	35	10	-26	9	-12	23	-13	11	1	178	400	Mg>N>P>Zn>S
23	67	-12	-5	29	19	-112	26	21	20	-17	20	11	292	500	Mg>Zn>N>P
24	70	-2	-8	44	21	-107	17	0	8	-11	27	11	256	600	Mg>Zn>P>N>Fe
25	71	-2	11	16	11	-59	14	0	12	-22	15	4	166	600	Mg>Zn>N>Fe
26	73	-4	-10	9	21	-35	12	-17	16	-12	9	11	156	980	Mg>Fe>Zn>P>N
27	74	8	4	40	-6	-50	-17	-28	17	-7	23	16	216	500	Mg>Fe>S>Zn>Ca
28	75	2	-18	34	34	-81	18	-21	15	-15	22	10	270	300	Mg>Fe>P>Zn
29	76	0	-11	24	14	-10	4	-18	5	-16	5	3	110	300	Fe>Zn>P>Mg
30	77	-2	-10	9	15	-45	11	13	9	-12	4	8	138	600	Mg>Zn>P>N
31	85	-1	-7	11	9	-4	44	-24	2	-24	0	-6	132	1200	Zn>Fe>P>B>Mg

4.5 Leaf nutrient standards for lime

For plant nutrients, leaf nutrient standards or optimum ranges were developed based on mean concentrations of nutrients and standard deviation (SD) from high yielding population. The concentrations of nutrients categorized in lime as deficient, low, optimal, high and excessive based on the DRIS principle are showed in Table 15.

The optimum N ranged from 1.14 to 1.3 per cent. The concentrations of leaf N were regarded to be less than 0.96 per cent and more than 1.48 per cent respectively deficient and excessive. The optimum P varied from 0.45 per cent to 0.78 per cent, which was generally much lower than other crops of fruit. The optimum K varied between 0.67 and 1.02 per cent. The concentration of leaf K were regarded to be less than 0.3 per cent and more than 1.39 per cent respectively as deficient and excessive. The optimum concentration of Ca, Mg and S ranged from 0.84 to 1.21, 0.39 to 0.64, and 0.25 to 0.36 per cent respectively. The optimum concentrations of Fe, Mn, Zn, Cu and B ranged from 21.63 to 31.94, 18.35 to 27.49, 11.24 to 19.65, 4.46 to 5.53 and 65.18 to 95.51 $\mu\text{g/g}$, respectively, among the micronutrients.

4.6 Classification of low-yielding orchards based on leaf nutrient norms in lime

Low yielding orchards have been categorized based on leaf nutrient standards in lime and the values are displayed in Table 16. The orchard classification stated that leaf N was optimal in 61 per cent of orchards and low in 13 per cent of orchards. On the other hand, 61 per cent of the orchards were optimal in P while the incidence of low P was not recorded in any of the orchards. Leaf K was optimum in 39 per cent orchards and the incidence of high K was recorded only in 39 per cent of the orchards.

Magnesium has often been discovered to be a significant yield limiting factor in lime. The leaf Mg was optimal in 10 per cent of the orchards and low in 65 per cent and deficient in 13 per cent of the orchards. However, Ca and Fe were found to

Table 15: Leaf nutrient standards in lime

Nutrient	Unit	Deficient	Low	Optimum	High	Excess
N	%	<0.96	0.97 - 1.13	1.14 - 1.3	1.31 - 1.47	>1.48
P	%	<0.11	0.12 - 0.44	0.45 - 0.78	0.79 - 1.11	>1.12
K	%	<0.3	0.31 - 0.66	0.67 - 1.02	1.03 - 1.38	>1.39
Ca	%	<0.44	0.45 - 0.83	0.84 - 1.21	1.22 - 1.60	>1.61
Mg	%	<0.13	0.14 - 0.38	0.39 - 0.64	0.65 - 0.90	>0.91
S	%	<0.11	0.12 - 0.24	0.25 - 0.36	0.37 - 0.48	>0.49
Fe	µg/g	<11.3	11.31 -21.62	21.63 - 31.94	31.9 5 - 42.26	>42.27
Mn	µg/g	<9.19	9.2 - 18.34	18.35 - 27.49	27.5 - 36.63	>36.64
Zn	µg/g	<2.8	2.81 - 11.23	11.24 - 19.65	19.66 - 28.08	>28.09
Cu	µg/g	<3.37	3.38 - 4.45	4.46 - 5.53	5.54 - 6.61	>6.62
B	µg/g	<34.84	34.85 -65.17	65.18 - 95.51	95.52 - 125.84	>125.85

Table 16: Classification of low-yielding lime orchards (%) based on leaf nutrient standards

Nutrient	Deficient	Low	Optimum	High	Excessive
N	16	13	61	10	0
P	0	19	61	13	6
K	0	13	39	39	10
Ca	0	6	29	58	6
Mg	13	65	10	10	3
S	0	19	58	19	3
Fe	0	26	23	35	16
Mn	0	3	35	61	0
Zn	0	100	0	0	0
Cu	0	6	74	19	0
B	0	26	74	0	0

be excess in a few orchards (6 and 16 per cent). Sulfur was discovered to be the yield-limiting nutrient as leaf S was optimal only in 58 per cent of orchards and low in 19 per cent of orchards. In 23 and 35 per cent of the orchards, were optimal Fe and Mn respectively. Among micronutrients, Zn and B were the main yield-limiting nutrients, and Zn was not shown to be optimal in any of the orchards, whereas low in 100 per cent trees, Cu and B were optimal in 74 per cent of each orchard and low in 6 per cent and 26 per cent.

5. DISCUSSION

The present study was on 'DRIS norms for identification of yield limiting nutrient in lime (*Citrus aurantifolia*) orchards of Vijayapura district Karnataka. A leaf nutrient concentration vs. yield information bank was developed through survey strategy for this purpose. The plant nutrient status of high and low yielding orchards was evaluated through leaf assessment. Leaf nutrient standards have been developed using mean and standard deviation. In addition, DRIS indices and the Nutritional imbalance Index (NII) were established for low yielding orchards to identify yield-limiting nutrients and were arranged in order of significance. The findings of the research are discussed in this section.

5.1 Soil properties and nutrient status of lime

5.1.1 Categorization of soils based on soil fertility status and nutrient index value for lime orchards.

5.1.2 Relationship between soil properties and soil extractable nutrients, soil properties and lime fruit yields, extractable soil nutrients and lime fruit yields

5.2.1 Leaf nutrient status of lime orchards

5.2.2 Leaf nutrients status of high and low yielding lime orchards

5.3.1 DRIS ratio norms in lime

5.3.2 DRIS indices and nutrient imbalance index (NII) in lime

5.4 Leaf nutrient standards for lime

5.5 Classification of low yielding orchards

5.1 Soil properties and nutrient status of lime

Soils of lime orchard, Vijayapura district are slightly saline to alkaline with a pH (1:2.5 soil and water suspensions) varied from 7.2 to 8.52 with a mean value of 8.01. The electrical conductivity of these soils ranged from 0.13 to 1.87 with a mean value of 0.36 dSm⁻¹ in 1:2.5 (soil: water suspensions). Organic content of soil ranged from 0.50 to 1.13 per cent with a mean value of 0.81 per cent. Kiran and Hundekar (2018) found the similar results of soils of the Hittnalli micro-watershed area of Vijayapura, Karnataka soils were moderately saline to alkaline in reaction (7.89 to 8.95) with a mean pH of 8.42. Shreekanth *et al.* (2018) reported the similar soil pH range in soils of grape orchards of Vijayapura. Bhandari *et al.* (2018) reported the electrical conductivity (0.48, dSm⁻¹), organic carbon content 0.94 per cent. Alkaline pH of grape soils may also be attributed to calcareous soils existing in and around Vijayapura soils (Pujar *et al.*, 2010). The soil organic-carbon were found in higher ranges (> 0.75 per cent) in most of the grape orchards of Vijayapura (Shreekanth *et al.*, 2018).

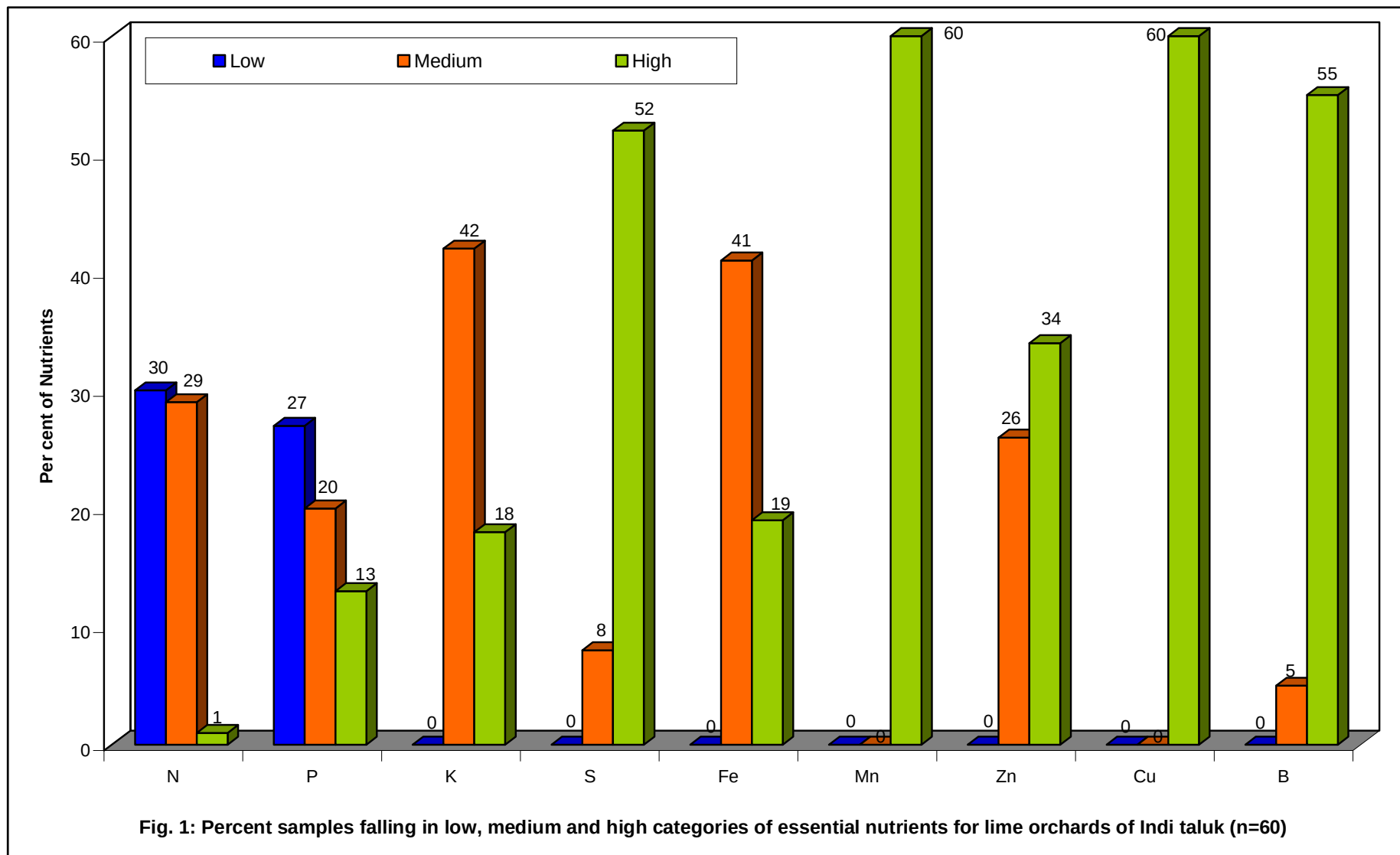
Mean values of soil Alkaline KMnO₄ hydrolysable N, Olsen's P and Neutral 1N ammonium acetate (NH₄OAc) K was 315.60, 14.89 and 246.46 kg ha⁻¹ respectively. Similar result was reported by Bhandari *et al.* (2018) stated that Olsen's P (14.7 kg ha⁻¹), Srivastava and Shirgure (2018) for soil extractable K in kashi mandarin orchards. The Neutral 1N NH₄OAc Ca and Mg were ranges from 15.53 to 28.58 and 3.18 to 16.60 cmol(p+) kg⁻¹ respectively. Whereas CaCl₂ (0.15%) extractable S, 11.33 to 74.00 mg kg⁻¹. Shreekanth *et al.* (2018) reported the similar status of Ca, Mg and S in soils of grape orchards of Vijayapura.

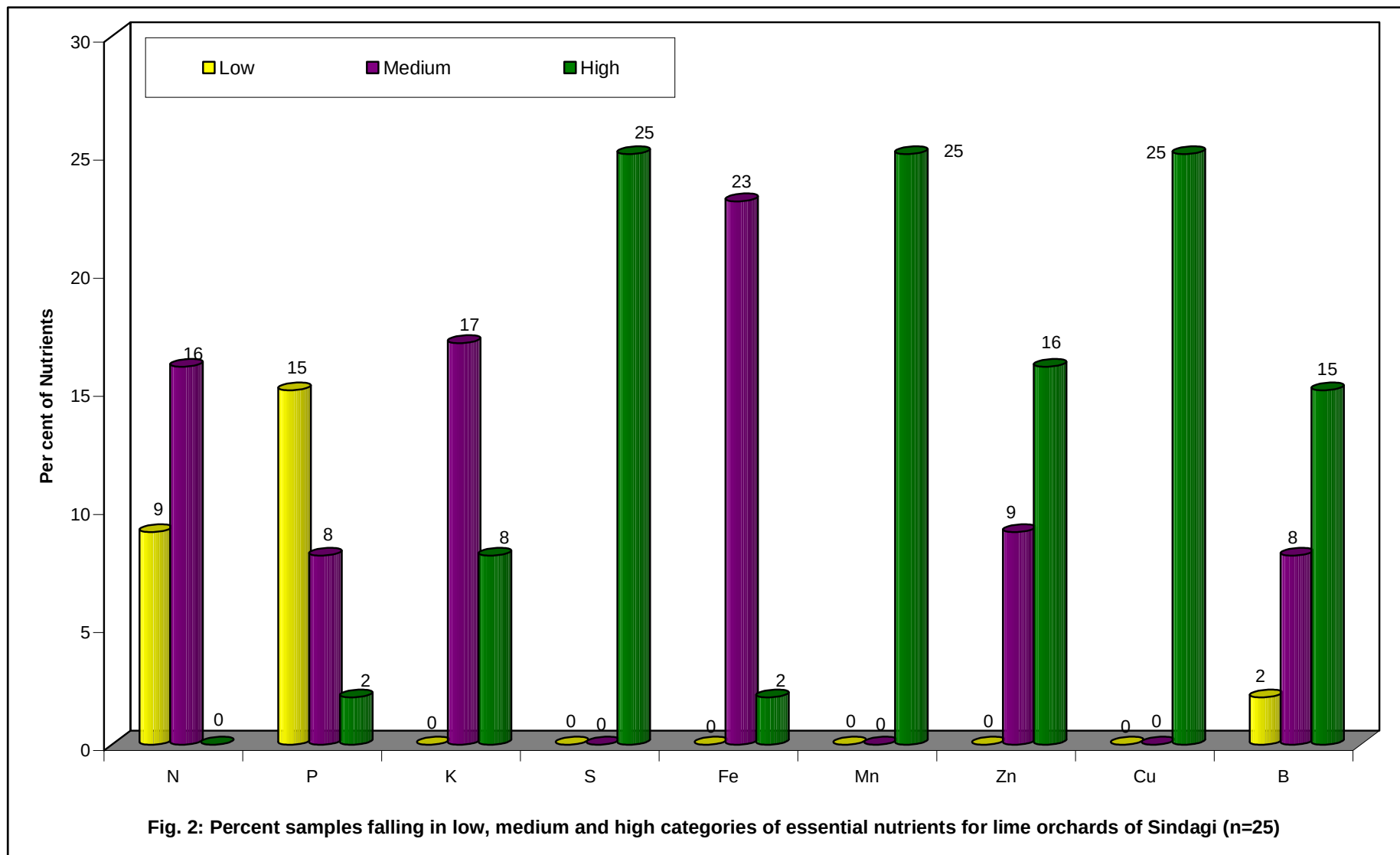
DTPA extractable (Fe, Mn, Zn, Cu and B) were 7.35, 23.66, 1.33, 5.39 and 0.70 mg kg⁻¹ respectively in soil. Wide variations were noticed in DTPA extractable micronutrients. These variations could be mainly due to types of soil, characteristics of soil, agro-ecological conditions and type of soil extractant used. Shreekanth *et al.* (2018) reported the similar results of Fe, Mn, Zn and Cu in soils of grape orchards of Vijayapura, where 100 per cent soil samples indicated Mn and Zn as high category. Somasundaram *et al.* (2011) reported the similar values of DTPA extractable Mn, Fe, Zn, and Cu in surface soils of citrus.

5.1.1 Categorization of soils based on soil fertility status and nutrient index value for lime orchards

For Indi taluk, the per cent of soil samples falling in low, medium and high categories for different nutrients and the calculated values of nutrient index value are presented in Table 4 and Figure 1. Among macronutrient N and P are 50 and 45 per cent soil samples falling in low categories respectively. Macronutrient N, P, K and S are 48, 33, 70 and 13 per cent soil samples falling in medium categories respectively and Fe, Zn and B are 68, 43 and 8 per cent soil samples falling in medium categories respectively. Whereas 2, 22, 30, 87, 32, 100, 57, 100 and 92 per cent of N, P, K, S, Fe, Mn, Zn, Cu and B falling in high categories respectively. The nutrient index values showed low for N (1.52) and medium for P (1.77), K (2.30) and Fe (2.32). Nutrient index values indicating high for S (2.87), Mn (3), Zn (2.57), Cu (3) and B (2.92). Kiran and Hundekar (2018) reported that nutrient index values, soils were predominantly low in available nitrogen (1.00), medium in available phosphorous (1.60) in Vijayapura. The soils of Indi taluk showing low in available N and medium in availability of P, K and Fe content while soils showing high content of S, Mn, Zn, Cu and B.

The per cent of soil samples falling in low, medium and high categories for different nutrients and the calculated values of nutrient indices for (Sindagi taluk) is presented in Table 5 and Figure 2. It is apparent from the data that among macronutrient N and P, and among micronutrient B showed 36 and 60 and 8 per cent soil samples were low respectively. The N, P, K, Fe, Zn and B find 64, 32 and 68 per cent 92, 36 and 32 per cent soil samples were in medium categories, respectively. In case of P, K, S, Fe, Mn, Zn, Cu and B showed 8, 32, 100, 8, 100, 64, 100 and 60 per cent soil samples were fall in high categories, respectively. For macronutrient N and P nutrient index value is 1.64 (L) and 1.48 (L), respectively. Whereas nutrient index for K is 2.32(M), Fe is 2.08(M), indicated as medium. Nutrient index showed high for S is 3(H), Mn is 3(H), Zn is 2.64(H), Cu is 3(H) and B is 2.52(H). These were categories based on according to Ramamoorthy and Bajaj (1969), NI value less than 1.67 indicated low fertility status, while between 1.67 to 2.33 as medium as and more than 2.33 was rated as high. The Sindagi taluk soils showing low in availability N, P and B and medium in available K and Fe, while high in availability of S, Mn, Zn, Cu and B.





The leaf nutrient status stated the average nutrient concentration of N, P, Mg, Zn and B were marginally lower while that of Ca and Fe were marginally higher in low-yielding orchards of lime as compared to high yielding orchards. There is not much changes occurred in K, S and Mn in between low and high yielding orchards. Significant differences between low and high yielding orchards were noted for the concentrations of all the nutrients except K, S, Cu and Mn. The high yielding orchards showed significantly higher N, P, Mg, Zn and B concentrations as compared to low yielding orchards showed in Figure 3 and 4.

5.1.2 Relationship between soil properties and soil extractable nutrients, soil properties and lime fruit yields, extractable soil nutrients and lime fruit yields

Soil pH had a significant and negative correlation with Olsen's P, Neutral 1N NH_4OAc exchangeable Ca (significant at $p = 0.01$), DTPA (pH 7.3) extractable Fe and hot water soluble B (significant at $p = 0.05$). Soil organic carbon content had a significant and negative correlation with Neutral 1N NH_4OAc extractable K (significant at $p = 0.01$) and Neutral 1N NH_4OAc extractable Mg (significant at $p = 0.05$). Simple correlation coefficients between soil properties and extractable nutrients content in soils are presented in Table 6. Lime fruit yield showed non-significant correlation with soil properties and lime fruit yields presented in Table 7. Lime fruit yields showed a significant and positive correlation with Neutral 1N NH_4OAc K, Hot water soluble B (significant at $p = 0.05$) and 0.15% CaCl_2 extractable S (significant at $p = 0.01$) presented in Table 8. Savita *et al.*, (2017) was also reported similar results that the soil pH had a significant and significant negative correlation with, Olsen's P, Neutral 1N NH_4OAc K, DTPA (pH 7.3) extractable Fe, (significant at $p = 0.01$). Savita *et al.*, (2017) also confirm similar result that the litchi fruit yields showed a significant and positive correlation with Neutral 1N NH_4OAc K (significant at $p = 0.05$).

5.2 Leaf nutrient status of lime orchards

The leaf nutrient concentration in lime were analyzed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B using standard procedure. Mean values of macronutrients N, P, K, Ca, Mg and S were 1.29, 0.74, 1.04, 1.26, 0.42 and 0.33 per cent respectively, whereas mean values of micronutrients Fe, Mn, Zn, Cu and B were 32.35, 2.16, 28.4, 5.66 and

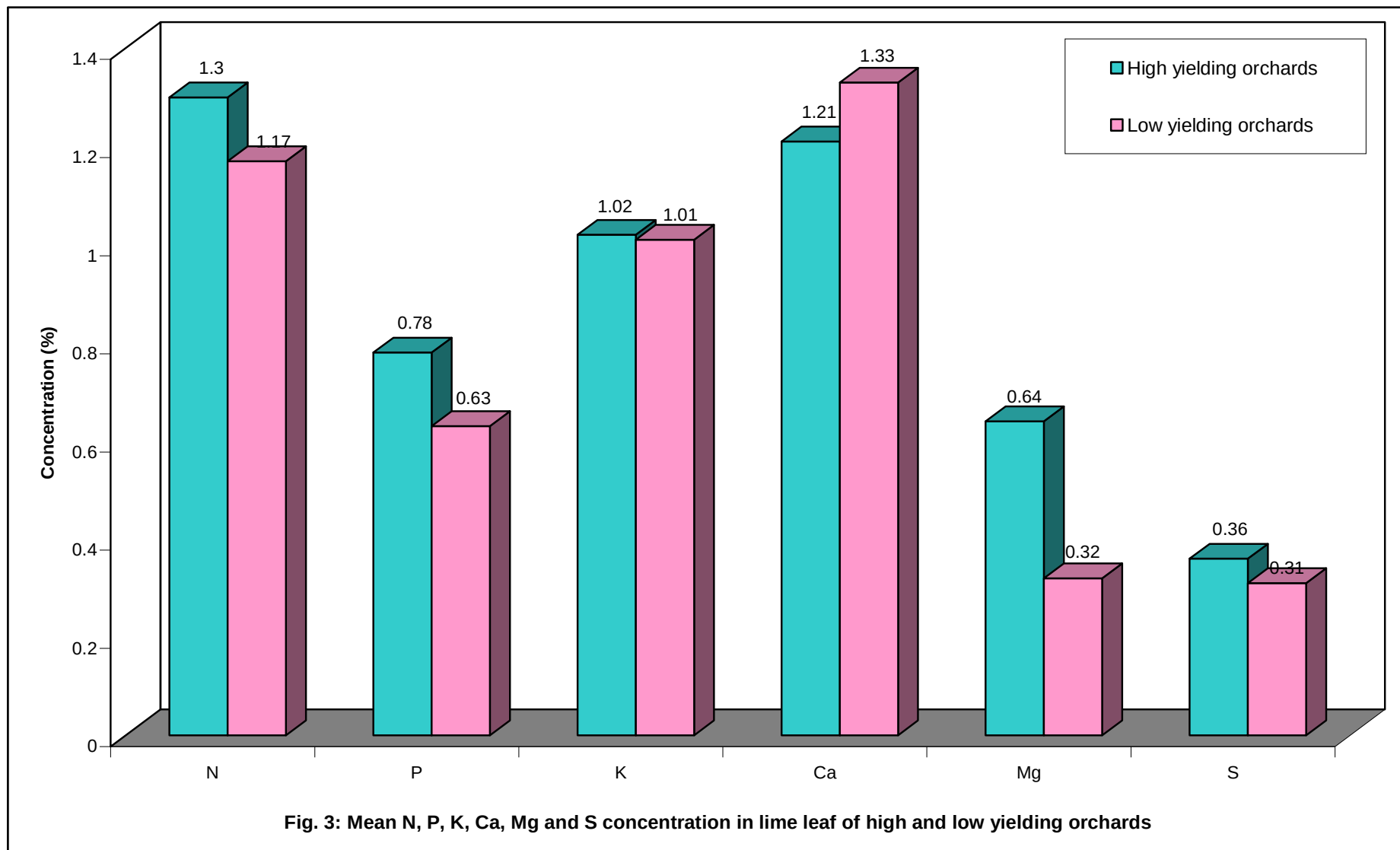
98.55 $\mu\text{g g}^{-1}$ respectively presented in Table 9. There is wide variations presence among the leaf nutrient concentration of different lime orchards representing the influence of different management systems. Since, there existed a large variation among orchards in terms of soil fertility status, sources of fertilizer and quantity of fertilizer applied, irrigation methods and other cultural operations such varied differences in leaf nutrients concentrations of different orchards were expected. Similar wide variations had been reported by Bhargava (2002) in grapes, Srivastava and Singh, 2004 in citrus orchards. The difference noted in leaf N concentration was quite high as compared to P and K which might be due to the fact that N being a structural component of proteins, amino acids and all membranes was probable to be higher in plant tissues with larger proportions of living cells (Clarkson and Hanson, 1980). Nutrient elements like P do not store in mature leaves, but are shifted via the phloem and by xylem to the growing points (Guha and Mitchell, 1966). Raghupathi and Bhargava (1999) reported similar wide variations in nutrient concentrations when survey approach was adopted for developing data bank of nutrient concentrations in mango orchards. Simple correlation analysis was performed between plant nutrient content of lime and fruit yields are presented in Table 12. Fruit yield showed a highly significant and positive correlation with P and Mg concentration in lime.

5.2.1 Leaf nutrients status of high and low yielding lime orchards

The mean of leaf macronutrients concentration in high yielding lime orchards were, N (1.3 %), P (0.78 %), K (1.02 %), Ca (1.21 %), Mg (0.64 %) and S (0.36 %), whereas total micronutrients Fe (31.94 $\mu\text{g g}^{-1}$), Mn (27.49 $\mu\text{g g}^{-1}$), Zn (19.65 $\mu\text{g g}^{-1}$), Cu (5.53 $\mu\text{g g}^{-1}$) and B (95.51 $\mu\text{g g}^{-1}$) presented in Table 10 and Figure 3.

In low yielding lime orchards followed same trend of leaf nutrients concentration. The mean of macronutrient in low yielding lime orchards were, N (1.17 %), P (0.63 %), K (1.01 %), Ca (1.33 %), Mg (0.32 %) and S (0.31 %), whereas total micronutrients Fe (32.47 $\mu\text{g g}^{-1}$), Mn (27.68 $\mu\text{g g}^{-1}$), Zn (7.89 $\mu\text{g g}^{-1}$), Cu (5.13 $\mu\text{g g}^{-1}$) and B (76.71 $\mu\text{g g}^{-1}$) presented in Table 11 and Figure 4.

The differences in concentrations of different nutrient elements in high and low yielding orchards were only marginal. Only the concentration of Ca, Fe and Mn were marginally lower while that of N, P, K, Mg, S, Zn, Cu and B were marginally higher in



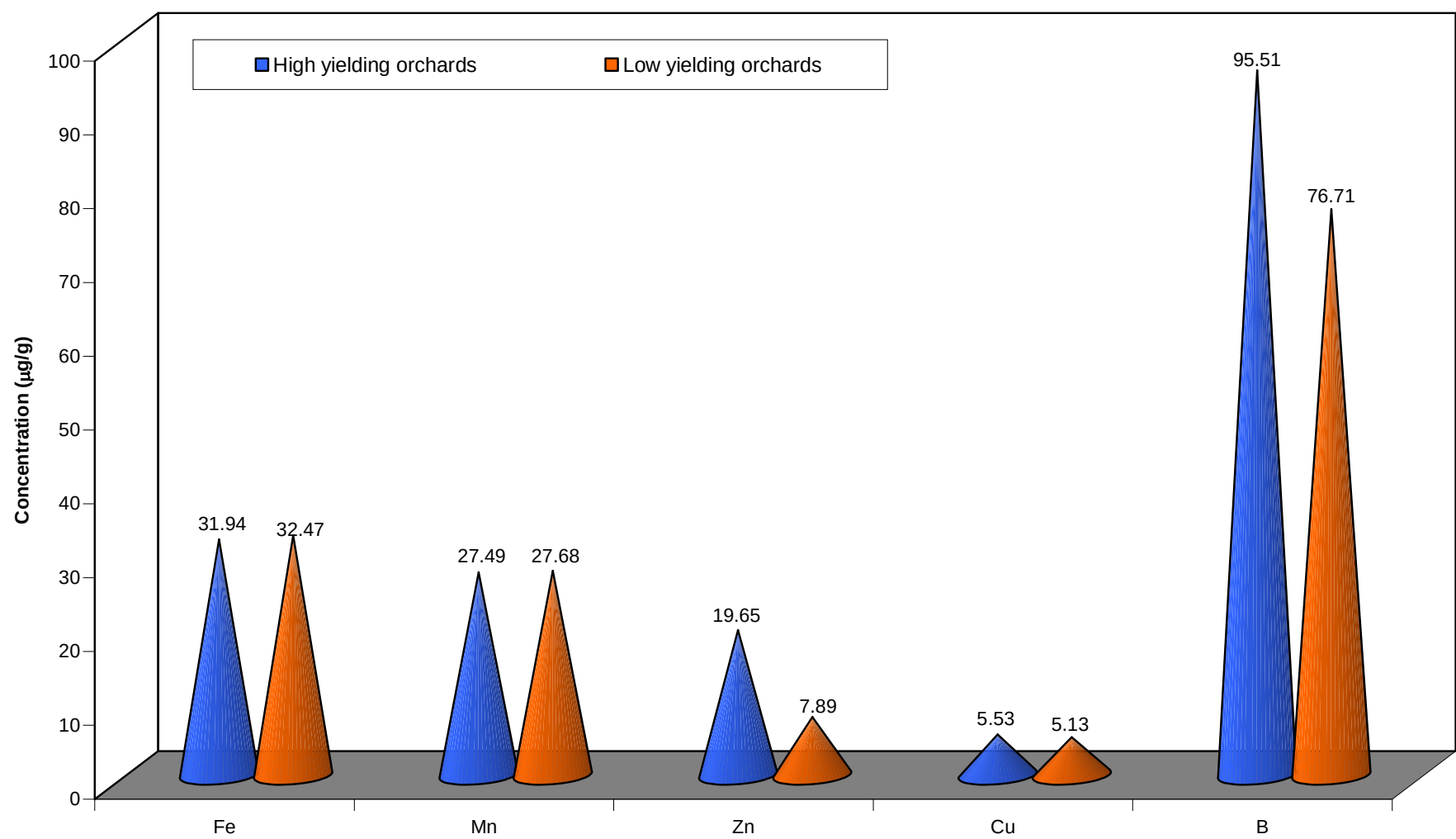


Fig. 4: Mean Fe, Mn, Zn, Cu, and B concentration in lime leaves of high and low yielding orchards

high yielding as compared to low-yielding orchards (Figure 3 and 4). The presence of higher concentration of most essential elements in the high yielding orchards showed that these nutrients might have directed the yield and growth attributes of lime to a larger extent. Since the samples were essentially collected from the orchards on soils rich in free Ca carbonate, the differences in Ca concentration between the two sets were more apparent (Fig 3 and 4). Higher concentration of essential elements in high yielding orchards as compared to low yielding orchards had also reported by Hundal and Arora (2001) in kinnow fruit, Raghupathi *et al.* (2004) in mango and Anjaneyulu (2007) for papaya

5.3 DRIS ratio norms in lime

In the present investigation, 55 nutrient expressions were chosen as diagnostic norms after separating the entire population into high and low yield classifications taking 1500 fruits/tree/year as the cut-off yield placed in such a manner that the high yielding population (54 out of 85 orchards) reflected circumstances considered desirable (Beaufils, 1973). Letzsch and Sumner (1984) also stated that, as long as it was not too small, the real cut-off value had little impact on the development of norms. In Table 13, together with their coefficient of variation in lime, a total of 55 nutrient ratio expressions used as diagnostic norms from the high yielding population are provided. Ideally, it was noted that for greater diagnostic accuracy, a specific nutrient ratio to be selected as a norm should have a high variance ratio and a low coefficient of variation (Raghupathi *et al.*, 2013).

The important nutrient ratio expressions were: K/N (0.79), Ca/N (0.94), N/S (3.28), Fe/N (24.66), Mn/N (21.22), Cu/N (4.29), Ca/K (1.25), K/S (2.94), K/Cu (0.19), Ca/S (3.52), Ca/Cu (0.23), S/Mg (0.59), Cu/Mg (9.21), S/Fe (0.01), Mn/Fe (0.89), Fe/Cu (5.81), and Mn/Cu (5.07) etc. This showed a lowest coefficient of variation relative to others. The significant nutrient expressions containing N were: Ca/N (0.94), N/Mg (2.22), N/S (3.82), Fe/N (24.66), Mn/N (21.22), and Cu/N (4.29).

The other important ratios involving K was: Ca/K (1.25), K/Mg (1.71), K/S (2.94), Fe/K (32.99) K/Cu (0.19) and B/K (99.57). The ratios of important ratios involving Ca were: Ca/S (3.52), Ca/Cu (0.23), Ca/B (0.01), for magnesium S/Mg (0.59),

Cu/Mg (9.21), for sulphur S/Fe (0.01), Mn/s (80.29), Cu/S (16.11), for iron Mn/Fe (0.89), Fe/Cu (5.81), Fe/B (0.35), and Mn/Cu (5.07), Mn/B (0.30) and Cu/B (0.06) from the physiological point of perspective, they were equally essential. The co-efficient of variation (CV) ranged from the lowest of 18 per cent for Cu/N to the highest of 73 per cent for B/Zn. Indicating greater variability in absolute concentration in the high yielding population.

The nutrient ratios that had a lowest coefficient of variation with a high variance ratio were more critically associated to yield than the nutrient ratios that had a low variance ratio and high coefficient of variation. These nutrient ratio norms have been developed as derived for grapes (Bhargava, 2002), banana (Angeles *et al.*, 1993) and mango (Raghupathi *et al.*, 2004).

5.3.1 DRIS indices and nutrient imbalance index (NII) for lime

A DRIS index is an average of ratio deviations that contain a specified nutrient from their ordinary or optimal values respectively. Thus, in the form of indices, DRIS provides a way to order nutrient ratios into meaningful expressions. The comparative abundance of each nutrient was thus assessed by comparing all the ratios comprising that nutrient with the DRIS norms (Beaufils, 1973).

Table 14 shows the DRIS indices. The nutrients are arranged in the order of significance in which limiting the yield. Simultaneously, DRIS recognized and ranked plant nutrient imbalances, deficiencies and excesses in order of significance (Walworth and Sumner, 1987). Before averaging, as the value of each ratio function was added to one index, subtotal and subtracted from another, all indices were balanced by zero.

Depending on the magnitude of the indices, the order in which distinct nutrients limit yields may also be stated. The nutrient index near to zero or zero indicates optimum level of that nutrient in leaf concentration, Negative values indicate relative deficiencies and positive values indicate relative nutrient sufficiency of particular nutrient. Nutrient imbalance index is the sum of indices of DRIS, regardless of the sign in each low yielding orchard. Higher the nutrient imbalance index (NII) more nutrients are imbalance and lower the yield whereas, lower the nutrient imbalance index (NII) lesser nutrients imbalance and higher the yield. Sometimes it is very difficult to decide

yield based on crop age young trees more responsive to fertilizer application than older. However, the mean percentage reaction over control varied based on the type of nutrient and the tree age by Raj and Rao (2006). Among 31 low yielding lime orchards the orchards 70, 75, 67 and 64 recorded highest NII as 253, 270, 278 and 337 respectively, that these orchards are more imbalanced than other orchards 56, 5 and 13 and 12 which recorded lower NII as 70, 86, 110 and 113 respectively. Simple correlation worked out between nutrient imbalance index and fruit yield showed significant and negative correlation ($r = -0.277$). Similar results were reported Raghupathi *et al.* (2013) in Coorg mandarin. Srivastava and Singh (2007) also reported a significant reduction in NII due to correction of yield limiting nutrients in Nagpur mandarin.

The orchard No.56, which showed the lowest NII of 70 had an index of B (-10), Mg (-9), Zn (-8), and P (-7) the yield limiting nutrients in decreasing order were $B > Mg > Zn > P$. The orchard no.64, showed the highest NII of 337 had an index of Mg (-156), Zn (-8) and P (-4) the yield limiting nutrients in decreasing order were $Mg > Zn > P$. Simultaneously, DRIS recognized and ranked plant nutrient imbalances, deficiencies and excesses in the order of significance (Walworth and Sumner, 1987). Since the value of each coefficient feature was added to one index subtotal and subtracted from another before to averaging, all indices were balanced by zero.

The nutrients were arranged in the order of significance in which the yield was limited. In particular, though some of the nutrients were more prominent, the yield limiting nutrients varied from orchard to orchard. Diagnosis of nutrient imbalance through DRIS indices stated that in low yielding orchards, Mg was the most yield limiting nutrient among major nutrients. The DRIS indices also stated that only in certain orchards, P and S limited yield. Zn, B and Fe were discovered to be the most yield-limiting nutrients in various lime orchards among the micronutrients.

In general among macronutrient order of limiting nutrient in decreasing order were Mg followed by P and S whereas among micronutrient Zn followed by B and Fe. Similarly, Hundal *et al.* (2007) also reported using DRIS yield limiting nutrient were Mg followed by S and Ca. The low micronutrient content in many orchards could be attributed to the high pH, with high Ca carbonate content resulting in low micronutrient availability. Mg was thus discovered to be the most dominant yield-

limiting nutrient in the major nutrients followed by micronutrients like Zn, B and Fe. Similar results were reported that the diagnosis of nutrient imbalance through DRIS indices stated that S followed by Zn and B were discovered to be the most yield-limiting nutrients in fruiting terminals of litchi (Savita *et al* 2017). The norms established by Savita and Anjaneyulu (2008) for sapota through DRIS stated that Zn and B were the prevalent deficient nutrient component. Also the most limiting nutrients in the plum were B followed by Zn (Disha *et al.*, 2012). In Coorg mandarin Raghupathi *et al.* (2013), DRIS recognized Zn and Mg as the most yield-limiting nutrients.

5.4 Leaf nutrient standards for lime

For plant nutrients, optimum ranges were established based on mean concentrations of nutrients and standard deviation (SD) from high yielding population. Table 15 presents the concentrations of nutrients categorized as deficient, low, optimum, high and excessive in lime based on the DRIS principle (Bhargava and Chadha, 1993).

The optimum leaf nutrient concentration for macronutrients N, P, K, Ca, Mg and S ranged from 1.14 to 1.30, 0.45 to 0.78, 0.67 to 1.02, 0.84 to 1.21, 0.39 to 0.64 and 0.25 to 0.36 per cent respectively. The optimum K ranged from 0.67 to 1.02 per cent and K's necessity has always been close to nitrogen alone, as it involves not only the manufacturing but also the improvement of lime quality. The leaf K concentrations less than 0.30 per cent and more than 1.39 per cent were considered as deficient and excess, respectively. If K concentration exceeded the upper limit/excess, physiological disruption in relation to Mg and Ca was probable to be induced.

The optimum level of Ca ranged from 0.84 to 1.21 per cent. Compared to primary nutrients, calcium concentration in lime leaves was greater, indicating elevated root activity and appropriate absorption of Ca from a soil wealthy in Ca content. Similarly, in the papaya plant, which has a constant flowering habit, Anjaneyulu (2007) reported greater Ca concentration. Therefore, it emerged that to a big extent fresh flushes and flowering pattern controlled the Ca concentration in lime.

The optimum Mg ranged from 0.39 to 0.64 per cent. Savita *et al.* (2017) noticed a similar range for Mg in litchi. The leaf Mg concentration of less than 0.13 per cent and more than 0.91 per cent were considered as deficient and excess respectively. The similar optimum Mg range had presented in cotton by Dhanwinder *et al.* (2012). Compared to other fruit crops, the sulfur concentration was relatively lower and the optimum S concentration ranged from 0.25 to 0.36 per cent. Similarly, Anjaneyulu (2006) reported S concentration in rose crop.

Optimum leaf nutrient concentration for micronutrients Fe, Mn, Zn, Cu and B ranged from 21.63 to 31.94, 18.35 to 27.49, 11.24 to 19.65, 4.46 to 5.53 and 65.18 to 95.51 $\mu\text{g g}^{-1}$ respectively. The optimum Mn and Cu concentrations ranged 18.35 to 27.49 $\mu\text{g g}^{-1}$ and 4.46 to 5.53 $\mu\text{g g}^{-1}$, respectively. Similar results for Mn and Cu were also been reported in sapota by Anjaneyulu (2007).

Sufficiency range of Zn was 11 to 19 $\mu\text{g g}^{-1}$ observed in mango by Hundal *et al.* (2005). Nutrient sufficiency ranges obtained from DRIS norms S were 0.18–0.28% in guava by Hundal *et al.* (2007). Nutrient sufficiency ranges for cotton crops for Cu were obtained from DRIS norms 5 to 8 $\mu\text{g g}^{-1}$ presented by Dhanwinder *et al.* (2012). Hanlon *et al.* (1995) recorded comparable results from the spring flushes (4–6 months old) for mature citrus trees for B in non-fruiting shoot leaves.

5.5 Classification of low yielding orchards

Based on leaf nutrient norms in lime, low-yielding orchards were classified and the values are presented in Table 16 and Figures 5. The orchard classification stated that N and P were significant yield limiting nutrients; leaf N was optimal in 61 per cent of the orchards and low in 13 per cent of the orchards. On the other hand, 61 per cent of the orchards were optimal in P while the incidence of low P in none of the orchards was recorded. Soil availability of nitrogen and phosphorous is also indicating low. Leaf K was optimum in 39 per cent orchards and the incidence of high K was recorded only in 39 per cent of the orchards. There was sufficient available potassium in soil showed.

Secondary nutrient like Ca indicating 10 per cent optimum and 58 per cent high, soils were usually high in calcium content. Mg is the most yield limiting nutrient as it showed 13 and 65 per cent leaf samples deficient and low only 10 per cent samples

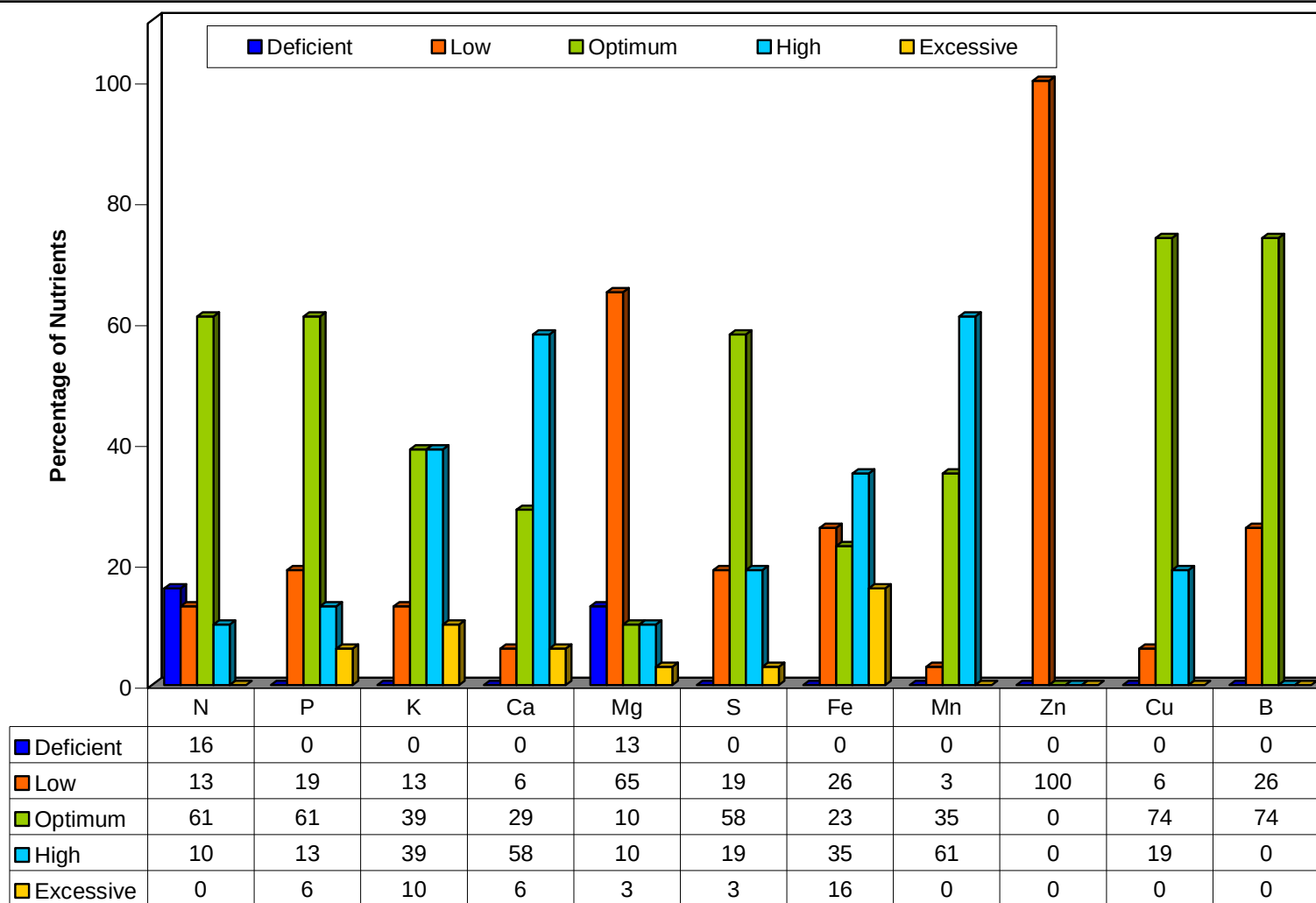


Fig. 5: Classification of low-yielding lime orchards (%) based on leaf nutrients norms

showing optimum. Sulphur was showed 19 per cent low and 58 per cent optimum. None of the micronutrients showing deficient but 26, 3, 100, 6 and 26 per cent Fe, Mn, Zn, Cu and B respectively. Among micronutrient Zn was 100 per cent samples indicating low so, it is the most yield limiting nutrient. The Zn concentration in low yielding orchards of lime ranges from 10.51 to 6.16 $\mu\text{g/g}$ with mean value is 7.89 $\mu\text{g/g}$, whereas, Zn concentration ranges from 2.81 - 11.23 $\mu\text{g/g}$ based on leaf nutrient norms classification comes under low category. Therefore, Zn was low in 100 per cent of orchards. Both of each Cu and B 74 per cent samples were optimum. Iron indicating 16 per cent samples excessive. However P, K, Ca and S were found to be excessive in few orchards. Anjaneyulu (2007) also reported similar classification for papaya.

Study stated that Mg followed by P and S were the most yield-limiting nutrients in lime orchards among macronutrients and Zn followed by B, and Fe among micronutrients. It is possible to formulate the type and amount of fertilizer to be applied based on the indices obtained, the soil fertility status, and the management levels of the lime fruit trees. The optimum ranges of nutrients created can serve as a guide for a fast and routine diagnostic and advisory purpose for the lime orchard district of Vijayapura, Karnataka.

6. SUMMARY AND CONCLUSIONS

A study was conducted during the period of 2018-19 in Indi and Sindagi taluk of Vijayapura districts, where lime is widely cultivated. The leaf and soil samples were collected from 85 orchards to establish the nutrient concentration and fruit yield database for assessment of yield limiting nutrients in low yielding orchards. Diagnosis and Recommendation Integrated System (DRIS) was used to interpret the leaf nutrient status. This section summarizes the significant results of this investigation.

- The soil pH ranged from 7.2 to 8.52 with a mean value of 8.01 (1:2.5 soil water suspensions). These soils electrical conductivity ranged from 0.13 to 1.87 dSm⁻¹ with average of 0.36 dSm⁻¹ in 1:2.5 soil water suspensions. These soils organic carbon content ranged from 0.50 to 1.13 per cent.
- The alkaline KMnO₄ hydrolysable N, Olsen's P and Neutral 1N ammonium acetate (NH₄OAc) K of soils ranged from 75.44 to 589.74, 4.38 to 54.43 and 148.39 to 356.91 kg ha⁻¹, respectively. The Neutral 1N NH₄OAcCa and Mg ranged from 15.53 - 28.58 and 3.18 - 16.60 cmol(P⁺) kg⁻¹ soil, respectively. The CaCl₂ (0.15%) extractable S content of soil varied from 11.33 - 74.00 mg kg⁻¹ with a mean of 40.42 mg kg⁻¹.
- The status of DTPA extractable Fe, Mn, Zn and Cu in soils ranged from 4.64 to 14.27, 7.50 to 40.00, 0.71 to 2.20 and 3.02 to 8.80 mg kg⁻¹, respectively. Hot water-soluble B in soils ranged from 0.18 to 1.66 mg kg⁻¹ with a mean value of 0.70 mg kg⁻¹.
- As per the calculated values of nutrient index value, soils of lime orchards of Indi taluk were low in N, medium in P, K and Fe and high in S, Mn, Zn, Cu and B. The soils of lime orchards of Sindagi taluk were low in N and P, medium in K and Fe and high in S, Mn, Cu, Zn and B.
- Simple correlation was carried out between soil properties and extractable soil nutrients. The pH of the soil had a significant and negative correlation with Olsen P, DTPA (pH 7.3) extractable Fe and Hot water soluble B. The pH of the soil was

highly significant but negative correlation with Neutral 1N NH_4OAc Ca whereas, organic carbon content was highly significant and negative correlated with Neutral 1N NH_4OAc K and significant and negative correlated with Neutral 1N NH_4OAc Mg.

- Fruit yields of lime tree ranged from 300 to 4200 fruits/tree/year with a mean fruit yield of litchi of 1661fruits/tree/year. Lime fruit yields showed a non-significant correlation with soil properties. Fruit yields also showed a significant and positive correlation with Neutral 1N NH_4OAc K and Hot water soluble B and highly significant and positive correlation with 0.15% CaCl_2 extractable S.
- The concentration of lime leaf nutrients in the entire population (n=85) ranged from 0.71 to 1.74, 0.22 to 1.42 and 0.53 to 1.89 per cent respectively for N, P and K. Concentrations of Ca, Mg and S in leaves ranged from 0.70 to 2.0, 0.10 to 1.26 and 0.13 to 0.95 per cent respectively. Leaf concentrations of Fe, Mn, Zn, Cu and B ranged from 6.79 to 120.21, 0.37 to 4.91, 7.08 to 39.66, 2.31 to 13.74 and 44.93 to 146.95 $\mu\text{g g}^{-1}$ respectively among micronutrients.
- The leaf nutrient concentrations of the high yielding orchards of lime (n=54) ranged from 0.97 to 1.74, 0.3 to 1.27 and 0.53 to 1.89 per cent respectively for N, P and K. Leaf concentrations of Ca, Mg and S ranged from 0.70 to 2.0, 0.35 to 1.12, and 0.2 to 0.75 per cent respectively. Leaf concentrations ranged from 18 to 51, 7.08 to 44, 3.82 to 29.6, 3.91 to 7.1 and 44.93 to 135.52 $\mu\text{g g}^{-1}$ respectively for Fe, Mn, Zn, Cu and B among micronutrients.
- The leaf nutrient concentrations of the low yielding orchards of lime (n=31) ranged from 0.71 to 1.41, 0.22 to 1.36 and 0.54 to 1.70 per cent respectively for N, P and K. Leaf concentrations of Ca, Mg and S ranged from 0.70 to 1.8, 0.10 to 0.94, and 0.16 to 0.71 per cent respectively. Leaf concentrations of Fe, Mn, Zn, Cu and B ranged from 12.29 to 67.45, 12.92 to 34, 6.16 to 10.51, 4.06 to 6.17 and 40 to 92.19 $\mu\text{g g}^{-1}$ respectively among micronutrients.
- The leaf nutrient status stated the average nutrient concentration of N, P, Mg, Zn and B were marginally lower while that of Ca and Fe were marginally higher in low-yielding

orchards of lime as compared to high yielding orchards. There is not much difference noticed in K, S and Mn in between low and high yielding orchards.

- Significant differences between low and high yielding orchards were noted for the concentrations of all the nutrients except K, S, Cu and Mn. The high yielding orchards showed significantly higher N, P, Mg, Zn and B concentrations as compared to low yielding orchards.
- Fifty-five nutrient expressions were chosen from the high yielding population as DRIS ratio standards in the current investigation and were discovered to provide statistically significant variance ratios and lower coefficient variation.
- The significant expressions of the nutrient ratio in lime were: Ca/N (0.94), N/S (3.28), Fe/N (24.66), Mn/N (21.22), Cu/N (4.29), Ca/K (1.25), K/S (2.94), K/Cu (0.19), Ca/S (3.52), Ca/Cu (0.23), S/Mg (0.59), Cu/Mg (9.21), S/Fe (0.01), Mn/Fe (0.89), Fe/Cu (5.81), and Mn/Cu (5.07) etc. These ratios as compared involving macro- and micro-nutrients showed a lower co-efficient of variation relative to others and therefore may have a higher physiological rationale.
- Diagnosis of nutrient imbalance for macronutrient through DRIS indices stated that the most yield-limiting nutrients were discovered to be Mg followed by P, and S. Among the most prevalent yield-limiting micronutrients Zn followed by B and Fe. The DRIS indices also stated that N, K and Cu limited yield only in some orchards. The yield restricting nutrients varied from orchard to orchard though some of the nutrients were more common.
- An additional index called the "nutrient imbalance index" (NII) ranging from 70 to 337 was derived by the complete sum values of the nutrient indices regardless of sign. Higher the NII, the higher the plant nutritional imbalance would result in the lower yield. Among the 31 low yielding orchards, the orchards (no. 64, 67 and 75) which recorded higher NII (337, 278 and 270) were having more imbalance as compared to the orchards (no. 13, 5 and 56), which recorded lower NII (110, 86 and 70). In the present investigation, NII in lime showed a non-significant negative correlation with yields.

- Five nutrient ranges/standards were obtained as deficient, low, optimal, high and excess for each nutrient by using mean and standard deviation. The optimum leaf N in lime ranged from 1.14 to 1.3 per cent, P from 0.45 to 0.78 per cent and K from 0.67 to 1.02 per cent. For secondary nutrients, the optimum concentrations in lime for Ca ranged from 0.84 to 1.21 per cent, for Mg 0.39 to 0.64 per cent and for S 0.25 to 0.36 per cent. Likewise, the optimum levels of Fe, Mn, Zn, Cu and B in lime ranged from 21.63 to 31.94, 18.35 to 27.49, 11.24 to 19.65, 4.46 to 5.53, and 65.18 to 95.51 $\mu\text{g g}^{-1}$, respectively.
- The classification of orchards based on leaf nutrient norms in lime stated that Mg was the most yield-limiting nutrient as leaf Mg was optimal only in 10 per cent of orchards and low in 65 per cent of orchards and deficient in 13 per cent. On the other side, 61 per cent of the orchards in P were optimal and 13 per cent low. Sulfur content low in 19 per cent and optimum in only 58 per cent of the orchards. Among major yielding limiting micronutrients were Zn, B and Fe as Zn was low in 100 per cent of orchards, while Fe and B were optimum only in 23 and 74 per cent of the orchards, respectively.
- DRIS norms obtained from this research have been shown to be reliable information tool to diagnose nutrient imbalances in the lime orchards of Vijayapura. DRIS's diagnosis of yield limiting nutrients stated that the most prevalent yield-limiting nutrients for lime were Mg, P and S for macronutrient and Zn, B and Fe for micronutrient.

CONCLUSION

Based on the current investigation, it is concluded that

- As per the calculated nutrient index values, soils of lime orchards of Indi were low in N, medium in P, K and Fe and high in S, Mn, Zn, Cu and B. The soils of Sindagi were low in N and P, medium in K and Fe and high in S, Mn, Cu, Zn and B.
- The leaf nutrient status indicated that the mean nutrient concentration of N, P, Mg, Zn and B was marginally lower while that of Ca and Fe was marginally higher in low-yielding lime orchards as compared to high yielding orchards. There are not much

change occurred in nutrient concentration of K, S and Mn in between low and high yielding orchards.

- The diagnosis of nutrient imbalance through DRIS indices indicated that Mg is most yields limiting nutrient followed by P and S, whereas among the micronutrients most yield-limiting nutrients were, Zn, followed by B and Fe in the low yielding lime orchards.

Thus, DRIS is the holistic approach which identified nutrient imbalances in lime and therefore, proved to be an important technique for evolving nutrient management strategies for realizing higher yields. Furthermore, DRIS approach was better than single nutrient methods in the treatment of nutrient imbalances in lime production. The optimum nutrient ranges can serve as a guide for the routine diagnosis and advisory purpose for the lime grower of Vijayapura district, Karnataka.

Practical utility of DRIS

- Diagnosis can be made over a wide range in stages of crop development, irrespective of cultivar.
- The optimum ranges of nutrients created can serve as a guide for a fast and routine diagnostic and advisory purpose of lime orchardist.
- The nutrients limiting yield either through excess or insufficiency can be readily identified and arranged in order of their limiting importance on yield.

Future line of work

- For better theoretical basis further improvement in foliar diagnosis like CND, DOP and PAAS are needed to be done.

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Appendix I: Details of lime growers along with latitude, longitude and fruit yield (n=85)

Sample No.	Farmer Name	Fruits/tree/year
1	Vittal badiger, Bandal	2500
2	Vittal badiger, Bandal	1200
3	Mallappa k Talawar, Bandal	4000
4	Sanganna M Badiger, Bandal	1500
5	Siddappa M Yalameli, Bandal	980
6	Siddappa M Yalameli, Bandal	1550
7	Khaza Huseni M Mulla, Bandal	3000
8	Mahibub I Mulla, Bandal	4000
9	Khanband Mulla, Bandal	2500
10	Sharanappa S Devarmani, Bandal	500
11	Gollalappa S Devarmani, Bandal	400
12	Gollalappa S Devarmani, Bandal	1600
13	Sharanappa B Tappaladoddi, Ganihar	1100
14	Sharanappa B Tappaladoddi, Ganihar	1700
15	Dyamagond Gollalappa, Ganihar	2500
16	Dyamagond Gollalappa, Ganihar	1600
17	Zakhir Angadi, Ganihar	1700
18	K K Natikar, Ganihar	2500
19	K K Natikar, Ganihar	400
20	Raju Uppin, Sindagi	1500
21	Shivaling Bammanajogi, Bandal	1200
22	Sharanabasu R Udachan, Bandal	1600
23	Irayya C Hiremath, Bandal	400
24	Basayya C Hiremath, Bandal	2000
25	Muttu Biradar, Bandal	1500
26	Ashok S Arjunagimath, Indi	3000
27	Ashok S Arjunagimath, Indi	3000
28	Yogiraj Patil, Indi	1250
29	Kallappa B Tamberi, Indi	2000
30	Ashok V sivoor, Indi	1500
31	Jatyappa Narale, Indi	2000
32	Ramaningappa Uppar, Roogi	1600

33	Basappa N Uppar, Roogi	1650
34	Ramaningappa Uppar, Roogi	2250
35	Tulajaram Uppar, Roogi	300
36	M L Gundagi, Roogi	2000
37	Bhimashankar Gundagi, Roogi	2000
38	Bhimashankar Gundagi, Roogi	2500
39	Sharanappa Gundagi, Roogi	2500
40	Duryodhan chavan, Roogi	1000
41	Srishail Salotagi, Roogi	1000
42	S B Kottennavar, Bolegav	2000
43	S B Kottennavar, Bolegav	1600
44	S B Kottennavar, Bolegav	3000
Sample No.	Farmer Name	Fruits/tree/year
45	Hanamanthray B Mirji, Tadavalaga	800
46	Muttappa M Tenyalli, Tadavalaga	2000
47	Revanasiddappa T Talawar, Tadavalaga	4000
48	Revanasiddappa T Talawar, Tadavalaga	4200
49	Hiliyalapa N Surpur, Tadavalaga	1800
50	Siddappa N Surpur, Tadavalaga	2000
51	Shivanna L Poojari, Indi	3000
52	Shivanna L Poojari, Indi	3500
53	Shivanna L Poojari, Indi	3000
54	Shivanna L Poojari, Indi	3000
55	Shantappa S Biradar, Indi	700
56	Shantappa S Biradar, Indi	700
57	Annaray R Bagali, Chikkabenur	600
58	Dr. S A Biradar, Indi	400
59	Dr. S A Biradar, Indi	400
60	Rvutappa I Male, Chikkabenur	1580
61	Nagappa I Male, Chikkabenur	1500
62	Chandappa L Malgar, Chikkabenur	1400
63	Vitoba B Manth, Chikkabenur	700
64	Kanteppa A Maitri, Indi	1000
65	Kanteppa A Maitri, Indi	400
66	Sangappa S Biradar,	1600
67	Sangappa S Biradar, Chikkabenur	500
68	G S Biradar, Chikkabenur	1500
69	G S Biradar, Chikkabenur	1700
70	Shankrappa B Madarkandi, Chikkabenur	600
71	Shankrappa B Madarkandi, Chikkabenur	600
72	Dareppa Ganiger, Chikkabenur	1550
73	R C Biradar, Chikkabenur	980
74	Shankargoud C Biradar, Chikkabenur	500
75	Dareppa Sudam, Roogi	300
76	Dareppa Sudam, Roogi	300
77	Santhosh sudam, Roogi	600
78	Santhosh sudam, Roogi	1600

79	Mantesh Nagappa Kumbar, Indi	2000
80	Hanamanth Hanjagi, Indi	2000
81	Hanamanth Hanjagi, Indi	3000
82	Indi road-1, Indi	1600
83	Indi road-2, Indi	1500
84	Indi road-3, Indi	1600
85	Indi road-4, Indi	1200

Appendix II: Soil properties and nutrients status of the entire population of lime orchards of Vijayapur District (n=85)

Sample	pH	EC	O C (%)	avail. N (kg/ha)	Olsen's.P (kg/ha)	K (kg/ha)	Exch. Ca (cmol(P ⁺)/kg)	Exch. Mg (cmol(P ⁺)/kg)	Avail. S (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	B (mg kg ⁻¹)
1	8.52	0.38	0.65	345.1	8.6	297.9	18.95	9.48	31.05	5.42	20.32	1.40	3.26	0.34
2	8.44	0.35	0.72	263.6	6.6	270.2	16.70	8.10	29.71	7.86	17.22	0.79	4.18	0.24
3	8.30	0.42	0.90	345.1	9.5	294.5	17.38	9.70	50.77	5.51	21.90	1.52	6.98	0.30
4	8.28	0.34	0.78	313.8	11.2	286.8	16.15	11.03	30.05	9.06	19.58	0.85	5.80	0.18
5	7.80	0.42	0.62	188.3	8.3	260.1	19.63	7.80	28.71	7.23	16.00	0.74	3.34	0.89
6	8.17	0.37	0.70	263.6	9.9	282.8	15.63	8.78	27.37	6.28	16.00	1.34	5.46	0.77
7	8.42	0.37	1.07	370.2	17.3	245.1	18.78	9.33	46.76	7.57	33.00	0.88	5.05	0.65
8	8.40	0.38	1.01	458.0	9.9	217.0	21.40	9.60	45.76	6.09	18.42	1.09	4.53	1.66
9	8.18	0.40	0.74	226.0	4.9	211.2	19.03	11.35	20.35	7.12	38.00	0.89	3.94	0.41
10	8.46	0.36	0.65	376.5	6.4	223.8	19.93	12.23	37.40	7.81	29.84	1.48	4.62	0.54
11	8.30	0.29	0.86	232.2	12.5	246.6	23.23	10.38	63.14	5.84	12.50	2.20	3.04	0.62
12	8.20	0.31	0.90	520.8	16.4	246.1	20.80	11.58	45.42	6.08	26.94	1.18	4.12	0.28
13	8.45	0.30	0.87	219.7	4.9	278.3	21.05	11.38	33.72	7.42	23.58	1.24	4.29	0.41
14	8.24	0.33	0.74	194.6	8.4	266.1	20.38	10.75	52.44	5.99	27.42	1.07	5.72	0.54
15	8.30	0.28	0.77	451.8	7.9	293.5	21.58	10.95	28.38	6.78	20.98	1.30	3.02	0.74
16	8.37	0.32	0.78	257.3	6.6	293.3	22.08	10.70	40.74	5.34	25.04	1.58	5.80	0.49
17	8.01	0.25	0.68	269.9	10.4	282.0	21.40	11.33	30.38	6.52	27.50	1.32	5.22	0.76
18	7.72	0.30	0.59	326.3	7.4	330.4	16.73	11.85	51.44	6.47	32.78	1.30	6.03	0.55
19	8.32	0.34	0.71	389.0	6.2	238.8	18.15	7.75	33.05	7.36	30.00	1.48	3.45	1.04
20	8.23	0.27	0.79	301.2	5.2	157.3	15.53	11.08	46.76	6.94	29.50	0.80	5.56	0.92
21	8.42	0.14	1.08	483.1	11.2	208.0	21.35	3.18	35.39	7.18	12.50	1.52	6.91	0.79
22	8.10	0.30	0.77	401.6	27.6	168.9	19.85	6.05	32.05	8.77	17.84	1.48	4.96	0.47
23	8.40	0.17	0.92	288.7	12.8	192.6	20.83	4.43	29.04	5.77	19.00	2.00	7.16	0.70

Sample	pH	EC	O C (%)	avail. N (kg/ha)	Olsen's.P (kg/ha)	K (kg/ha)	Exch. Ca (cmol(P ⁺)/kg)	Exch. Mg (cmol(P ⁺)/kg)	Avail. S (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	B (mg kg ⁻¹)
24	8.14	0.33	0.99	414.1	25.2	157.5	21.68	4.83	35.39	7.00	23.68	1.49	6.00	0.53
25	8.48	0.24	0.90	295.0	23.0	167.4	22.93	6.03	33.05	5.06	17.50	2.00	6.28	0.42
26	7.55	0.36	0.92	263.6	36.8	206.6	24.35	5.08	47.43	6.88	25.74	0.73	5.19	0.95
27	7.60	0.16	0.98	495.7	52.8	230.2	24.25	5.50	74.00	10.66	28.00	2.12	5.76	1.50
28	7.78	0.25	0.92	420.4	15.4	305.5	23.98	7.90	36.40	5.67	13.34	1.06	6.21	0.43
29	7.20	0.13	0.83	426.7	7.6	305.9	26.53	8.83	72.49	9.89	18.02	2.18	6.29	0.40
30	7.68	0.14	0.99	407.9	5.7	262.0	27.55	5.38	28.71	7.98	23.64	1.07	4.39	1.37
31	7.81	0.48	0.84	432.9	7.0	275.8	23.38	7.73	52.11	11.88	17.58	2.01	5.41	0.56
32	7.80	0.37	0.90	357.7	7.8	356.9	28.58	4.33	29.71	5.96	32.84	1.32	5.97	0.76
33	7.91	0.68	0.68	207.2	7.0	323.9	25.63	9.10	45.76	6.30	22.50	1.15	8.19	0.74
34	7.97	0.41	0.74	326.3	19.2	316.4	27.25	5.85	35.06	6.73	32.06	1.49	5.81	0.54
35	7.83	0.30	0.66	232.2	5.2	289.7	20.88	6.55	40.07	6.94	38.00	1.79	5.10	1.03
36	7.90	0.33	0.54	251.1	7.0	190.8	20.55	6.03	22.36	6.35	23.34	1.30	3.37	0.66
37	8.04	0.33	0.89	326.3	5.7	181.0	20.60	5.05	45.09	6.35	40.00	1.61	6.33	0.51
38	7.70	0.35	0.95	301.2	6.6	204.8	20.65	5.35	49.77	7.21	22.96	1.59	6.69	0.31
39	7.80	0.38	0.96	276.1	4.6	167.5	22.55	6.90	62.47	6.87	15.60	1.18	3.62	0.72
40	7.90	0.26	1.08	263.6	9.1	174.0	21.25	5.25	25.03	5.82	20.90	1.49	4.54	0.38
41	7.52	0.40	0.90	232.2	4.4	218.7	22.23	10.58	51.77	7.24	24.72	1.60	8.51	0.85
42	8.10	0.38	1.04	138.2	18.8	187.8	24.90	10.03	42.08	7.40	20.98	1.49	5.42	0.94
43	7.88	0.13	0.98	200.9	43.5	231.6	22.58	11.55	33.72	7.64	18.50	1.91	6.51	0.74
44	7.80	0.51	0.89	263.6	16.2	238.1	23.50	8.65	66.00	6.83	24.84	1.11	4.07	0.94
45	7.52	1.87	0.83	326.3	8.8	258.6	23.38	8.95	24.03	6.92	17.02	1.01	4.30	0.82
46	8.10	0.45	0.96	138.2	7.1	305.9	23.48	14.60	46.42	6.35	22.20	0.88	4.45	0.70
47	8.02	0.36	0.80	200.9	12.3	297.8	24.85	11.00	41.74	6.47	36.00	1.39	5.09	0.84

Sample	pH	EC	O C (%)	avail. N (kg/ha)	Olsen's.P (kg/ha)	K (kg/ha)	Exch. Ca (cmol(P ⁺)/kg)	Exch. Mg (cmol(P ⁺)/kg)	Avail. S (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	B (mg kg ⁻¹)
48	7.60	0.23	0.98	400.0	20.0	326.9	23.10	14.00	72.83	12.00	38.00	2.20	6.80	1.50
49	8.27	0.16	0.62	138.2	7.6	271.0	23.20	7.00	39.74	6.52	25.48	1.08	5.44	0.70
50	7.80	0.50	0.59	200.9	6.6	300.7	24.30	12.70	13.00	8.76	28.66	1.23	4.80	0.90
51	7.95	0.53	0.51	389.0	54.4	281.8	23.93	11.25	46.42	9.15	21.92	1.90	5.87	0.81
52	7.70	0.80	0.72	200.9	28.5	288.4	20.35	9.98	62.00	7.40	26.66	1.45	7.14	0.93
53	8.01	0.32	0.63	263.6	26.4	288.5	19.85	8.48	69.82	11.76	22.06	1.89	6.73	0.82
54	7.72	0.32	1.02	301.2	18.8	195.6	19.90	8.95	48.43	6.70	26.80	1.26	6.32	0.79
55	8.32	0.32	0.77	251.1	8.2	238.1	19.05	10.28	31.72	6.88	30.00	1.29	5.65	0.82
56	8.28	0.81	0.89	326.3	7.4	253.8	20.83	8.38	29.38	9.80	27.14	1.21	7.89	0.78
57	7.95	0.26	0.80	320.0	11.9	255.0	20.48	6.95	44.42	8.38	33.00	1.16	4.75	0.82
58	7.52	0.20	1.10	514.5	8.2	235.3	22.60	9.33	29.04	7.31	18.52	1.01	3.53	0.79
59	8.06	0.31	0.80	200.9	5.3	214.8	21.78	10.05	18.35	7.07	25.74	1.50	8.15	0.82
60	8.02	0.23	1.04	75.4	12.9	171.5	20.20	10.35	44.42	8.82	16.98	2.05	3.92	0.82
61	7.52	0.19	0.86	138.2	10.4	148.4	18.63	14.58	22.36	5.87	20.66	0.97	3.72	0.70
62	8.05	0.35	0.99	200.9	18.1	240.2	23.93	10.20	11.33	6.03	27.14	1.02	6.11	0.63
63	8.18	0.76	0.77	232.2	8.6	266.2	24.48	11.63	54.45	4.94	27.50	0.90	3.08	0.75
64	8.17	0.26	0.78	138.2	43.0	244.4	24.85	9.95	71.49	9.01	10.78	1.33	4.65	0.64
65	7.80	0.23	0.59	200.9	8.6	219.0	23.38	9.23	12.67	5.44	37.00	1.24	5.38	0.62
66	8.07	0.62	0.72	389.0	27.8	313.5	27.35	7.55	72.83	9.24	17.36	0.71	6.16	0.66
67	7.90	0.22	0.54	514.5	21.6	271.2	27.68	7.30	66.00	10.58	11.70	0.82	4.35	0.67
68	8.04	0.34	0.68	451.8	7.4	298.8	27.98	8.15	12.00	13.68	17.52	1.13	7.11	0.68
69	8.01	0.20	0.65	589.7	10.6	194.4	19.18	11.88	52.44	4.64	15.94	1.03	5.29	0.65
70	7.72	0.36	0.56	514.5	28.7	255.3	16.60	12.18	45.76	14.27	14.50	0.83	7.64	0.63
71	8.32	0.25	0.95	389.0	10.4	276.6	16.85	10.10	54.11	7.62	23.34	1.20	5.90	0.59

Sample	pH	EC	O C (%)	avail. N (kg/ha)	Olsen's.P (kg/ha)	K (kg/ha)	Exch. Ca (cmol(P ⁺)/kg)	Exch. Mg (cmol(P ⁺)/kg)	Avail. S (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	B (mg kg ⁻¹)
72	7.80	0.34	1.13	514.5	11.4	209.3	17.95	11.55	65.14	5.18	20.12	1.04	6.13	0.62
73	8.38	0.13	0.93	451.8	7.6	182.1	21.30	7.30	17.01	4.72	20.16	1.24	7.45	0.57
74	8.14	0.23	1.05	295.0	16.0	222.2	21.93	9.05	34.73	6.35	24.58	0.81	4.99	0.55
75	8.48	0.45	0.86	514.5	24.2	193.2	22.88	9.30	33.39	4.65	12.50	1.55	7.07	0.66
76	7.55	0.33	0.89	263.6	35.6	174.8	24.03	9.50	33.72	8.14	34.96	0.97	8.80	0.67
77	7.60	0.25	0.96	370.2	10.8	226.4	23.00	11.10	47.09	5.99	22.50	1.32	6.08	0.62
78	8.09	0.29	0.80	458.0	43.5	260.2	23.63	10.08	25.37	7.26	33.14	1.64	5.30	0.62
79	8.01	0.31	0.68	226.0	15.4	319.9	23.70	12.30	67.81	8.74	27.00	1.85	5.74	0.62
80	7.40	0.46	0.77	514.5	41.8	305.6	22.48	14.10	14.34	7.71	24.80	1.83	4.17	0.56
81	7.72	0.28	0.50	295.0	25.1	287.3	22.55	10.98	26.04	6.68	27.50	1.43	4.95	0.59
82	8.07	0.56	0.69	200.9	9.2	175.1	22.85	13.68	17.68	6.11	21.98	1.11	3.28	1.48
83	8.14	0.21	0.80	263.6	5.7	229.2	18.13	16.60	40.74	8.50	27.20	1.20	4.17	0.56
84	8.16	0.45	0.63	200.9	9.2	213.8	20.20	11.85	40.07	5.42	26.94	0.85	3.74	0.49
85	8.20	0.23	0.56	232.2	12.1	254.7	21.48	11.53	37.07	8.57	7.50	1.18	4.36	0.51
MAX	8.52	1.87	1.13	589.74	54.43	356.91	28.58	16.60	74.00	14.27	40.00	2.20	8.80	1.66
MIN	7.20	0.13	0.50	75.44	4.38	148.39	15.53	3.18	11.33	4.64	7.50	0.71	3.02	0.18
AVRGE	8.01	0.36	0.81	315.60	14.89	246.46	21.77	9.40	40.42	7.35	23.66	1.33	5.39	0.70

Appendix III : Soil properties and soil nutrient status of lime orchards of Indi taluk (n=60)

Soil sample	pH	EC	O C (%)	Alk. KMnO ₄ N (kg/ha)	Olsen's.P (kg/ha)	Neutral 1N NH ₄ OAc K(kg/ha)	Neutral 1N NH ₄ OAc Ca (cmol(P+)/kg)	Neutral 1N NH ₄ OAc Mg (cmol (P+)/kg)	CaCl ₂ extr. S (mg kg ⁻¹)	DTPA extr. Fe, Mn, Zn and Cu				Hot water sol. B (mg kg ⁻¹)
										Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	
26	7.55	0.36	0.92	263.6	36.8	206.6	24.35	5.08	47.43	6.88	25.74	0.73	5.19	0.95
27	7.6	0.16	0.98	495.7	52.8	230.2	24.25	5.5	74	10.66	28	2.12	5.76	1.5
28	7.78	0.25	0.92	420.4	15.4	305.5	23.98	7.9	36.4	5.67	13.34	1.06	6.21	0.43
29	7.2	0.13	0.83	426.7	7.6	305.9	26.53	8.83	72.49	9.89	18.02	2.18	6.29	0.4
30	7.68	0.14	0.99	407.9	5.7	262	27.55	5.38	28.71	7.98	23.64	1.07	4.39	1.37
31	7.81	0.48	0.84	432.9	7	275.8	23.38	7.73	52.11	11.88	17.58	2.01	5.41	0.56
32	7.8	0.37	0.9	357.7	7.8	356.9	28.58	4.33	29.71	5.96	32.84	1.32	5.97	0.76
33	7.91	0.68	0.68	207.2	7	323.9	25.63	9.1	45.76	6.3	22.5	1.15	8.19	0.74
34	7.97	0.41	0.74	326.3	19.2	316.4	27.25	5.85	35.06	6.73	32.06	1.49	5.81	0.54
35	7.83	0.3	0.66	232.2	5.2	289.7	20.88	6.55	40.07	6.94	38	1.79	5.1	1.03
36	7.9	0.33	0.54	251.1	7	190.8	20.55	6.03	22.36	6.35	23.34	1.3	3.37	0.66
37	8.04	0.33	0.89	326.3	5.7	181	20.6	5.05	45.09	6.35	40	1.61	6.33	0.51
38	7.7	0.35	0.95	301.2	6.6	204.8	20.65	5.35	49.77	7.21	22.96	1.59	6.69	0.31
39	7.8	0.38	0.96	276.1	4.6	167.5	22.55	6.9	62.47	6.87	15.6	1.18	3.62	0.72
40	7.9	0.26	1.08	263.6	9.1	174	21.25	5.25	25.03	5.82	20.9	1.49	4.54	0.38
41	7.52	0.4	0.9	232.2	4.4	218.7	22.23	10.58	51.77	7.24	24.72	1.6	8.51	0.85
42	8.1	0.38	1.04	138.2	18.8	187.8	24.9	10.03	42.08	7.4	20.98	1.49	5.42	0.94
43	7.88	0.13	0.98	200.9	43.5	231.6	22.58	11.55	33.72	7.64	18.5	1.91	6.51	0.74
44	7.8	0.51	0.89	263.6	16.2	238.1	23.5	8.65	66	6.83	24.84	1.11	4.07	0.94
45	7.52	1.87	0.83	326.3	8.8	258.6	23.38	8.95	24.03	6.92	17.02	1.01	4.3	0.82
46	8.1	0.45	0.96	138.2	7.1	305.9	23.48	14.6	46.42	6.35	22.2	0.88	4.45	0.7
47	8.02	0.36	0.8	200.9	12.3	297.8	24.85	11	41.74	6.47	36	1.39	5.09	0.84
48	7.6	0.23	0.98	400	20	326.9	23.1	14	72.83	12	38	2.2	6.8	1.5

Soil sample	pH	EC	O C (%)	Alk. KMnO ₄ N (kg/ha)	Olsen's.P (kg/ha)	Neutral 1N NH ₄ OAc K(kg/ha)	Neutral 1N NH ₄ OAc Ca (cmol(P+)/kg)	Neutral 1N NH ₄ OAc Mg (cmol (P+)/kg)	CaCl ₂ extr. S (mg kg ⁻¹)	DTPA extr. Fe, Mn, Zn and Cu				Hot water sol. B (mg kg ⁻¹)
										Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	
49	8.27	0.16	0.62	138.2	7.6	271	23.2	7	39.74	6.52	25.48	1.08	5.44	0.7
50	7.8	0.5	0.59	200.9	6.6	300.7	24.3	12.7	13	8.76	28.66	1.23	4.8	0.9
51	7.95	0.53	0.51	389	54.4	281.8	23.93	11.25	46.42	9.15	21.92	1.9	5.87	0.81
52	7.7	0.8	0.72	200.9	28.5	288.4	20.35	9.98	62	7.4	26.66	1.45	7.14	0.93
53	8.01	0.32	0.63	263.6	26.4	288.5	19.85	8.48	69.82	11.76	22.06	1.89	6.73	0.82
54	7.72	0.32	1.02	301.2	18.8	195.6	19.9	8.95	48.43	6.7	26.8	1.26	6.32	0.79
55	8.32	0.32	0.77	251.1	8.2	238.1	19.05	10.28	31.72	6.88	30	1.29	5.65	0.82
56	8.28	0.81	0.89	326.3	7.4	253.8	20.83	8.38	29.38	9.8	27.14	1.21	7.89	0.78
57	7.95	0.26	0.8	320	11.9	255	20.48	6.95	44.42	8.38	33	1.16	4.75	0.82
58	7.52	0.2	1.1	514.5	8.2	235.3	22.6	9.33	29.04	7.31	18.52	1.01	3.53	0.79
59	8.06	0.31	0.8	200.9	5.3	214.8	21.78	10.05	18.35	7.07	25.74	1.5	8.15	0.82
60	8.02	0.23	1.04	75.4	12.9	171.5	20.2	10.35	44.42	8.82	16.98	2.05	3.92	0.82
61	7.52	0.19	0.86	138.2	10.4	148.4	18.63	14.58	22.36	5.87	20.66	0.97	3.72	0.7
62	8.05	0.35	0.99	200.9	18.1	240.2	23.93	10.2	11.33	6.03	27.14	1.02	6.11	0.63
63	8.18	0.76	0.77	232.2	8.6	266.2	24.48	11.63	54.45	4.94	27.5	0.9	3.08	0.75
64	8.17	0.26	0.78	138.2	43	244.4	24.85	9.95	71.49	9.01	10.78	1.33	4.65	0.64
65	7.8	0.23	0.59	200.9	8.6	219	23.38	9.23	12.67	5.44	37	1.24	5.38	0.62
66	8.07	0.62	0.72	389	27.8	313.5	27.35	7.55	72.83	9.24	17.36	0.71	6.16	0.66
67	7.9	0.22	0.54	514.5	21.6	271.2	27.68	7.3	66	10.58	11.7	0.82	4.35	0.67
68	8.04	0.34	0.68	451.8	7.4	298.8	27.98	8.15	12	13.68	17.52	1.13	7.11	0.68
69	8.01	0.2	0.65	589.7	10.6	194.4	19.18	11.88	52.44	4.64	15.94	1.03	5.29	0.65
70	7.72	0.36	0.56	514.5	28.7	255.3	16.6	12.18	45.76	14.27	14.5	0.83	7.64	0.63
71	8.32	0.25	0.95	389	10.4	276.6	16.85	10.1	54.11	7.62	23.34	1.2	5.9	0.59
72	7.8	0.34	1.13	514.5	11.4	209.3	17.95	11.55	65.14	5.18	20.12	1.04	6.13	0.62

Soil sample	pH	EC	O C (%)	Alk. KMnO ₄ N (kg/ha)	Olsen's.P (kg/ha)	Neutral 1N NH ₄ OAc K(kg/ha)	Neutral 1N NH ₄ OAc Ca (cmol(P+)/kg)	Neutral 1N NH ₄ OAc Mg (cmol (P+)/kg)	CaCl ₂ extr. S (mg kg ⁻¹)	DTPA extr. Fe, Mn, Zn and Cu				Hot water sol. B (mg kg ⁻¹)
										Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	
73	8.38	0.13	0.93	451.8	7.6	182.1	21.3	7.3	17.01	4.72	20.16	1.24	7.45	0.57
74	8.14	0.23	1.05	295	16	222.2	21.93	9.05	34.73	6.35	24.58	0.81	4.99	0.55
75	8.48	0.45	0.86	514.5	24.2	193.2	22.88	9.3	33.39	4.65	12.5	1.55	7.07	0.66
76	7.55	0.33	0.89	263.6	35.6	174.8	24.03	9.5	33.72	8.14	34.96	0.97	8.8	0.67
77	7.6	0.25	0.96	370.2	10.8	226.4	23	11.1	47.09	5.99	22.5	1.32	6.08	0.62
78	8.09	0.29	0.8	458	43.5	260.2	23.63	10.08	25.37	7.26	33.14	1.64	5.3	0.62
79	8.01	0.31	0.68	226	15.4	319.9	23.7	12.3	67.81	8.74	27	1.85	5.74	0.62
80	7.4	0.46	0.77	514.5	41.8	305.6	22.48	14.1	14.34	7.71	24.8	1.83	4.17	0.56
81	7.72	0.28	0.5	295	25.1	287.3	22.55	10.98	26.04	6.68	27.5	1.43	4.95	0.59
82	8.07	0.56	0.69	200.9	9.2	175.1	22.85	13.68	17.68	6.11	21.98	1.11	3.28	1.48
83	8.14	0.21	0.8	263.6	5.7	229.2	18.13	16.6	40.74	8.5	27.2	1.2	4.17	0.56
84	8.16	0.45	0.63	200.9	9.2	213.8	20.2	11.85	40.07	5.42	26.94	0.85	3.74	0.49
85	8.2	0.23	0.56	232.2	12.1	254.7	21.48	11.53	37.07	8.57	7.5	1.18	4.36	0.51
Minimum	8.48	1.87	1.13	589.74	54.43	356.91	28.58	16.6	74	14.27	40	2.2	8.8	1.5
Maximum	7.2	0.13	0.5	75.44	4.38	148.39	16.6	4.33	11.33	4.64	7.5	0.71	3.08	0.31
Mean	7.9	0.37	0.82	310.51	16.46	247.21	22.66	9.49	41.62	7.6	23.9	1.33	5.56	0.74

Appendix IV: Soil properties and soil nutrient status of lime orchards of Sindagi taluk (n=25)

Soil sample	pH	EC	O C (%)	Alk. KMnO ₄ hyd. N (kg ha ⁻¹)	Olsen's. P (kg ha ⁻¹)	Neutral 1N NH ₄ OAc K(kg ha ⁻¹)	Neutral 1N NH ₄ OAc Ca (cmol(P ⁺) /kg)	Neutral 1N NH ₄ OAc Mg (cmol(P ⁺) /kg)	CaCl ₂ extr. S (mg kg ⁻¹)	DTPA extr. Fe, Mn, Zn and Cu				Hot water sol. B (mg kg ⁻¹)
										Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	
1	8.52	0.38	0.65	345.1	8.6	297.9	18.95	9.48	31.05	5.42	20.32	1.4	3.26	0.34
2	8.44	0.35	0.72	263.6	6.6	270.2	16.7	8.1	29.71	7.86	17.22	0.79	4.18	0.24
3	8.3	0.42	0.9	345.1	9.5	294.5	17.38	9.7	50.77	5.51	21.9	1.52	6.98	0.3
4	8.28	0.34	0.78	313.8	11.2	286.8	16.15	11.03	30.05	9.06	19.58	0.85	5.8	0.18
5	7.8	0.42	0.62	188.3	8.3	260.1	19.63	7.8	28.71	7.23	16	0.74	3.34	0.89
6	8.17	0.37	0.7	263.6	9.9	282.8	15.63	8.78	27.37	6.28	16	1.34	5.46	0.77
7	8.42	0.37	1.07	370.2	17.3	245.1	18.78	9.33	46.76	7.57	33	0.88	5.05	0.65
8	8.4	0.38	1.01	458	9.9	217	21.4	9.6	45.76	6.09	18.42	1.09	4.53	1.66
9	8.18	0.4	0.74	226	4.9	211.2	19.03	11.35	20.35	7.12	38	0.89	3.94	0.41
10	8.46	0.36	0.65	376.5	6.4	223.8	19.93	12.23	37.4	7.81	29.84	1.48	4.62	0.54
11	8.3	0.29	0.86	232.2	12.5	246.6	23.23	10.38	63.14	5.84	12.5	2.2	3.04	0.62
12	8.2	0.31	0.9	520.8	16.4	246.1	20.8	11.58	45.42	6.08	26.94	1.18	4.12	0.28
13	8.45	0.3	0.87	219.7	4.9	278.3	21.05	11.38	33.72	7.42	23.58	1.24	4.29	0.41
14	8.24	0.33	0.74	194.6	8.4	266.1	20.38	10.75	52.44	5.99	27.42	1.07	5.72	0.54
15	8.3	0.28	0.77	451.8	7.9	293.5	21.58	10.95	28.38	6.78	20.98	1.3	3.02	0.74
16	8.37	0.32	0.78	257.3	6.6	293.3	22.08	10.7	40.74	5.34	25.04	1.58	5.8	0.49
17	8.01	0.25	0.68	269.9	10.4	282	21.4	11.33	30.38	6.52	27.5	1.32	5.22	0.76

Soil sample	pH	EC	O C (%)	Alk. KMnO ₄ hyd. N (kg ha ⁻¹)	Olsen's. P (kg ha ⁻¹)	Neutral 1N NH ₄ OAc K(kg ha ⁻¹)	Neutral 1N NH ₄ OAc Ca (cmol(P ⁺) /kg)	Neutral 1N NH ₄ OAc Mg (cmol(P ⁺) /kg)	CaCl ₂ extr. S (mg kg ⁻¹)	DTPA extr. Fe, Mn, Zn and Cu				Hot water sol. B (mg kg ⁻¹)
										Fe (mg kg ⁻¹)	Mn (m ⁻¹ g kg-1)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)	
18	7.72	0.3	0.59	326.3	7.4	330.4	16.73	11.85	51.44	6.47	32.78	1.3	6.03	0.55
19	8.32	0.34	0.71	389	6.2	238.8	18.15	7.75	33.05	7.36	30	1.48	3.45	1.04
20	8.23	0.27	0.79	301.2	5.2	157.3	15.53	11.08	46.76	6.94	29.5	0.8	5.56	0.92
21	8.42	0.14	1.08	483.1	11.2	208	21.35	3.18	35.39	7.18	12.5	1.52	6.91	0.79
22	8.1	0.3	0.77	401.6	27.6	168.9	19.85	6.05	32.05	8.77	17.84	1.48	4.96	0.47
23	8.4	0.17	0.92	288.7	12.8	192.6	20.83	4.43	29.04	5.77	19	2	7.16	0.7
24	8.14	0.33	0.99	414.1	25.2	157.5	21.68	4.83	35.39	7	23.68	1.49	6	0.53
25	8.48	0.24	0.9	295	23	167.4	22.93	6.03	33.05	5.06	17.5	2	6.28	0.42
Minimum	8.52	0.42	1.08	520.75	27.61	330.36	23.23	12.23	63.14	9.06	38	2.2	7.16	1.66
Maximum	7.72	0.14	0.59	188.34	4.91	157.31	15.53	3.18	20.35	5.06	12.5	0.74	3.02	0.18
Mean	8.27	0.32	0.81	327.83	11.13	244.65	19.64	9.18	37.53	6.74	23.08	1.32	4.99	0.61

Appendix V: Leaf nutrients status of the entire population of lime orchards of Vijayapur District (n=85).

Sl. No.	N%	P%	K%	Ca%	M%	S%	Fe(µg/g)	Mn (µg/g)	Zn (µg/g)	Cu (µg/g)	B (µg/g)
1	0.97	0.47	1.03	0.95	0.51	0.19	30.13	2.59	26.99	5.88	50.29
2	0.71	0.46	1.15	1.10	0.89	0.20	6.79	3.33	29.58	4.00	68.50
3	1.28	0.50	1.59	0.90	0.32	0.23	53.55	0.65	31.76	5.88	59.21
4	1.23	0.54	1.54	0.82	0.47	0.24	23.79	0.37	24.90	4.69	44.93
5	1.32	0.61	1.70	0.93	0.38	0.28	25.37	2.22	25.87	5.88	130.17
6	1.34	0.61	1.18	0.91	0.27	0.35	29.74	2.50	26.25	5.88	115.64
7	1.55	0.62	1.74	0.90	0.52	0.31	20.21	1.94	17.98	7.07	57.07
8	1.38	0.72	1.10	1.40	0.50	0.26	15.45	0.65	25.96	4.69	47.07
9	1.26	0.62	1.86	0.80	0.40	0.46	28.94	3.43	19.86	9.45	73.02
10	1.20	0.72	1.61	1.30	0.19	0.32	32.91	1.02	31.25	5.88	88.14
11	1.16	0.71	1.15	1.20	0.34	0.27	17.04	2.50	36.96	5.88	97.55
12	1.45	0.67	1.07	1.10	0.23	0.39	21.40	2.13	31.25	3.50	57.19
13	1.40	0.81	0.63	1.40	0.36	0.21	20.61	1.40	24.87	3.50	72.90
14	1.33	0.84	1.11	1.20	0.57	0.19	14.66	1.11	37.92	3.50	88.14
15	1.08	0.81	1.31	0.90	0.49	0.39	25.77	4.17	25.86	3.50	111.24
16	1.21	0.97	0.82	0.80	1.09	0.13	15.85	1.67	34.87	3.50	81.95
17	1.13	0.91	0.98	1.30	0.45	0.20	29.74	1.30	24.58	3.50	114.45
18	1.51	0.89	1.05	1.20	0.36	0.24	42.44	1.39	32.20	3.50	89.57
19	1.30	1.02	0.91	1.40	0.33	0.29	67.83	0.56	30.52	4.69	146.95
20	1.52	1.06	0.81	1.30	0.41	0.26	46.01	3.61	28.14	5.88	133.50
21	1.42	1.05	0.72	1.50	0.69	0.38	39.66	1.20	30.52	7.07	117.43
22	1.44	1.05	0.77	1.30	0.19	0.36	43.23	1.76	32.08	7.07	80.17
23	1.58	1.10	0.72	1.20	0.48	0.29	27.36	1.76	12.92	5.88	106.60
24	1.32	1.15	1.10	1.20	0.28	0.33	25.37	2.22	17.92	4.69	86.95
25	1.37	1.22	1.20	1.00	0.26	0.25	43.63	2.22	30.77	5.88	73.86

Sl. No.	N%	P%	K%	Ca%	M%	S%	Fe(µg/g)	Mn (µg/g)	Zn (µg/g)	Cu (µg/g)	B (µg/g)
26	1.29	1.18	0.99	1.10	1.06	0.29	31.33	3.06	36.72	7.55	68.62
27	1.19	1.14	0.99	0.70	0.56	0.35	37.67	2.32	37.08	7.07	105.52
28	1.46	1.12	0.92	0.80	0.94	0.31	33.31	1.20	27.05	4.69	75.05
29	1.33	1.22	0.65	0.90	0.85	0.36	32.12	1.48	34.45	10.17	71.48
30	1.30	1.34	0.53	0.90	0.81	0.29	26.96	1.94	32.07	4.69	106.83
31	1.29	1.34	0.61	1.00	0.48	0.31	46.80	0.74	36.83	4.69	89.93
32	1.35	1.35	0.78	0.80	1.26	0.33	29.34	1.20	32.07	11.12	114.69
33	1.37	1.42	0.77	0.80	0.75	0.25	34.10	3.52	27.31	10.64	112.07
34	1.35	1.35	0.80	0.90	0.80	0.32	40.06	2.96	32.07	7.07	88.14
35	1.42	1.36	0.54	1.20	0.65	0.27	65.45	1.39	23.75	4.69	146.71
36	1.17	0.47	0.53	1.10	0.96	0.24	30.13	1.30	28.70	3.50	102.79
37	1.19	0.93	0.55	1.10	0.61	0.20	39.26	1.48	29.58	4.69	84.81
38	1.30	1.06	0.77	0.90	0.92	0.24	36.48	1.48	31.58	4.69	61.00
39	1.34	0.90	0.90	1.30	0.46	0.19	30.93	1.11	29.20	5.88	109.57
40	1.30	0.58	0.63	1.40	0.21	0.26	30.53	2.04	25.63	3.50	68.74
41	1.27	0.22	1.37	1.20	0.27	0.24	38.87	3.70	29.20	5.88	105.05
42	1.18	1.20	1.18	1.50	0.43	0.36	23.79	1.67	18.48	11.83	83.98
43	1.37	0.46	1.00	1.40	0.38	0.34	40.06	1.48	33.96	7.07	112.07
44	1.20	1.10	1.26	1.60	0.24	0.40	52.36	1.94	28.01	12.98	135.52
45	1.28	0.75	0.99	1.40	0.20	0.26	30.53	2.32	28.01	4.69	121.60
46	1.41	0.62	1.30	1.20	0.17	0.29	56.72	3.15	34.55	4.69	107.19
47	1.30	0.64	1.22	1.40	0.22	0.31	34.90	2.50	31.35	3.50	124.21
48	1.74	1.27	1.89	1.80	1.26	0.85	9.58	3.96	39.25	11.50	126.12
49	1.34	1.10	1.35	1.40	0.27	0.24	47.60	3.70	32.51	4.69	107.31
50	1.32	0.66	1.02	1.40	0.38	0.31	26.56	2.87	39.66	7.07	131.12
51	1.25	0.70	1.06	1.50	0.11	0.31	54.34	1.76	32.51	4.69	119.81

Sl. No.	N%	P%	K%	Ca%	M%	S%	Fe(µg/g)	Mn (µg/g)	Zn (µg/g)	Cu (µg/g)	B (µg/g)
52	1.27	0.65	0.98	1.10	0.30	0.35	62.67	2.13	31.32	4.69	103.86
53	1.30	1.12	1.13	1.20	0.47	0.40	26.96	1.30	28.70	9.45	120.76
54	1.29	0.52	1.13	1.40	0.12	0.34	72.99	2.78	35.63	5.88	117.55
55	1.53	0.55	0.92	1.70	0.20	0.32	71.01	3.52	30.87	4.69	121.83
56	1.41	0.50	0.92	1.20	0.42	0.34	38.47	4.91	26.11	13.74	116.60
57	1.41	0.43	0.85	1.60	0.28	0.33	120.21	2.41	30.87	5.88	120.76
58	1.20	0.52	0.76	1.40	0.12	0.23	29.74	3.24	36.35	4.69	117.55
59	1.25	0.53	1.18	1.50	0.17	0.30	31.72	2.78	24.93	4.69	121.83
60	1.33	0.49	1.07	1.40	0.20	0.36	36.09	1.85	30.88	5.88	121.83
61	1.32	0.77	0.93	1.30	0.70	0.37	30.93	2.13	7.08	5.88	107.31
62	1.30	0.27	0.55	1.10	0.37	0.16	23.79	2.50	28.50	3.50	99.21
63	1.36	0.55	0.87	1.30	0.19	0.39	41.64	2.13	24.93	4.69	113.50
64	1.39	0.49	1.14	1.40	0.10	0.39	36.09	3.43	36.24	3.50	99.81
65	1.34	0.35	1.26	1.20	0.26	0.32	16.64	2.32	37.98	3.50	97.43
66	1.37	0.58	1.47	1.50	0.25	0.37	31.72	2.22	27.10	3.50	102.79
67	1.34	0.47	1.16	1.40	0.12	0.40	32.52	1.48	28.92	4.69	103.86
68	1.19	0.33	1.54	1.50	0.14	0.37	28.94	1.48	30.11	11.36	105.17
69	1.18	0.65	1.01	1.60	0.10	0.44	28.15	2.32	26.54	3.50	101.60
70	1.15	0.45	1.41	1.50	0.12	0.35	22.20	2.69	24.16	3.50	98.98
71	1.15	0.80	1.17	1.40	0.20	0.39	25.37	1.57	30.11	4.69	93.98
72	1.30	0.47	0.99	1.50	0.17	0.31	12.67	1.39	22.97	3.50	97.79
73	1.02	0.41	0.80	1.50	0.22	0.33	14.66	2.21	28.50	4.69	91.71
74	1.06	0.51	1.18	0.70	0.16	0.16	10.29	2.50	24.93	2.31	88.62
75	1.21	0.35	1.13	1.80	0.14	0.35	14.26	1.67	26.31	3.50	102.67
76	1.23	0.41	1.12	1.40	0.35	0.30	15.06	1.67	24.13	8.26	103.14
77	1.19	0.46	0.89	1.50	0.22	0.37	33.31	3.24	27.70	9.69	97.79

Sl. No.	N%	P%	K%	Ca%	M%	S%	Fe(µg/g)	Mn (µg/g)	Zn (µg/g)	Cu (µg/g)	B (µg/g)
78	1.18	0.30	1.30	1.80	0.49	0.36	15.45	2.41	19.37	3.50	97.90
79	1.23	0.40	0.88	2.00	0.44	0.35	16.64	2.56	20.56	3.50	97.67
80	1.32	0.43	0.78	1.20	0.51	0.28	13.87	2.23	20.56	7.79	90.29
81	1.05	0.58	0.68	1.40	0.14	0.30	23.39	2.21	25.32	4.69	94.21
82	1.25	0.34	0.76	1.20	0.32	0.30	16.25	2.41	22.94	3.50	99.93
83	1.32	0.65	0.68	1.40	0.59	0.63	15.85	1.76	20.56	3.50	90.05
84	1.37	0.50	1.10	1.70	0.31	0.95	16.25	2.21	21.75	3.50	81.71
85	1.39	0.55	1.09	1.50	0.50	0.71	17.04	2.04	27.70	3.50	84.69
Minimum	1.74	1.42	1.89	2.00	1.26	0.95	120.21	4.91	39.66	13.74	146.95
Maximum	0.71	0.22	0.53	0.70	0.10	0.13	6.79	0.37	7.08	2.31	44.93
Mean	1.29	0.74	1.04	1.26	0.42	0.33	32.35	2.16	28.40	5.66	98.55
SD	0.14	0.32	0.31	0.28	0.27	0.12	17.24	0.88	5.86	2.49	21.99
variance	0.02	0.10	0.09	0.08	0.07	0.02	297.11	0.78	34.39	6.20	483.54
CV	10.92	42.74	29.50	22.31	65.42	38.11	53.28	40.94	20.65	43.95	22.31

**DRIS NORMS FOR IDENTIFICATION OF YIELD LIMITING NUTRIENTS IN
LIME (*Citrus aurantifolia*) ORCHARDS OF VIJAYAPURA DISTRICT,
KARNATAKA**

AMBAREESH NEMU JADHAV 2019

**Dr. SAVITA B.
Major Advisor**

ABSTRACT

A survey was conducted during 2018-19 in Indi and Sindagi taluks of Vijayapura district. Surface (0 - 22.5 cm) soil samples (n=85) of lime orchards were collected and analysed for soil properties and extractable nutrients. As per the calculated nutrient index values, soils of Indi were low in N, medium in P, K and Fe and high in S, Mn, Zn, Cu and B. The soils of Sindagi were low in N and P, medium in K and Fe and high in S, Mn, Cu, Zn and B. Leaf samples (n=85) of lime (selecting 3-5 months shoot of new growth 1st leaf during June) collected and analysed for macro and micro-nutrient status to develop nutrient diagnostic norms and identification of most yield limiting nutrients. The mean of leaf nutrient concentrations of N, P, K, Ca, Mg and S in lime is 1.29, 0.74, 1.04, 1.26, 0.42 and 0.33 per cent respectively. Whereas mean of micronutrients Fe, Mn, Zn, Cu and B in lime are 32.35, 2.16, 28.4, 5.66 and 98.55 µg/g respectively. The entire population was divided into two i.e, low-and high-yielding populations based on cut-off yield 1500 fruits/tree/year. Fifty-five nutrient expressions were chosen as diagnostic norms, important are: K/N(0.79), Ca/N(0.94), N/S(3.28), Fe/N(24.66), Mn/N(21.22), Cu/N(4.29), Ca/K(1.25), K/S(2.94), K/Cu(0.19), S/Mg(0.59), Cu/Mg(9.21), S/Fe(0.01), Mn/Fe(0.89), Mn/Cu(5.07) and Cu/B(0.06) etc. The diagnosis of nutrient imbalance through DRIS indices indicated Mg is most yield limiting nutrient followed by P and S, whereas among the micronutrients most yield-limiting nutrients were, Zn followed by B and Fe in low yielding lime orchards. Thus, DRIS concludes the holistic approach which identified nutrient imbalances in lime and therefore, proved an important technique for evolving nutrient management strategies for realizing higher yields. The optimum nutrient ranges can serve as a guide for routine diagnosis and advisory purpose for the lime.

Key words: DRIS, lime, yield, limiting nutrients, optimum nutrient range