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Review article

Recent developments in diagnosis and management of nutrients constraints in acid lime

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A B S T R A C T

Acid lime is considered highly nutrient responsive crop. Occurrence of multiple nutrient deficiencies makes the redressal of such nutrient deficiencies all the more complex exercise. Site specific nutrient management studies find a greater weight age over conventional but classical progressive fertilization response studies, if constraint specific fertilization is to be worked out. Simultaneously use of integrated strategies viz., soil application of macronutrients (NPKS) and foliar application of micronutrients (Fe, Mn, Zn, B); and INM using rationale of organic manures fortified with microbial consortium based microbial reactor through isolation and characterization of native and dual purpose microbes and inorganic fertilizers have produced encouraging responses to improve production dividends underlying their undeniable utility. But, fertilizer requirement experiments have generated a vast variation in their recommendations depending upon orchard age, soil type and climatic features besides very limited information on micronutrients requirement. There is a still a bigger constraint in form of non-availability of reproducible nutrient diagnostics to determine frequency distribution of nutrient constraints duly verifiable at orchard level. Countrywide studies on development of nutrient diagnostics have suggested optimum range of nutrients based on leaf and soil analysis. For the optimum yield using DRIS (diagnosis and recommendation integrated system) based interpretation tool. Development of morphological descriptors and juice nutrient norms have further aided in defining the nutrient constraint more precisely. Such studies strongly warrant refining diagnostics at regional, and still finer at orchard level, so that once the correct diagnosis of nutrient constraint is made, management becomes a comparatively easier task.

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1. Introduction

Acid lime is one of the premier commercially grown citrus cultivars of India. The crop as limes/lemons occupy an area of 3.16 lakh ha with a production of 25.7 lakh tons and productivity of 8.1 tons/ha. Like any other crop, diagnosis and management of nutrient constraints are the two pillars of effective nutrient management programme. The mechanistic steps involved in an efficient nutrition program are: absorption, translocation and utilization of applied nutrients. All three steps are altogether different, but equally dependent to each other. Renewed and intensified efforts are in progress to identify nutrient constraints using latest diagnostic tools and managing them more precisely through intervention of geospatial technologies (GPS, GIS etc.). There have been consistent concerns about the relegated fertilizer use efficiency, warranting further the revision of ongoing practices (whose origin is presumed to be age-old, popularly known as traditional farming), and adoption of some alternative strategies (Srivastava, 2013a; 2013b).

However, in recent years, nutrient additions have been exclusively in favour of mineral fertilizers in the persuit of quick and substantial response eclipsing gradually the older practices of fertilization, on-setting the dawn of INM (integrated nutrient management) concept (Srivastava *et al*., 2002; 2008). Diagnosis of nutrient constraints and their effective management has, therefore, now shifted in favour of INM through collective use of organic manures, inorganic fertilizers and consortium of crop rhizosphere specific effective microorganisms.

2. Diagnosis of Nutrient Constraints

There are large variety of diagnostic tools viz., leaf analysis, soil analysis, juice analysis, inflorescence analysis, biochemical analysis using metalloenzymes as markers and morphological descriptors as indicator of nutritional disorders with varied precision through which nutrient constraints are diagnosed with varying precision(Srivastava and Singh, 2002; 2004; 2005; Srivastava et al., 2008). However, only leaf and soil analysis-based interpretations have yielded some reproducible diagnostic efficacy (Srivastava and Singh, 2006).

2.1. Leaf analysis

Leaf analysis integrates all the factors that might influence nutrition availability in soil and plant uptake, and pinpoints the nutritional balance of the plant at the time of sampling. Sampling index leaves from correct type of shoots is the most important step in establishing optimum values of nutrient concentration.

2.2. Sampling index leaves

Analysis of leaf samples derived from 10-years-old acid lime orchard established in medium deep black soil taxonomically classified as Vertic Ustochrept during the entire growth period revealed that the leaf N content was stable during 3rd October to 5th month (December) at concentration of 1.9%. Thereafter, it showed irregular variation till the end of the season. While, leaf K concentration reached to a maximum of 1.04% in October and thereafter, no distinct variation was observed between 0.71 to 0.64% during November to February. No significant variation in leaf Ca content was recorded at concentration of 3.5% during October - November months and in December, a significantly higher concentration of 7.4% was obtained. The leaf Ca content was maximum (7.9%) in June towards the end of the season. On the other hand, leaf Mg status was least varying from 0.29 to 0.27% during October to December and thereafter, reduced to lowest (0.12%) in March. The leaf Fe and Mn content also showed minimum variation in their concentration from 83.2 to 88.7 ppm and from 32.5 to 36.2 ppm during

October to December. Thereafter, Fe content indicated irregular variation till the end of season, whereas leaf Mn content showed irregular variation upto May and in the following months, it reduced to 25.0 ppm in July, the end of the season (Srivastava et al., 2008).

The above observations indicated minimum variation in leaf nutrient composition when leaves were 3 to 5-months old, irrespective of soil type which can be used for leaf analysis in Acid lime. Studies carried out on 4-year old lemon trees by Sema et al. (1999) showed that the stable period (leaf age in months) as 5-6 for Fe, 2-3 for Zn, and 7-8 for Mn. Lateral shoots indicated higher foliar contents. Interaction between growth flushes and leaf age produced a marked effect on foliar micronutrient concentration. Socalo and Guzman (1986) observed that leaf N, P and K decreased during the flowering periods viz., September-November and April-June in Citrus aurantifolia budded on Citrus jambhiri in coast of Peru. The average lowest values of N, P, and K were observed as 2.7, 0.16, and 0.70%, respectively.

2.3. Sampling suitable shoot type

An appraisal of nutrient composition of leaves collected at positions of 2nd, 3rd and 4th leaf on a shoot indicated statistically non-significant variation in the concentration of different nutrients viz., N, P, K, Ca, Mg, S, Fe, Mn, Cu and Zn studied in 6 to 8 month old leaves during both the years. These observations indicated that all the leaf positions were equally effective index leaves for finding out the nutrient status of tree. The earlier studies showed that concentration of N, P, K and Ca in 3rd and 4th leaves behind the fruit were nearer to the concentration in leaves from non-fruiting growth (Table 1). These minimum variations in leaf nutrient composition indicated that leaf sample size as low as 30 leaves covering 2 % trees was equally effective for foliar analysis as much as 70 leaves covering even 10% trees (Srivastava et al., 1999; 2001).

2.4. Optimum nutrient values

Very limited efforts have so far been made to work out the leaf nutrient standards in acid lime. Studies by Varalaxmi and Bhargava (1998) suggested that the optimum leaf nutrient concentration for acid lime as : 1.53-2.10% N, 0.10-0.15% P, 0.96-1,66% K, 3.05-3.43% Ca, 0.40 – 0.60% Mg, 0.25-0.29% S, 117-194 ppm Fe, 21-63 ppm Mn, 9-15 ppm Cu, 25-50 ppm Zn for the yield of 17.7-19.4 tons/ha. From the nutrient dynamics point of view, often different nutrient standards are suggested as per crop phenophases. Abaev (1977) suggested various level of N, P, and K according to critical growth stages as : 2.1-2.3% N, 0.22% P_2O_5, and 1.8% K_2O at flowering; 2.4-2.7% N, 0.25-0.28% P_2O_5, and 1.85-2.0% K_2O at fruit formation; and 2.1-2.3% N, 0.25% P_2O_5, and 1.7-1.8% K_2O at fruit ripening stage for lemons grown in Western Georgia.

2.5. Soil analysis

The soil analysis method is based on the assumption that the chemical extractants stimulate the root system acquisition of soil nutrients in a comparable manner. The quantity of a nutrient extracted through the soil using a suitable extractant is an index of nutrient actually available to trees. Another limitation of soil analysis based diagnosis is the suitable soil sampling, which is usually to represented by the soil portion explored by the roots. The soil singled out as the best or ideal in terms of productivity, represents the standard by which the other soils are judged. An appraisal of soil suitability criteria may, therefore, help to identify suitable soils, to avoid any risk of sub-optimum production on account of soil-related-constraints. Researches carried out under different soil and climatic conditions have shown varying responses in relation to properties of soil on the performance of citrus orchards (Srivastava and Singh, 2001; 2008).

Very limited information is available with regard to acid lime as test crop. The researches undertaken under AICRP at Periyakulam (TNAU) Centre, studies revealed that high yielding acid lime orchards (101.5 kg/tree) registered the available N, P, and K as 442, 21, and 282 kg/ha, respectively. While, at Rahuri Centre, it is reported that high yielding acid lime orchards observed available N, P, and K as 205-235, 16-18, and 345-390 kg/ha, respectively (Sidhu *et al*., 2011). The interpretation of data collected through DRIS will further establish the order in with different soil fertility constraints are limiting the productivity, and accordingly, the remediation measures could be appropriately worked out. The efforts such has this, would go a long way in providing a plausible solution to different soil fertility constraints limiting the productivity within an orchard.

3. Redressal of nutrient constraints

Long term fertilizer response studies are the most conventional method of redressal of different nutrient constraints, often regarded as recommended doses of fertilizers (RDF). But, the same RDF when replicated across varieties, soils and climate, has commonly failed to respond with the same magnitude of success due to spatial variation in soil fertility within an orchard warranting intervention of concept like site specific nutrient management (SSNM). Such SSNM studies could further be linked to INM strategy to harness much improved use efficiency of applied fertilizers (Srivastava *et al*., 2006; Srivastava and Singh, 2009).

3.1. Optimum fertilizer requirement

Optimum nutrient dose is the one that sustains the optimum productivity without either affecting quality production or causing any nutrient depletion in soil. This aspect over the years has undergone sea change from conventional fertilizer response experiment to site specific nutrient management, transforming rhizosphere environment through substrate addition etc.

Long term fertilizer response studies showed significant increase in growth and yield of acid lime with application of 400 g and 800g N with 55.52 kg, 73.66 kg and 81.81 kg fruit yield per plant, respectively, in second year. The leaf nitrogen content also increased with increasing doses of nitrogen (Huchche *et al.,* 1996). Other field responses of both macro- as well as micronutrients (Table 2) are briefly summarised below:

3.2. Site specific nutrient management

Large variation in tree canopy and subsequently, the tree-to-tree yield difference are common in many of the large size citrus orchards. Knowing the required nutrients for all stages of growth, and understanding the soil's ability to supply those needed nutrients are critical to profitable crop production. The recommendations on fertilizer application may not, however, produce the same magnitude of yield response when practised in an orchard of large area, because of its inability to accommodate variation in soil fertility status. Slight changes in the nature of soil, local climate, and agronomic practices etc. may seriously affect the nutrient utilisation capacity of the plant.

The conventional long term fertilizer trials (Tiwari, 2002) revealed that: i. omission of limiting macro- or micronutrient leads to its progressive deficiency due to heavy removals; ii. sites initially well supplied with P, K or S become deficient when continuously cropped using N alone; and iii. fertilizer rates considered optimum still resulted in nutrient depletion at higher productivity levels, if continued, become sub-optimum rates. There is a strong necessity to keep overall nutrient balance in relation to total crop load. Application of a single rate of nutrients may result in over-application of nutrients at some sites and under-application at other sites, often lead to reduce fertilizes use efficiency. Under such circumstances, site specific nutrient management is adopted in big orchards requiring variable precision application as per soil variability so as to improve the orchard efficiency (average yield of specified trees in relation to average orchard yield) in ultimate terms.

With new advances in technology, grid sampling for precision citriculture is increasing. The first step in the process is to divide large fields into small zones using a grid. Next, a representative location within the grid is identified for precision soil sampling. Grid sampling is integrated into global positioning system (GPS) based soil sampling and nutrient-mapping that in turn uses a geographic information systems (GIS) to employ variable rate technology for fertilizer applications (Zaman *et al*., 2005).

Site specific nutrient management (SSNM) offers the most appropriate option to address the spatial variation in soil fertility using variable rate fertilization as per soil test values. The spatial variability in available NPK Fe Mn Cu and Zn was measured through exhaustive grid sampling and their geocoding. Accordingly, two contrasting soil types viz., Typic Ustorthent and Typic Haplustert showed a significantly different magnitude of response of Nagpur mandarin to fertilization (Table 3) Best fertilizer treatments in terms of response on canopy growth, fruit yield, fruit quality and leaf nutrient concentration were observed to be 1200 N - 600 P_2O_5 - 600 K_2O - micronutrients (300 g each of $ZnSO_4$ and $MnSO_4$ alongwith 100 g borax / tree) on Typic Ustorthent soil type. While on Typic Haplustert soil type, 600 g N - 400 g P_2O_5 - 300 g K_2O + micronutrients (300 g each of $ZnSO_4$ and $MnSO_4$ alongwith 100 g borax / tree) and 400 g $MgSO_4$ / tree proved most effective. Higher application of K at the rate of 900 g / tree alongwith 600 g N - 400 g P_2O_5 produced much higher acidity and induced late maturity on Typic Haplustert when compared in combination with 1200 g N - 600 g P_2O_5. Such a differential response of fertilization showed no similarity with recommended fertilizer doses earlier worked out through multilocation field trials.

Table 1
Changes in leaf nutrient composition in response to leaf position in acid lime.

Nutrients	2nd leaf			Critical	3rd leaf			Critical	4th leaf			Critical
	Age in months			difference	Age in months			difference	Age in months			difference
	3.	4	5	(*P=0.05*)	3	4	5	(*P=0.05*)	3	4	5	(*P=0.05*)
Nitrogen (%)	2.14	2.17	2.22	NS	2.22	2.14	2.16	NS	2.17	2.36	2.11	NS
Phosphorus (%)	0.10	0.11	0.11	NS	0.09	0.11	0.09	NS	0.11	0.12	0.09	NS
Potassium (%)	0.99	0.61	0.63	NS	1.28	1.03	0.70	NS	1.20	1.21	1.10	NS
Calcium (%)	2.19	2.26	2.28	NS	2.04	2.10	2.28	NS	2.16	2.07	2.37	NS
Magnesium (%)	0.32	0.29	0.27	NS	0.24	0.28	0.33	NS	0.29	0.23	0.29	NS
Iron (ppm)	98.4	90.8	93.0	NS	100.2	88.8	92.1	NS	94.5	98.8	87.7	NS
Manganese (ppm)	53.8	55.9	54.4	NS	51.8	53.0	41.3	NS	46.2	48.5	47.2	NS
Copper (ppm)	10.3	10.2	8.2	NS	10.0	8.7	8.4	NS	9.5	9.4	8.7	NS
Zinc (ppm)	22.5	20.8	23.6	NS	23.6	22.3	24.6	NS	25.4	22.6	22.3	NS

NS: Non-significant at 5% level of significance.
Source: Srivastava and Singh (1998).

Table 2
Optimum nutrient requirement (soil application and foliar spray) for different cultivars in acid lime.

Dose	Crop/*Citrus* spp.	Reference
Macronutrients (Soil application)		
– 750 g N – 200 g P_2O_5 – 500 g K_2O/tree	Egyptian Balady lime	Ahmed *et al*. (1988)
– 1500 g N – 400 g P_2O_5 – 750 g K_2O/tree	Egyptian Balady lime	Maatouk *et al.* (1988)
Micronutrients (Soil application)		
– $ZnSO_4$ - K_2SO_4 (0.5% foliar spray) - K_2O as K_2SO_4 (210 g/tree soil application)	Kagzi lime	Singh *et al.* (1989)
– $ZnSO_4$ (810 g/tree soil application) - $MnSO_4$ (630 g 100/gallon foliar spray)	Lemon	Embleton *et al.* (1966)
Micronutrients (Foliar spray)		
– Fe-polyflavonoid (1%)	*Citrus limon*	Fernandez-Lopez *et al.* (1993)
– $MnSO_4$ (378 g/l) - $ZnSO_4$ (378 g/l)	Lemon	Alcarez *et al.* (1986)
– $ZnSO_4$ (0.6%) - 20 ppm 2,4-D	Kagzi lime	Singh and Misra (1986)
– $ZnSO_4$ (0.5%) – K_2SO_4 (4%)	Kagzi lime	Singh *et al.*(1989)
– $ZnSO_4$ (0.5%) – $FeSO_4$ (0.5%)	Kagzi lime	Ingle *et al*. (2002)
– Zn-EDTA - Mn-EDTA (0.10%)	Lemon	Rawash *et al.* (1983)
– $ZnSO_4$ (0.5%) - urea (1.5%)	Kagzi lime	Rathore and Chandra (2001)

Table 3
Response of site specific fertilizer treatment compared to farmers'practices/recommended doses of fertilizers (Nagpur mandarin).

Treatments	Yield (kg/ tree)	Leaf nutrients concentration				Fruit quality (%)		
		Macronutrients (%)			Micronutrient (ppm)	Juice	TSS	Acidity
		N	P	K	Zn			
Soil Type -1 : Shallow soil (Typic Ustorthent)								
Farmers' Practices : T_5 (N_{600} + P_{400} + K_0 + M_1S_1)	7.7	1.98	0.07	0.99	17.8	44.5	0.62	8.2
Recommended doses of fertilizers : T_{16} (N_{600} + P_{200} + K_{100}) – RD	10.4	2.04	0.09	1.15	21.2	45.7	0.56	9.1
Site specific treatment: T_9 ($N_{12\,00}$ + P_{600} + K_{600} + M_1S_1)	14.7	2.38	0.13	1.35	25.7	48.3	0.48	9.6
Soil Type -2 : Deep soil (Typic Haplustert)								
Farmers' Practices : T_5 (N_{600} + P_{400} + K_0 + M_1S_1)	11.9	2.07	0.08	1.05	19.2	45.5	0.77	8.1
Recommended doses of fertilizers : T_{16} (N_{600} + P_{200} + K_{100}) – RD	16.2	2.40	0.10	1.29	22.1	46.9	0.62	8.4
Site specific treatment: T_6 (N_{600} + P_{400} + K_{300} + M_1S_1)	19.0	2.55	0.13	1.67	31.0	49.8	0.53	9.0

M_1 stands for application of 300 g each of $ZnSO_4$, $FeSO_4$, $MnSO_4$ and 100 g borax tree^{-1}; Mo stands for no application of micronutrient fertilizers; S_1 stand for application of 400 g $MgSO_4$ tree^{-1} and 100 g elemental S tree^{-1}; So stands for no application of Mg and S; RD stands for recommended doses of fertilizers.
Source: Srivastava *et al*., (2006).

4. Integrated nutrient management

The ultimate rationale of INM is, the judicious use of its all the three principal components viz., exploiting the existing synergism between dual purpose microbe (growth promoting as well as biocontrol agent against soil-borne pathogens) types with limited use of inorganic chemical fertilizers, triggering the multiplication of indigenous soil microbial diversity through a suitable substrate of organic origin, in such a way that the nutrients inflow always exceeds the nutrients flow leaving the system, besides ensuring the market favouring production economics. However, still there are many core areas where an urgent redressal is required in order to tag INM, a globally vibrant nutrient management strategy (Srivastava, 2009a, 2009b).

4.1. Abundance of microbial communities and diversity

Higher correlation of fruit yield with the population density of *Azotobacter* (r = 0.692, *p* = 0.01), ammonifiers (r = 0.512, *p* = 0.01), and phosphate solubilising bacteria (r = 0.618, *p* = 0.01) than with available N (r = 0.489, *p* = 0.01), P (r = 0.316, *p* = 0.05), and K (r = 0.321, *p* = 0.05) in soil, suggesting the possibility of using microbial biomass and its turnover as a potential diagnostic tool for soil fertility evaluation.

Various indices of soil fertility were correlated with fruit yield (Table 4) in order to develop multiple-tier system of soil fertility evaluation. The fruit yield was significantly correlated with available N (r = 0.532, *p = 0.01*), P(r= 0.412, *p = 0.01*), K (r = 0.389, *p = 0.05*), Fe (r = 0.508, *p = 0.01*), Mn (r = 0.489, *p = 0.01*), and Zn (r = 0.532, *p = 0.01*). While, bacterial and fungal count as an effective parameters of soil microbial population, were more significantly correlated with fruit yield (r = 0.561 and r = 0.612, *p = 0.01*). With correlation worked to further finer parameters such as soil microbial biomass nutrients (SMBN) viz., C_{mic} (r = 0.582, *p = 0.01*), N_{mic}(r = 0.692, *p = 0.01*) and P_{mic} (r = 0.698, *p = 0.01*) further improved, suggesting that microbial biomass nutrients are more sensitive indicators than soil microbial population. Similarly soil enzymes viz., urease (r = 0.712, *p = 0.01*), alkaline phosphatase (r = 782, *p = 0.01*) and dehydrogenase (r = 789, *p = 0.05*) were still highly correlated with fruit yield demonstrating their most sensitive nature to input response in soil fertility fluctuations. These parameters are currently being indexed for further refinement (Srivastava and Huchche, 2011).

Table 4
Relationship of fruit yield with different soil properties influencing fruit yield.

				Soil available nutrients			
	N	**P**	**K**	**Fe**	**Mn**	**Cu**	**Zn**
Yield	0.532**	0.412**	0.389*	0.508**	0.489**	0.312	0.532**
				Soil microbial population			
		Bacterial count				Fungal count	
Yield		0.561**				0.612**	
				Microbial biomass nutrients			
		C_{mic}		N_{mic}		P_{mic}	
Yield		0.582**		0.692**		0.698**	
				Soil enzymes			
		Urease		Alkaline phosphatase		Dehydrogenase	
Yield		0.712**		0.782**		0.799*	

- C_{mic}, N_{mic}, and P_{mic} stand for microbial biomass C, microbial biomass N and microbial biomass P, respectively.

4.2. Development of microbial consortium

Exploiting microbial synergisms is one of the popular methods of substrate dynamics and associated changes in nutrient environment of rhizosphere. A large number of microbes were isolated from rhizosphere of citrus orchards established on acid soils of northeast India, neutral alkaline soils of central India and northwest India. The microbial diversity existing within top 0-20 cm rhizosphere soil was characterized and isolated the promising microbes. These microbes comprised of N-fixers (*Azotobacter chroococcum* and *Azospirillum brasilens*), P-solubilizers fungi (*Trichoderma harzianum* and *T. viride*) and P-solubilizing bacteria viz., *Pseudomonas fluorescens, P. striata, Bacillus subtilis, B. mycoides, B. polymyxa, B. stearothermophilus, B. cereus, B. coagulans, B.*

licheniformis, B. circulans, B. pumilus, and *B sphaericus*. The efficient microbes isolated through soil (*B. polymyxa* 12 x 10^3 cfu /g, *P. fluorescens* 5 x 10^3 cfu /g, *T. harzianum* 12 x 10^3 cfu /g, *A.chroococcum* 16 x 10^3 cfu /g, and *B. mycoides* 3 x 10^3 cfu / g) were brought in broth in order to achieve much high population as a substantial value addition (*B. polymyxa* 33 x 10^7 cfu / ml, *P. fluorescens* 14 x 10^7 cfu / ml *T. harzianum* 32 x 10^7 cfu / ml, *A. chroococcum* 10 x 10^6 cfu /ml and *B. mycoides* 7 x 10^5 cfu / ml) known as microbial consortium. Different steps involved in developing microbial consortium could be summarised in Fig. 1.

4.3. Response evaluation

Different INM-based treatments involving microbial consortium so developed displayed distinctive advantage over exclusive use of chemical fertilizers in the nursery evaluation in terms of soil microbial biomass nutrients (C_{mic}, N_{mic} and P_{mic}) and carbon loading of soil besides bringing significant changes in soil fertility. Promising responses on both root and shoot weights were observed in nursery plants treated with MC compared to untreated plants (Table 5). These results suggested two cardinal points viz., i. the developed microbial consortium holds a good promise in possible INM format and ii. exclusive combination with inorganic fertilizers produced depleting effect of population buildup. The microbial consortium thus developed is currently being assessed through long term field study on development of suitable INM module.

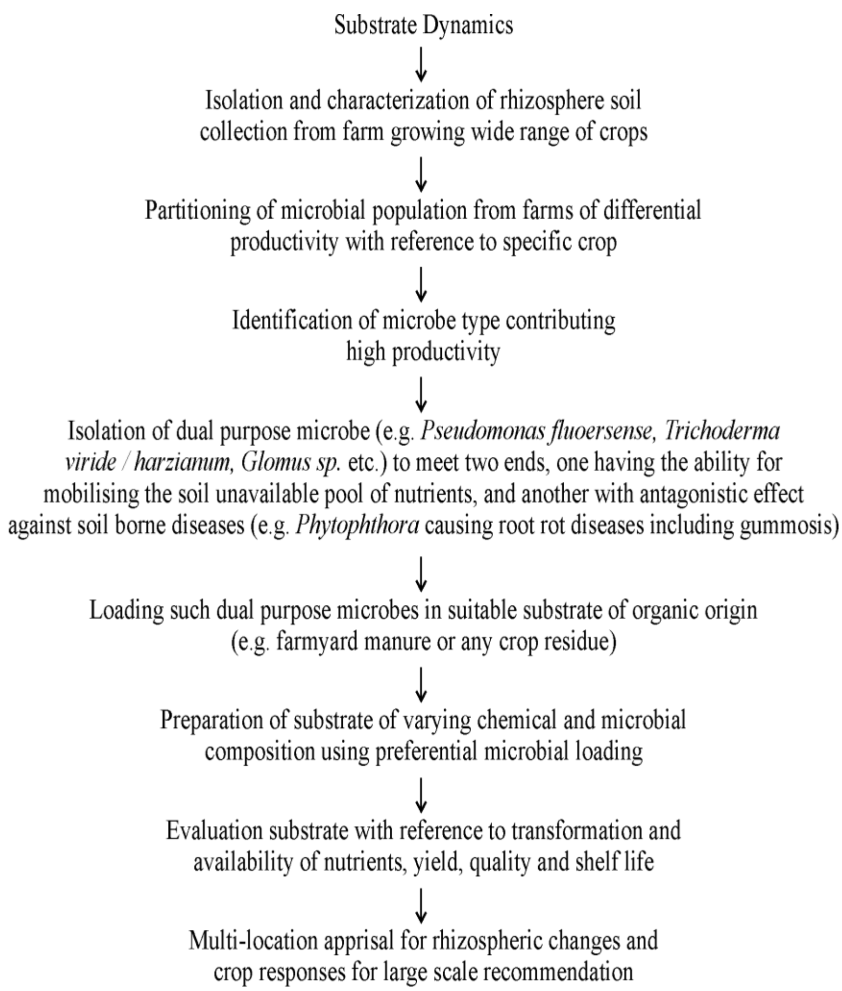

Fig. 1. Different steps involved in developing microbial consortium.

Under All India Coordinated Research Projects on Tropical Fruits, the concept of INM has been attempted across different regions with acid lime as test crop. The results are briefly summarized:

Inclusion of biofertilizers viz., AM, PSB, *Azospirillum* and *T.harzianum* at Akola 500, 100, 100 and 100 g/plant/year respectively along with 75% RDF (600 g N, 300 g P_2O_5 and 300 g K_2O /tree/year) has recorded higher yield (48.66 kg/tree for 810; 13.48 t/ha) with favourable growth attributes (plant height of 3.70 m and canopy spread of 21.93 m^3) and quality parameters (51.46% juice with 7.6°Brix TSS and 31.27 mg ascorbic acid/ 100 ml juice) in kagzi lime at Akola, Maharashtra.

Inclusion of biofertilizers viz., AM, PSB, *Azospirillum, T. harzianum* at 500, 100, 100, and 100 g respectively along with 100 % RDF has recorded higher yield (35.72 kg/tree having 731.6 fruits) and quality (juice content of 27.98 ml, TSS of 7.14° Brix, ascorbic acid of 35.36 mg/100 g) in Jai-Devi acid lime at Periyakulam, Tamil Nadu.

Source: Based on Report of AICRP on Tropical Fruits**,** Sidhu *et al*. (2011).

Table 5

Evaluation of microbial consortium in nursery plants.

Treatment	Root weight (g)	Shoot weight (g)	Root:shoot	Stem diameter (mm)
		Seedlings (Period : 45 days)		
Control	3.17	9.55	1:3.1	9.1
Treated	10.55	28.37	1:2.7	12.3
$t_{P = 0.05}$	5.2	6.9	-	1.86
		Buddlings (Period : 124 days)		
Control	4.27	10.3	1:2.4	22.1
Treated	11.3	24.5	1:2.1	29.3
$t_{P = 0.05}$	2.1	6.1	-	2.10

Source (Srivastava *et al*., 2010)

5. Emerging Issues

Despite many cutting edge technologies addressing a variety of core issues of nutrient management, many more issues are yet to be attempted which are highlighted as:

5.1. Role of improved plant nutrition on changes on anti-oxidant versus drought tolerance

These include**:** Field identification of different nutrient deficiencies and their profiling for different antioxidants; evaluation of changes in anti-oxidants in response to different nutrients in a progressive nutrient field experiment; and establishment of relation between antioxidant system with indices of drought tolerance.

5.2. Expansion of DRIS indices and their validation to different acid lime varieties and development of soil fertility diagnostics as per soil type

There are number of issues warranting their redressal. These are: **S**urvey and establishment of database for soil analysis, leaf analysis and fruit yield from across different belts; modelling for nutrient diagnostics vis-à-vis climate change; and validation of nutrient diagnostics.

5.3. Development of acid lime specific INM module and carbon sequestration vis-à-vis microbial turnover of nutrients and substrate dynamics versus nutrient transformation

Various issues could be highlighted as: Survey of cultivar specific citrus orchards and intensive collection of soil samples from rhizosphere zone; isolation and characterization of microbial diversity within cultivar specific rhizosphere; identification of promising microbes through incubation studies and development of microbial consortium; and evaluation of microbial consortium in INM module and recommendation for appropriate INM module depending upon region specific varieties.

5.4. Development of SSNM into Senor-based DSS (Decision Support System) for variable rate fertilization and improved fertilizer use efficiency

This is the most important as pect which can dealt in issues like: Development of spatial soil fertility variogram (by developing GPS and GIS database) as decision support tool for precision fertilizer recommendation ; development of SSNM strategy and evaluation through long term field experiments; development of logical relationship between canopy volume (using canopy sensors) and fertilizer requirement; and identification and evaluation of variable rate fertilization for possible improvements in fertilizer use efficiency through field experimentation.

5.5. Development of protocol for organic cultivation of acid lime

It consists of two very important components featuring: Identification of components of organic acid lime and nutrient profiling of available organic fertilizer sources of manures and field evaluation of organic practices involving nutrition, insect pests and disease/management alongwith influence on post-harvest handling and processing.

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