Annals of Plant and Soil Research 26(2): 175-183 (2024)
https://doi.org/10.47815/apsr.2024.10349

Citrus nutrition research in northeast India: An overview

L.D. SHARMA[1] AND A.K. SRIVASTAVA[2]

[1]College of Horticulture, Central Agriculture University, Thenzawl, Mizoram

Received, March, 2024; Revised accepted, May, 2024

ABSTRACT

History of citrus growing in northeast India is as old as the tradition of citrus as its natural home of citrus hots-spots. Unfortunately, citrus of late is being tagged highly uncomfortable in its natural homeyard in northeast India, with some exceptions in Garo hills of Meghalaya and Pasighat of Arunachal Pradesh. Multiple nutrient deficiencies backed up by staggering nutrient mining have made citrus suffer from both production as well as quality issues, besides other issues of early onset of citrus decline and reduced post -harvest shelf life. Such depleted production incentives have put citrus growing on back-foot. Distinct absence of nutrient diagnostics coupled with lack of balanced fertilization have further hiked the miseries of citrus growers in the region. Citrus -based Soil health Card is another missing link putting citrus growers always managing their citrus orchards with complete guess-work, a complete sorry-state-of-affair, unless something too early and too quickly is done in this direction before it becomes too late and too little. Research need a complete reorientation in their objectivity of citrus nutrition with an eye on organic citrus integrating agroecological considerations using strictly adopted on-farm citrus module coupled with contingency irrigation planning by holding surplus rain-water.

Keywords: Citrus, northeast India, organic citrus, rain water, multiple nutrient deficiencies, nutrient mining

INTRODUCTION

Khasi mandarin (*Citrus reticulata* Blanco) a high quality loose skinned mandarin variety, covers the largest area in the region and confined mostly to submontane, with limited area in the hills up to an altitude of about 1000m above mean sea level (Srivastava and Singh , 2008a ; 2008b ; 2008c) . Growing Khasi mandarin in Mizoram is no different than any other hill state of northeast India (Srivastava and Bora, 2023; Srivastava and Pongener, 2023). The major citrus belts of Mizoram comprise of Kolasib, Tawitaw, Aizawl, Thingdawal, Hachhek, Hangdung, Mawait, Pukui, Phuldungsei etc. Diagnosis of nutrient constraints and their management are the two pillars of successful nutrient management program (Srivastava and Das, 2017; Srivastava *et al.,* 2007). Most of the Khasi mandarin citrus is concentrated in the hills with some citrus in valley lands. The temperature in these hills fluctuates between18^0 - 26^0 C in summer and 7^0 - 14^0 C in winter. Whereas, in the valleys and lower hills, it ranges from 22^0 - 31^0 C in summer and 15^0 t- 18^0 C in winter with perhumid climate receiving around 2900 mm annual rainfall on an average (Srivastava and Patil, 2014). Hill soils of Mizoram representing various altitudes (250-1700 m) showed a distinct horizonation with clear differentiation and highly leached surface horizon, strongly acidic in reaction (4.1-5.1), low in soluble salts (EC 0.14 x 10^{-4}- 0.036 x10^{-3} mmhos /cm), free of $CaCO_3$, CEC in range of 5.6-13.0 me $100g^{-1}$ distribution of exchangeable ions in the order of H^+>Al^{3+} > Ca^{2+} Mg^{2+}> K^+ Na^+, and base saturation of less than 50 % (Srivastava *et al.,* 2010; Srivastava and Das, 2017 ; Malhotra and Srivastava , 2023) typical features of soils represented by Entisols, Inceptisols, Alfisols and Ultisols predominantly cultivated for citrus.

Guides for nutrient constraints identification

The major breakthroughs have come though leaf analysis and soil analysis standards backed up by deficiency symptomologies:

Leaf nutrient guide: The concentration of different nutrients in leaf showed a significant difference at various yield levels, except Fe and Mn (Srivastava, 2015; 2023a). The variation in optimum values are dominantly governed by site specific conditions including the nature of soil type even if the cultivar is same over a range of growing conditions (Table 1).

[2]*Corresponding email: aksrivas2007@gmail.com, ICAR-Indian Agricultural Research Institute, Dhemaji, Assam*

Table 1: Leaf nutrient guide for Khasi mandarin grown in hill states of northeast India

Nutrients	Leaf nutrient indices				
	Deficient	Low	Optimum	High	Excess
N(%)	< 1.67	1.67 – 1.96	1.97 - 2.56	2.57 - 2.85	> 2.85
P(%)	< 0.06	0.06 - 0.08	0.09 - 0.10	0.11 - 0.13	> 0.13
K(%)	< 0.52	0.52 - 0.98	0.99 - 1.93	1.94 - 2.40	> 2.40
Ca(%)	< 1.72	1.72 - 1.96	1.97 - 2.49	2.50 - 2.75	> 2.75
Mg(%)	< 0.14	0.14 - 0.23	0.24 - 0.48	0.49 - 0.54	> 0.54
Fc(ppm)	< 22.6	22.6 - 84.5	84.6 - 249.0	249.1- 331.3	> 331.3
Mn (ppm)	< 18.6	18.6 - 41.5	41.6 - 87.6	87.7 - 110.6	> 110.6
Cu (ppm)	< 1.83	1.83 - 2.12	2.13 - 14.4	14.5 - 20.6	> 20.6
Zn (ppm)	< 11.1	11.1 - 16.2	16.3 - 26.6	26.7 -31.8	> 31.8
Yield(kg/ tree)	< 19.1	19.1 - 31.5	31.6 - 56.3	56.4 - 68.8	> 68.8

Soil fertility guide: The soil fertility standards developed exclusively for Khasi mandarin orchards can be effectively used for fertility evaluation of citrus growing soils (Table 2). These values fit well with the range of values obtained for high performance mandarin orchards having fruit yield of 45-62 kg /tree (Srivastava, 2013a; 2013b; 2013c). The observations suggest that soil test or leaf analysis values of high yielding elite mandarin orchards could well serve as reference (Srivastava, 2010a).

Table 2: Soil fertility guide developed for Khasi mandarin grown in hill states of northeast India

Parameters		Soil fertility indices			
	Deficient	Low	Optimum	High	Excess
pH	< 4.5*	4.5 – 5.0	5.1 - 6.2	6.2 - 6.8	> 6.8
Organic c (g/ kg)	< 8.6	8.6 – 15.6	15.7- 32.5	32.6 - 50.2	> 50.2
N (mg /kg)	< 82.1	82.1 – 160.9	161.0 – 418.7	418.8 – 547.6	> 547.6
P (mg /kg)	< 2.3	2.3 – 4.4	4.5 – 8.7	8.8 – 10.9	> 10.9
K (mg/ kg)	< 20.3	20.3 – 82.2	82.3 – 287.5	287.6 – 390.2	> 390.2
Ca (mg/ kg)	< 80.4	80.4 – 148.7	148.8 -285.4	285.5 – 353.7	> 353.7
Mg (mg/ kg)	< 4.7	4.7 – 31.2	31.3 - 84.4	84.5 – 111.0	> 111.0
Fe (mg/ kg)	< 31.4	31.4 – 39.4	39.5 – 180.9	181.0 - 251.6	> 2581.6
Mn (mg/ kg)	< 8.9	8.9 – 26.9	27.0 – 80.3	80.4 – 116.1	> 116.1
Cu (mg/ kg)	< 0.53	0.53 – 0.66	0.67 – 2.90	2.91 – 4.09	> 4.09
Zn (mg /kg)	< 2.17	2.17 – 2.83	2.84 -5.14	5.15 – 8.70	> 8.70
Yield (kg/ tree)	< 19.1	19.1 – 31.5	31.6 – 56.3	56.4 – 68.8	> 68.8

**To be treated as very low*

Deficiency symptoms: A great variety of deficiency symptoms based on morphological changes in leaf and fruit have been suggested which are summarized below (Srivastava *et al.,* 2007) :

- Deficiency symptoms of nitrogen are characterized by general nature of the yellowing of foliage over the entire tree without any distinctive pattern of leaf symptoms. Deficiency symptoms of phosphorus are characterized by leaves smaller in size and narrow with purplish or bronze, coupled with lusterless discoloration and large hallow centre (Srivastava and Singh, 2009). The core of fruits .Potassium deficiency symptoms are seen in form of leaf pattern showing yellowing of tips and margins, yellow area then gets broader, necrotic areas develop on leaves, more prominently on older leaves, reduced fruit size with very thin peel of smooth texture and pre-mature shedding of fruits having lower acidity (Srivastava *et al.,* 2008) .
- The Ca- deficiency symptoms are characterized by fading of chlorophyll along the leaf margins and between the main veins with twig dieback, multiple bud growth of new leaves coupled with undersized and misshapen fruits .The deficiency symptoms

of Mg are characterized by irregular yellow blotches on either side of mid-rib, later the yellow area enlarges until only the tip and the base of the leaf are green showing an inverted V- shaped area pointed on the mid-rib (Srivastav and Singh, 2003a; 2003b) .

- The Fe- toxicity is most common and easily characterized by accretions developed along the mid- rib and veins of the leaves. while, rest of leaf area remains green .The deficiency symptoms of Mn are characterized mainly by the fine network of interwoven green veins in the yellow background .The symptoms of Zn-deficiency are marked by the appearance of resetting, premature shedding, whitish chlorotic streaks between veins in older pointed leaves, bands along the mid –rib and main vein on a background of light yellow to almost white are characterized by wilting of terminal shoots, fruits showing brown stained areas of hardened gum on the rind of the fruit often precedes the appearance of leaf and twig symptoms (Srivastava *et al.,* 2022). The symptoms of B-deficiency are indentified by shortened internodes of terminal shoots, usually form resetting in addition to apical meristems turn blackened and later die coupled with impaired flower development and seed production. The symptoms of Mo- deficiency are seen as yellow spots with deposits of brown gum on the lower leaf surface which would turn black (Srivastava and Singh, 2004a).

Distribution of nutrient constraints

Differential response of citrus cultivars to various kinds of nutritional stress is more or less a commonality (Srivastava. Using the diagnostics developed for soil fertility showed that Ca was low in as many as 85% orchards followed by Mg (83.3%), P (74.1%), Cu (33.3%), and K (20.3%). While, using the leaf analysis norms, most of the orchards (79.7 – 82.4%) were low in Ca and Mg.

Table 3: Frequency distribution (%) of nutrient constraints in khasi mandarin grown in hill states of northeast India

Nutrients	Distribution pattern (%)		
	Low	Optimum	High
Soil fertility constraints			
N	14.8	55.5	29.7
P	74.1	85.5	7.4
K	20.3	70.4	9.3
Ca	85.2	14.8	-
Mg	83.3	16.7	-
Fe	-	3.7	96.3
Mn	13.0	18.5	68.5
Cu	33.3	20.4	46.3
Zn	7.4	9.3	83.3
Leaf nutrient constraints			
N	48.1	22.2	29.7
P	81.5	14.8	3.7
K	27.8	64.8	7.4
Ca	79.7	20.3	-
Mg	82.4	17.6	-
Fe	-	1.8	98.2
Mn	22.2	25.9	51.8
Cu	44.5	18.5	37.0
Zn	77.8	16.7	5.5

Phosphorus was observed low in as many as 81.5% orchards on account of most of the readily available P being fixed as Fe- and A1-phosphates invariably in entire aci soils of northeast India. . Soils in the region being highly acidic in nature, the slow release source of P like rock phosphate or basic slag hold the most promising choice (Srivastava, 2015). Most of the micronutrients viz., Fe, Mn, Cu and Zn were high in 96.3, 68.5, 46.3, and 83.3% orchards, respectively. However, these figures showed not much variation when interpreted on the basis of leaf analysis except Zn. As many as 77.8% orchards were observed to test low in Zn concentration (Table 3).

The Zn-deficiency apparently visible is in-fact the Fe induced Zn-deficiency. These multi-nutrient deficiencies are the biggest bottleneck to improved production. The northeast India is nearly a natural farming region, and organic farming is more of a tradition than convention. It has to be therefore, specifically seen that how best these nutrient constraints could be addressed within the preamble of organic culture of citrus if the use of organic sources is to be preferred over chemical fertilizers. Extensive surveys carried out previously in Thangal village, Nungba sub-division, Tamenglong district, Manipur (2010–2011) on 40 khasi mandarin orchards highlighted critical nutrient constraints, including N, P, Ca, Mg, Cu, and Zn. These findings underscore the importance of incorporating these elements into fertilizer programs for sustained optimal fruit yield in mandarin orchards in the region (Sarangthem *et al.,* 2014), something warrant seriously to be addressed.

Addressing multiple nutrient deficiencies

The cultural practices are the key issue to arrest loss of top fertile soil from terraced citrus orchards on sloppy lands. The first step in this regard is the *in situ* methods, especially contour planting of trees. Deep ploughing is not advisable in these areas, as it tends to loosen top soil too much, and make it vulnerable to erosion. In fact, for light soils in hilly areas, zero tillage is recommended. Depending on the slope, rainfall intensity and soil properties, well-known measures like bunding, terracing, plugging and strengthening of slides of gullies etc. have proved effective in citrus orchards (Jeyabaskaran *et al.,* 2023). Mulching is also known to reduce the impact of rain and check erosion. The easily decomposable live mulches locally available are effectively used to combat such twin problem (Srivastav and Singh, 2007). The upper ridges of the hills should be under perennial plantations to reduce the initial velocity of run-off water down the slope.

Macronutrient application: In the context of prevailing practices, hardly any citrus orchard receives fertilizers according to its requirement and as such, no fertilizer schedules for different citrus cultivars have been worked out on scientific lines. Khasi mandarin orchards showed different optimum fertilizer doses. Studies carried out by ICAR Research Complex for NEH Region, Barapani at Umiam, Meghalaya showed 300 g N + 250 g P_2O5 + 300 g K_2O was economical fertilizer dose in the experiment on rejuvenation of declining Khasi mandarin orchard. But, the best fertilizer dose consisted of 400 g N + 250 g P_2O_5 + 400 g K_2O. It is most important to remember that fertilizer rates considered as optimum, can still result in nutrient depletion at higher productivity levels, if continued, become sub-optimum rates. Higher fertilizer recommendations are given based on higher productivity of well grown big trees (Table 4).

Table 4: Fertilizer schedule for khasi mandarin orchards adopted in northeast India (though such schedules are periodically subjected to revision depending upon soil fertility paradigm changes and plants budded or seedlings in origin)

Measures/ Fertilizers	Age of trees (years)							
	I	II	III	IV	V	VI	VII	VIII
FYM (Kg/plant)	5	10	15	20	25	30	30	30
Urea (g/plant)	200	400	600	800	850	1000	1200	1300
SSP (g/plant)	600	900	1200	1500	1800	2400	2700	3000
MOP (g/plant)	200	400	500	600	800	900	1100	1200

FYM (Farmyard manure), SSP (single superphosphate) and MOP (Muriat of potash)

Micronutrients application: An encouraging response of different micronutrients on Khasi mandarin has been invariably obtained. Positive effects of various other nutrients like B, Mg and certain combinations of Zn, Cu, Mg and Ca on yield of Khasi mandarin could be easily obtained. A micronutrient doses of 200 g $ZnSO_4$ + 100 g $CuSO_4$ + 50g each of borax and ammonium molybdate to be enriched with 5-10 kg farmyard manure or alternatively any other manure, incubated for 8-10 days and thereafter should be applied either in half moon trenches or within the skirtbelt of trees established on terraced land treated earlier each tree with 5-10 Kg of dolomite. Sometimes, nutrient enriched manures are filled up in inverted V-shaped trenches made in the upper elevated half portion of trees in order to facilitate regulated movement of nutrients (Srivastava *et al.,* 2002).

Comparisons on efficacy of foliar spray versus soil application of micronutrients have shown sustained effectiveness of soil application. While, foliar application in most of the cases has been effective for a short duration since a substantial concentration of micronutrients especially Zn has to be ensured in the roots to facilitate smooth movement of auxin-Zn complex acropetically and besipetal movement of Zn-auxin complex from foliage to roots to very slow in case of foliar application (Srivastava *et al.,* 2007).

Stress on organic citrus

Organic manures play a critical role in both short-term nutrient availability and long-term maintenance of soil organic matter vis-à-vis production sustainability, especially in small holder farming systems. Despite this importance, there is little predictive understanding for the management of organic inputs is different agrosystems (Srivastava *et al.,* 2002). Crop yields are a fundamental factor of economic success, and depend very much on N fertilization. A crucial question is how to guarantee optimum nutrition along with production on a sustained basis by organic measures only. Application of 25-30 kg vermicompost in two splits (One half with preliminary monsoon showers and second half into later half of monsoon period) has shown an improvements in canopy growth, fruit yield, fruit quality parameters (Juice content, total soluble solids and acidity content), soil carbon loading, better post-harvest shelf life of fruits. Green manuring was more effective compared to vermicompost, FYM poultry manure or inorganic fertilizers (Srivastava and Singh, 2004b; 2005).

Exploiting microbial synergisms is one of the popular methods of substrate dynamics and associated changes in nutrient environment of rhizosphere to finally fit into value added microbially enriched organic manures. Growth promoting microbes were isolated from rhizosphere (0-20 cm) for development of Microbial Consortium through extensive soil sampling (from the rhizosphere of as many as 110 plants) at the experimental site. The microbial diversity existing within rhizosphere soil was isolated following standard procedures, and characterized the promising microbes for their nutrient mobilizing capacity through laboratory-based incubation study using the same experimental soil. The efficient microbes viz., *Micrococcus yunnanensis* (Asymbiotic N-form*), Bacillus pseudomycoides* (K-solubilizer), *Paenibacillus alvei* (P-solubilizer), *Acinetobacter radioresistens* (P-solubilizer) and *Aspergillus flavus* (P-solubilizer) were identified. Pure culture of these microbes in value added form was developed in broth, and prepared a mixture called Microbial Consortium9 Srivastava *et al.,* 2017). The compatibility amongst these microbes was tested by thoroughly their population dynamics in consortium mode which showed no antagonism amongst them (Srivastava, 2010b; 2012; Srivastava and Das, 2014) .The microbial consortium, thus, developed was tested under different Integrated Nutrient Management-based combinations. Results showed some exciting improvements in soil health in terms of microbial community build-up and microbial biomass nutrients besides crop growth and fruit yield, besides carbon sequestration as evident from lesser magnitude of carbon dioxide release from the inoculated plant rhizosphere than bulk soils (Joseph *et al.,* 2015). This consortium holds a very good promise in khasi mandarin (Srivastava *et al.,* 2015; 2014).

Regenerative citriculture, a new look

While considering the sustainability of citrus in northeast India, land degradation neutrality has been one of the major challenges inviting an invitable coalition of conventional and traditional farming through regenerative citriculture (Keditsu and Srivastava, 2014). In a way , regenerative agriculture (no legal or regulatory definition of term “regenerative agriculture” exists nor has a wide accepted definition emerged in common usage) is firmly rooted to the same basics of modern form of agriculture (using conservation and rehabilitation approach for sustaining the top soil fertility functions, frequently coined as quite opposite to conventional agriculture), addressing core issues like natural resource conservation, soil microbial diversity, resilience against forging climate change, expanding water intake capacity, scavenging soil contaminants, usage of cover crops (field buffers and plant strips on contours) for reduced run-off loss and maintaining the environmental health as well, but it emphasizes more firmly the rejuvenation of depleted land from physical , biological and chemical barriers restricting the targeted optimised crop agronomy and aid further in recuperating the full potential for crop carrying capacity of a given land or land use in a farming system module (Srivastava, 2012). Regenerative agriculture vis-à-vis citriculture recognizes all sustainable practices those affect the natural systems and uses all the management techniques to restore the system towards improved crop productivity. Despite these accruing benefits, regenerative agriculture is often associated with number of disadvantages like need for new knowledge and skills, excessive weeds infestation and potentially lower crop yields (Srivastava, 2023b). However, regenerative agriculture is applicable to all types of farms, big, small or organic in nature. The term “Regenerative Agriculture” came into existence by Robert Rodale Institute in 1980s. India made some modest contribution to realise the strength of this form of sustainable agriculture through i. national project on organic farming , ii. systematic rice intensification and iii. zero budget natural farming.

Regenerative agriculture in the backdrop of citrus growing also into account towards sequestering atmospheric carbon into the annual/perennial framework of crops as well as soil , so that atmospheric CO_2 offset is exercised through two-way process, offering carbon neutral approach amidst climate change (Srivastava, 2010b; 2023b).The importance of regenerative agriculture was prominently emphasized in Intergovernmental Panel on Climate Change enlisting ecological functions in building resilience of agroecosystems as climate –smart regenerative agriculture. Regenerative citriculture is very often synonymously compared with organic citriculture (Kohli *et al.,* 1998). Both the concepts have some difference with a common goal of outcomes on ecological balance and biological diversity, leading to emergence of another concept called regenerative organic agriculture. The regenerative agriculture (about principles not practices as adaptive management approach supported by soil health principles) is based around observable improvements in ecological and social function of the farm and farming community, while organic agriculture(prescriptive standards for crop production) is more about a set of rules to follow with major emphasis on avoidance of agrochemicals. Interestingly, the technique of cover cropping as a part of regenerative agriculture, the definition remains murky, and many other beneficial practices are in a grey area covering the legal definitions, certification and clear methods of measurements and monitoring. On the other hand, organic farming may not have a specific definition, but certifications at least provide a clear understanding about the required practices to adopt (Srivastava *et al.,* 2002).

While comparing regenerative agriculture with organic agriculture, we comprehensively overlook the harmful effects of organic pesticides, could be even more harmful than synthetic pesticides in organically produced fruits and vegetables for example as wide spread myth. Are natural pesticides safer than artificial pesticides?. The candid answer is, not necessarily. Comparing copper sulphate and pyrethrum with synthetic pesticides like chlorpyrifos or chlorothalonil, the former have more acute and chronic toxicity over latter group of pesticides. Likewsie, Bt insecticides producing natural toxins, of late have shown som symptoms of toxicity to wetland crops. The other group represented by spinosad and abamectin , the organic pesticides at lower doses are reported triggering lysosomal defects , elevated accumulation reactive oxygen species, lipid dysregulation and neurodegeneration to non-target insects. These scientific outcomes put an alarm bell to researchers and policy makers to keep a regular guard on health of agro-ecosystem, the modus-operandi of which need to be developed and put to stringent practice.

Role of organic manures and composts, biochars and terra preta, no till and pasture cropping, annual organic cropping, holistic management of grazing, ecological aquaculture, perennial cropping, silvipasture and agroforestry, all aid in developing a sound success of regenerative agriculture (Malhotra and Srivastava, 2023). Of late, some novelties have emerged suiting to regenerative agriculture, comprising microbial consortium (developing synthetic microbes using synonymous molecules of secondary metabolites secreted by different microbes participating in both plant grwioth regulation as well as microbial bioagents) exploiting varied microbial niches of phytobiome to develop microbes- mediated crop production system, rhizosphere hybridization for developing more biochemically active rhizosphere through elevated loading of active and novel microbes, on-farm organic module for organic farm waste recycling and exploiting the rhizosphere and endosphere microbial diversity , in addition to bioprospecting microbiome for soil health-plant health management addressing both soil fertility constraints and plant diseases as a value –chain –management of microbes (Srivastava *et al.,* 2022) . Development of crop-based soil health card addressing biological improvements in soil health in response to regenerative agriculture is another futuristic pivotal agenda (Srivastava and Bora, 2023).

When no legitimate definition of regenerative agriculture (no doubt, it seeks to rehabilitate and enhance agro-ecosystem as a whole) is offered, it is every likely that the punch of outcomes of such practices could be diluted over time, thereby goes to extinction or overtaken by some other concept, since many of terms like agro-ecological farming, alternate agriculture, alternate, sustainable agriculture, nature inclusive agriculture , green agriculture, biodynamic agriculture etc are often used synonymously to challenge the outcomes of regenerative agriculture (Jeyabaskaran *et al*., 2021; Srivastava, 2023b). Unless, we adhere to such policy regulations, we will not be able to harness the real impact of regenerative agriculture as holistic approach and make further inroads through scientific funding and pan-India collaborative research networking. Sooner we do it , better it is for the future health of contemporary agriculture (expanding agriculture to newer land is almost bare minimum and arresting further land degradation with lowered carbon-and water foot-prints is a numero-uno priority of policy makers). Therefore , a complete technical and scientific dos and don't with clear-cut policy paper on regenerative citriculture in Indian context is the call of the day, considering our current agriculture system is already so over-worked , over-used and depleted.

REFERENCES

Jeyabaskaran, K. J., Shirgure, P. S., Srivastava, A.K., Pandey, V. and S. Uma (2021) Fertigation in horticulture : A guarantee to economized quality production . *Indian Journal of Fertilizers*. **17**: 3:4-383.

Joseph, M.H., Dhargave, T.S., Deshpande, C.P. and A.K. Srivastava (2015) Microbial solubilisation of phosphates ; Pseudomonas versus Trichoderma. *Annals of Plant and Soil Research*. 17(3): 227-32.

Keditsu, R. and A.K. Srivastava (2014) Substrate dynamics: Developments and issues. *Annals of Plant and Soil Research.* **16**(1): 1–8.

Kohli, R. R., Srivastava, A. K. and V. J. Shivankar (1998) Organic culture in citrus cultivation. *Indian Horticulture.* **43**: 12-15.

Malhotra, S. K. and A.K.Srivastava (2023) Horticulture research amidst current challenges in northeast India. *Indian Horticulture*. **68**(6): 4-5.

Sarangthem,I,, Sharma, L. D. and A.K. Srivastava (2014) Development of nutrient diagnostic technique for Khasi mandarin (Citrus reticulata Blanco) Grown in Manipur. *Journal of the Indian Society of Soil Science*. **62**(2): 118-125.

Srivastava, A. K. (2010a) Integrated nutrient management in citrus: Frontier developments. *Indian Journal of Fertilizers*. **6**: 34-44.

Srivastava, A. K. (2010b) Development of integrated nutrient management to harmonise with improved citrus production. *Advances in Plant Physiology*. **12**: 294-368.

Srivastava, A. K. (2012) Integrated nutrient management in citrus. (*In) Advances in Citrus Nutrition,* pp 369-89. Srivastava A K. (Ed). Springer-Verlag, The Netherlands.

Srivastava, A. K. **(**2013a. Nutrient deficiency symptomology in citrus: An effective diagnostic tool or just an aid for post–mortem analysis. *Agricultural Advances*. **2**:177-94.

Srivastava, A.K. (2013b) Site specific nutrient management in citrus. *Scientific Journal of Agricultural (Agricultural Advances).* **2**:1-15.

Srivastava, A.K. (2013c) Nutrient diagnostics in citrus: Are they applicable to current season crop. Agrotechnology*.* **2**: 104-05. (Doi.10.4172/2168P-9881.1000e104).

Srivastava, A. K. (2015) Nutrient diagnostics in citrus: Are they applicable in current season crop. *Agrotechnology* **2**,104-105.

Srivastava, A. K. (2023a) Integrating natural farming with agroecology for soil health care under fruit production system. *Annals of Plant and Soil Research*. **25**(4): 524-533.

Srivastava, A.K. (2023b) Agroecology and sustainable citriculture. *Open Access Journal of Agricultural Research.* **9**(1): doi: 10.23880/oajar-16000346.

Srivastava, A.K. and P. Bora (2023) Multiple dimensions of agroecology in sustaining agriculture. *Indian Farming*. **73**(6): 524-533.

Srivastava, A.K. and S. N. Das (2017) Nutrient optima-based productivity zonality and rationale of fertilizer use in citrus. In; Sustainable Management of Land Resources. Apple Academic Press, USA. pp. 717-738.

Srivastava, A.K., Das, A.K., Jagannadham, P.T.K., Bora, P., Ansari, F.A. and R. Bhate (2022) Bioprospecting soil and plant health management amidst huanglongbing threat in citrus; a review. *Frontiers in Plant Science*. **13**: 858-842.

Srivastava, A.K., Das, S.N., Malhotra, S.K. and K. Majumdar (2014) SSNM-based rationale of fertilizer use in perennial crops; a review. *Indian Journal of Agricultural Sciences*. **84**(1): 3-1

Srivastava, A. K. , Huchche, A. D., Lallan ,Ram. and S. Singh (2007). Yield prediction in intercropped versus monocropped citrus orchards. *Scientia Horticulturae* **114**: 67-70.

Srivastava, A.K. and S. K. Malhotra (2017) Nutrient use efficiency in perennial fruit crops- a review. *Journal of Plant Nutrition*. **40**(13): 1928-1953.

Srivastava, A. K., Malhotra, S. K. and N.K. Krishna Kumar (2015) Exploiting nutrient-microbe synergy in unlocking productivity potential of perennial fruits: A review. *Indian Journal of Agriculture Sciences.* **85**(4): 459-81.

Srivastava, A. K. and P. Patil (2014) Soil fertility indexing in acid lime grown on smectite rich soils. *Annals of Plant and Soil Research.* **16**: 25-28.

Srivastava, A.K. and A. Pongener (2023) Asian citrus: a meta-analysis on soil fertility and plant nutrition constraints. *Annals of Plant and Soil Research*. **25**(3): 345-352.

Srivastava, A. K . And S. Singh (2003a) Soil-plant nutrient limits in relation to optimum fruit yield of sweet orange (*Citrus sinensis* Osbeck) cultivar Mosambi. *Indian Journal of Agriculture Sciences.* **73**(4)**:** 209-11.

Srivastava, A.K. and S. Singh (2003b) Plant and soil diagnostic norms for optimum productivity of Nagpur mandarin (*Citrus reticulata* Blanco). *Fertilizer News* .**48**(2): 47-63.

Srivastava, A. K. and S. Singh (2004a) Soil and plant nutritional constraints contributing to citrus decline in Marathawada region, India. *Communications in Soil Science and Plant Analysis.* **35**(17/18): 2537-2550**.**

Srivastava, A.K. and S. Singh (2004b) Zinc nutrition, a global concern for sustainable citrus production*. Journal of Sustainable Agriculture.* **25**(3): 5-42.

Srivastava, A. K. and S. Singh (2005) Diagnosis of nutrient constraints in citrus orchards of humid tropical. *Journal of Plant Nutrition.* **29**(6): 1061-1076.

Srivastava, A.K. and S. Singh (2006) Citrus nutrition and biochemical markers. *Journal of Plant Nutrition.* **29**(5): 827-55.

Srivastava, A.K. and S. Singh (2007) DRIS-based nutrient norms for Nagpur mandarin (*Citrus reticulata Blanco*). *Indian Journal of Agriculturale Sciences* **77**(6): 363-65

Srivastava, A. K. and S. Singh (2008a) Analysis of citrus orchard efficiency in relation to soil properties. *Journal of Plant Nutrition.* **30**: 2077-2090.

Srivastava, A. K. and S. Singh (2008b) Citrus nutrition research in India: Problems and prospects. *Indian Journal of Agriculture Sciences.* **78**: 3-16.

Srivastava, A.K. and S. Singh (2008c) DRIS norms and their field validation in Nagpur mandarin (*Citrus reticulata* Blanco). *Journal of Plant Nutrition.* **31**, 1091-1097.

Srivastava, A. K. and S. Singh (2009) Citrus decline: Soil fertility and plant nutrition. *Journal of Plant Nutrition.* **32**(2): 197-45.

Srivastava, A. K., Singh, S. and L. G. Albrigo (2008) Diagnosis and remediation of nutrient constraints in Citrus. *Horticulture Reviews.* **34:** 277-64.

Srivastava, A. K., Singh, S. and R.A. Marathe (2002) Organic citrus: Soil fertility and plant nutrition. *Journal of Sustainable Agriculture .***19**(3): 5-29.

Srivastava, A. K., Singh,S.and K.N. Tiwari (2007) Diagnostic tools for citrus: Their use and implications in India. *Better Crops* – India. **1**: 26-29.

Srivastava, A.K., Singh, S., Das, S.N. and H. Singh (2010) Delineation of productivity zones in mandarin orchards using DRIS and GIS. *Better Crops* – South Asia. **4**: 13-15.