Leaf Analysis in Citrus-Recent Development

Research & Reviews: A Journal of
Agricultural Science and Technology
ISSN: 2278-2206 (Online)
ISSN: 2349-3682 (Print)
Volume 10, Issue 2, 2021
DOI (Journal): 10.37591/RRJoAST
http://sciencejournals.stmjournals.in/index.php/RRJoAST/index
Review RRJoAST

Leaf Analysis in Citrus: Recent Development

L. Devarishi Sharma[1,*], Indira Sarangthem[2], Rahul Sadhukhan[3], Rojeet Thangjam[4], Y. Herojit Singh[5], C.G. Sawant[6], Lalhmingsanga[7], R. Lalrinfeli[8]

Abstract

This article encompasses nutrient diagnosis through leaf analysis and leaf nutrient composition. The corresponding leaf nutrient values expressed in % were: N (2.23–2.49), P (0.10–0.11), K (1.86–2.12), Ca (2.12–2.32), Mg (0.28–0.38), and in ppm Fe (148.2–179.8), Mn (72.2–84.8), Cu (10.4–18.6), and Zn (24.2–38.8) representing eight states viz., West Bengal, Sikkim, Assam, Meghalaya, Tripura, Mizoram, Arunachal Pradesh, and Manipur. Nutrient constraints in the form of nitrogen, phosphorus, calcium, magnesium, copper and zinc through leaf nutrient diagnostics tools were diagnosed. It finds a due place in the region's fertilizer program of mandarin orchards to obtain sustainable optimum fruit yield. While through leaf analysis in Manipur, DRIS indices revealed different nutrients to be ordered as zinc < phosphorus < calcium < magnesium < nitrogen < potassium < iron < manganese <copper.

Keywords: DRIS, leaf nutrient diagnosis, Khasi mandarin, NE India.

INTRODUCTION

Globally, citrus is one of the essential fruit crops being cultivated in an area of 3.35 million ha, with a total production of 91 million tons. The current average productivity of citrus orchards in India is 8.9 tons ha^{-1} compared to 4.52 tons ha^{-1} obtained in northeast India [1–6]. The region is historically believed to have witnessed the citrus distribution to other parts of the globe. In northeast India, cultivation of Khasi mandarin (*Citrus reticulata* Blanco) is mainly limited to the mid-hills, up to an elevation of 1200 meters above mean sea level, in a humid tropical climate Soil orders such as Alfisol, Oxisol, Ultisol, Entisol, and Inceptisol constitute the maximum volume of production harvested globally [7–12]. As a result, orchards continue to generate below-optimal yields as the gap between the amounts of nutrients given and annual requirement widens with orchard age. The threat of the problem has been intensified by the growth of citrus orchards on steep slopes without contour trench planting or terracing, exposing the comparably more acidic and barren sub-surface with low nutrient reserve to sustain the required nutrition of plants [1, 13–17]. Leaf and soil-based nutrient standards have proven to be superior to other diagnostic procedures among the many diagnostic tools [18–22].

***Author for Correspondence**
L. Devarishi Sharma
E-mail: rambosharmalaimayum0@gmail.com

[1]Assistant Professor, Department of Soil Science and Agricultural Chemistry, MTTC & VTC, Mizoram, (CAU-Imphal),
[2]Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Iroisemba, CAU, Imphal,
[3]Assistant Professor, Department of Agronomy, MTTC & VTC, Mizoram, (CAU-Imphal)
[4,8]Assistant Professor, Department of Entomology, College of Horticulture, Thenzawl, Mizoram (CAU, Imphal)
[5]Subject Matter Specialist, Krishi Vigyan Kendra (KVK), East Garo Hills, Meghalaya (CAU, Imphal)
[6]Assistant Professor, Department of Plant Protection, MTTC & VTC, Mizoram, (CAU-Imphal)
[7]Assistant Professor, Department of Vegetable Science, MTTC & VTC, Mizoram, CAU-Imphal)

Received Date: September 30, 2021
Accepted Date: October 25, 2021
Published Date: November 25, 2021

Citation: L. Devarishi Sharma, Indira Sarangthem, Rahul Sadhukhan, Rojeet Thangjam, Y. Herojit Singh, C.G. Sawant, Lalhmingsanga, R. Lalrinfeli. Leaf Analysis in Citrus: Recent Development. Research & Reviews: Journal of Agricultural Science and Technology. 2021; 10(2): 35–43p.

LEAF ANALYSIS

Leaf analysis, according to [23–28] is based on four basic assumptions viz., (i) leaf is the leading site for the plant metabolism, (ii) change in the nutrient supply is reflected in the composition of leaf, (iii) change is more pronounced at certain stages of development, and (iv) concentration of nutrient in the leaf at a specific growth stage is related to crop performance. The distribution pattern of nutrients, e.g., B, tends to accumulate in mid-rib and interveinal areas of the leaf compared to leaf petiole. It isn't easy to get any information about the biochemical requirement of nutrients by the plant using the average values of leaf analysis [29–33]. Therefore, the total reliance on leaf analysis for fertilizer recommendation could be a hazard without field trials to verify the validity of the outcome of constraint diagnosis [34–39].

The use of foliar diagnosis developed rapidly in the USA, where most works were done in the 1940s. Its use later spread to South Africa, then to Israel, and gradually to other citrus-growing countries. A tentative leaf nutrient standard for the first-time using Valencia sweet orange, which was intended for adoption to individual situations and varieties [40–45]. Determination of the quantity of nutrients present in the whole tree provided information on the relative amount and distribution of nutrients, with leaves accumulating the highest concentration. It is common to see that the leaves on the summer growth are more significant than those on spring shoots, reached maturity more quickly [46–50].

General Guidelines

The nutrient concentration in the plant is an integral value of all the factors that have interacted to affect it. The nutrient levels in the leaf are related to the validity of leaf analysis as a tool for controlling mineral nutrition. It provides a detailed picture of the crop's production output and its reliance on the availability of each nutrient. At present, a classical leaf analysis can indicate the quality of effective absorption of nutrients and their distribution to different organs to participate in various metabolic processes [51–54]. However, it must be pointed out that an estimation of the quantitative mineral composition of leaves gives only a static picture. Nevertheless, it must be acknowledged that the critical level concept has served as a foundation for more effective theories.

The nutritional status of citrus trees can be determined using two types of testing viz., diagnostic and predictive testing [55–58]. Diagnostic testing is undertaken to diagnose the causes of poor crop vigor, e.g., patches of poor growth in an otherwise healthy crop, or to confirm a diagnosis based on plant symptoms and soil tests. Predictive (Prognostic) testing is used in the following three ways: (i) analysis of samples collected during the early crop development to predict the likelihood of the nutrient deficiencies appearing before the crop maturity, (ii) analysis of fruits to predict its likely behavior in the storage, and (iii) analysis of seeds to predict the deficiencies in the succeeding crops. Each form of testing may identify latent deficiencies (hidden hunger) that limit crop production while the plants exhibit no obvious deficiency symptoms. The distinction among the above three types of testing is necessary because of the variation in intensity and the pattern of sampling for each testing method.

Period of Sampling

Studies of late [59–63] showed that the leaves initially act as a sink and later as a source with a period in between known as transition across the sink to source happens to be the best time of sampling. Accordingly, the leaf sampling time was suggested as 5–7 months [64, 65] in Nagpur mandarin (*Citrus reticulata* Blanco) and 3–5 months in acid lime (*Citrus aurantifolia* Swingle) using non-fruiting terminals under hot sub-humid tropical climate of central India.

The selection of leaf from the non-fruiting instead fruiting terminals has the following advantages:

- Sampling is much faster due to the more excellent representation of non-fruiting terminals.
- Using fruits as an aid, the leaf age is not wholly reliable, as the same may develop on older twigs that could facilitate erroneous sampling.

- Leaves from fruiting terminals generally have lower nutrient concentrations except Ca and Mg than those from non-fruiting terminals. Subsequently, other studies showed a higher concentration of nutrients in non-fruiting than fruiting terminals of Kinnow mandarin [66–68].
- These terminals are likely to bear the next season's fruits.

Leaf Nutrient Diagnostics

A comprehensive survey of 108 Khasi mandarin orchards was conducted in northeast India's humid tropical climate from 52 locations across eight states from 2001 to 2004 [69–72]. The significance of leaf analysis as a tool for controlling mineral nutrition is related to its validity; the total concentration in the leaf provides a precise image of the crop's production output and its reliance on nutrient supply. Leaf nutrient concentration (Table 1) like N, P, K, Ca and Mg showed a wide variation, from 2.05–2.35%, 0.09–0.13%, 1.12–2.13%, 1.82–2.42%, and 0.22 to 0.42% respectively. Similarly, the micronutrients Fe, Mn, Cu, and Zn, ranged from 133.5 to 281.2 ppm, 51.6 to 100.3 ppm, 5.1 to 22.4 ppm, and 14.5 to 25.6 ppm, with a median of 138.9, 60.2, 8.5, and 25.5, respectively. The concentration of different nutrients in the leaf exhibited a substantial variation when categorized at various yield levels, except Fe and Mn (Table 2). Earlier studies [73, 74] used Nagpur mandarin (Citrus reticulata Blanco) as a test crop grown on Ca-rich alkaline montmorillonitic black clay soils under hot sub-humid tropical climate in central India showed a similar kind of delineation of nutrient levels having a statistically significant difference concerning fruit yield. Fruit yield was more strongly correlated with nutrients such as N ($r = 0.708$, $p = 0.01$), P ($r = 0.697$, $p = 0.01$), Ca ($r = 0.817$, $p = 0.01$), Cu ($r = 519$, $p = 0.01$), and Zn ($r = 0.793$, $p = 0.01$) than K ($r = 0.436$, $p = 0.01$), Fe ($r = -0.309$, $p = 0.05$), and Mn ($r = -0.296$, $p = 0.05$).

Table 1. Leaf nutrient status of in citrus orchards across 8 states of east-northeast India (Pooled values for n=108)

States	**Leaf nutrient concentration (%)**								
	Macronutrients (%)					***Micronutrients (ppm)***			
	N	*P*	*K*	*Ca*	*Mg*	*Fe*	*Mn*	*Cu*	*Zn*
1. Meghalaya (13)	2.35	0.12	1.28	2.14	0.24	148.2	51.6	5.8	20.4
2. Assam (4)	2.31	0.13	1.12	2.22	0.28	155.0	62.0	5.1	22.2
3. Arunachal Pradesh (6)	2.17	0.09	1.42	2.01	0.22	156.3	51.6	7.0	22.8
4. West Bengal (6)	2.28	0.10	1.45	1.92	0.32	144.2	58.5	8.1	24.3
5. Sikkim (3)	2.05	0.09	2.13	2.38	0.42	133.5	100.3	7.4	24.2
6. Manipur (4)	2.17	0.09	1.97	2.42	0.38	153.3	70.9	5.7	14.5
7. Mizoram (7)	2.16	0.10	1.73	1.82	0.32	150.1	72.9	22.4	25.6
8. Tripura (9)	2.11	0.09	2.03	1.94	0.29	281.2	83.5	15.3	22.2
Mean	2.20	0.09	1.64	2.11	0.31	165.2	68.9	9.6	22.0
Median	2.47	0.11	1.43	1.98	0.34	138.9	60.2	8.5	25.5

Figures in parenthesis indicate the number of locations in each state.
***Source:** [69]*

Table 2. Leaf nutrient indices concerning varying levels of fruit yield

Nutrient	**Levels of fruit yield (kg tree^{-1})**				**LSD (p=0.05)**
	< 15 (n = 18)	***15-30 (n=26)***	***30-45 (n=30)***	***45-60 (n=34)***	
N (%)	1.62c	2.12b	2.56a	2.63a	0.23
P (%)	0.06c	0.10b	0.14a	0.15a	0.03
K (%)	1.62c	1.82b	2.20a	2.14a	0.18
Ca (%)	1.10d	1.83c	2.30b	2.80a	0.42
Mg (%)	0.20c	0.28b	0.38a	0.42a	0.06
Fe (ppm)	242.8a	210.4a	280.8a	262.8a	NS

Mn (ppm)	52.3a	51.4a	46.4a	48.3a	NS
Cu (ppm)	7.8c	6.9c	15.8b	23.9a	4.2
Zn (ppm)	15.1c	21.4b	29.3a	33.8a	5.3

Means in columns by different letters are separated according to LSD test (P=<0.05).
Source: *[69]*

The optimum values of leaf nutrients using multivariate quadratic regression analysis were estimated as: 2.32% N, 0.010% P, 1.92% K, 2.26% Ca, 0.30% Mg, 158.4 ppm Fe, 82.0 ppm Mn, 12.2 ppm Cu, and 30.3 ppm Zn with fruit yield of 46.3 kg tree^{-1} (Table 3). These values were very similar to the concentrations of various nutrients in leaves obtained from high-performance orchards, implying that maximum yield can be achieved while maintaining the same optimum level of nutrients. For Satsuma mandarin grown in Jeju Island, Korea, [75] suggested optimum leaf N, P, K, Ca, and Mg as 2.5–2.8, 0.19–0.20, 1.5–1.7, 2.5–3.0, and 0.30–0.35 percent, respectively, under similar growing conditions.

While other studies in Japan using clementine mandarin as a test crop, [76] observed optimum values of various nutrients like N, P, K, Ca, and Mg as follows 2.5–2.7%, 0.10–0.15%, 0.80–0.90%, 4.0–5.0%, and 0.25–0.30% respectively. Even if the cultivar is still the same across a range of growing conditions, site-specific conditions, including soil type, dominate the variation in optimum values. These observations call for the necessity of developing the cultivar-specific diagnostic norms to precisely identify nutrient constraints commensuration with field conditions [19–25].

In another study, the DRIS indices projected the optimal value of various nutrients as follows: 1.86–2.62% N, 0.08–0.10% P, 0.89–1.86% K, 1.62–2.12% Ca, 0.40–0.50% Mg, 119.4–219.4 ppm Fe, 58.7–84.7 ppm Mn, 2.2–3.3 ppm Cu, and 20.8–29.8 ppm Zn to fruit yield of 28.2–49.6 kg tree^{-1} for Khasi mandarins grown in Manipur (Table 4) [77]. Through leaf analysis, various nutrients were rated as Zn,

Table 3. Comparison of optimum values of leaf nutrient concentration versus values from high-performance orchards

Nutrients	***High performance orchards (Range)***	***Optimum values****
N (%)	2.23–2.49	2.32
P (%)	0.10–0.11	0.10
K (%)	1.86–2.12	1.92
Ca (%)	2.12–2.32	2.26
Mg (%)	0.28–0.38	0.30
Fe (ppm)	148.2–179.8	158.4
Mn (ppm)	72.2–84.8	82.0
Cu (ppm)	10.4–18.6	12.2
Zn (ppm)	24.2–38.8	30.3
Fruit yield (kg tree^{-1})	45.0–62.0	46.3

** Optimum values were determined through multivariate quadratic regression equation:*
$Y(Yield) = 687.62 + 6.12x_1(N) + 22.12x_2(P) + 4.32x_3(K) + 11.12x_4(Ca) + 9.21x_5(Mg) + 0.02x_6(Fe) + 42.89x_7(Mn) + 189.62x_8(Cu) + 82.68x_9(Zn) - 182.11x_1^2 - 5001.10x_2^2 - 42.11x_3^2 - 812.32x_4^2 - 318.21x_5^2 - 0.12x_6^2 - 0.41x_7^2 - 28.19x_8^2 - 3.11x_9^2$
Source: *[69]*

Table 4. Leaf nutrient indices (derived from DRIS based analysis) for Khasi mandarin grown in Manipur

Nutrient	**Indices**							
	Deficient	***Low***		***Optimum***		***High***		***Excess***
N (%)	< 1.52	1.52	- 1.85	1.86	- 2.62	2.63	- 2.92	> 2.92
P (%)	< 0.05	0.05	- 0.07	0.80	- 0.10	0.11	- 0.12	> 0.12
K (%)	< 0.56	0.56	- 0.88	0.89	- 1.86	1.87	- 2.28	> 2.28
Ca (%)	< 1.48	1.48	- 1.61	1.62	- 2.12	2.13	- 2.48	> 2.48

Mg (%)	< 0.28	0.28	- 0.39	0.40	- 0.50	0.51	- 0.62	> 0.62
Fe (ppm)	< 81.4	81.4	- 119.3	119.4	- 219.4	219.5	- 320.3	> 320.3
Mn (ppm)	< 36.3	36.3	- 58.6	58.7	- 84.7	84.8	- 118.2	> 118.2
Cu (ppm)	< 1.1	1.1	- 2.1	2.2	- 3.3	3.4	- 4.8	> 4.8
Zn (ppm)	< 11.2	11.2	- 20.7	20.8	- 29.8	29.9	- 37.8	> 37.8
Yield (kg/tree)	< 12.7	12.7	- 28.1	28.2	- 49.6	49.7	- 58.9	> 58.9

Source: [77]

Table 5. Identifying nutrient constraints in Khasi mandarin using leaf analysis-based (Diagnosis and recommendation integrated system) analysis

	Nutrient found deficient and low (n=30)						**Nutrients found high and excess (n=10)**		
	Zn	***P***	***Ca***	***Mg***	***N***	***K***	***Fe***	***Mn***	***Cu***
Concentration† (mg/kg)	14.2	0.05	1.47	0.28	1.58	0.72	220.4	110.4	3.4
DRIS indices	-160	-140	-110	-100	-60	-40	+110	+210	290

Source: *[77]*

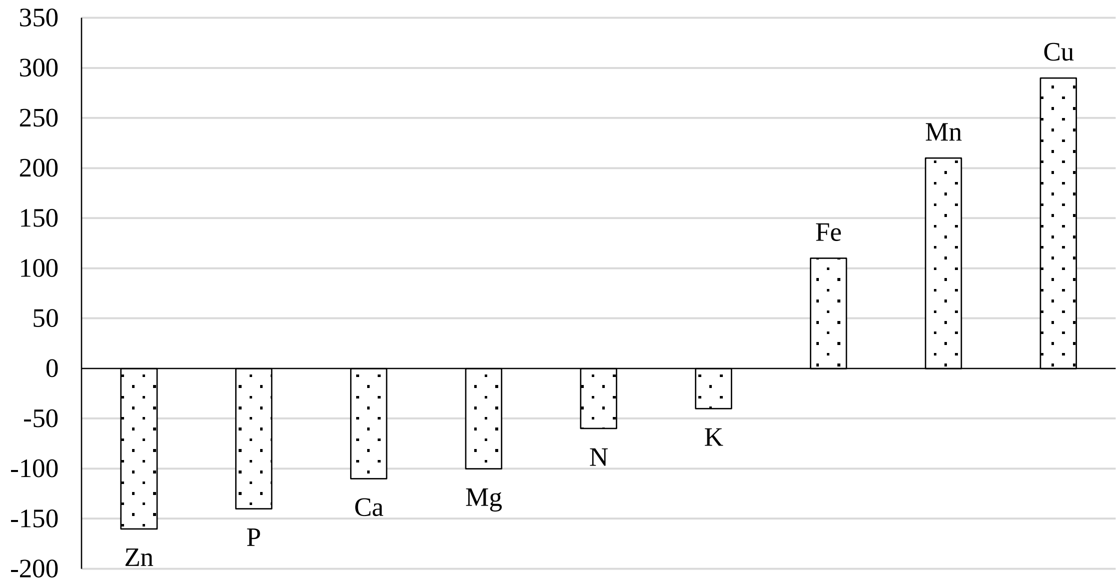

Figure 1. Identifying nutrient constraints in Khasi mandarin using leaf analysis-based DRIS analysis. (Source: [77])

P, Ca, Mg, N, K, Fe, Mn, Cu, in order of decreasing influence on yield (Table 5). Nutrient deficiencies of Zn, P, Ca, Mg, N, and K due to their negative values in decreasing order were observed through leaf analysis. Using the progressive nutrient diagnosis, if the first limiting factor Zn is corrected by its supply, the next nutrient that will limit the yield is P. Further, if Zn and P are satisfied, the next limiting nutrient is Ca, and Mg followed by N and K (Figure 1).

CONCLUSION

In the light of the preceding discussion, the best possible nutrient management strategy particular to a site is the identification of high-yielding orchards in a given location and then using the soil and leaf analysis values as reference guidelines to arrive at the type of nutrient constraint(s). An attempt would overcome fertilization's frequently inconsistent response due to regional differences in soil fertility and plant nutritional problems.

REFERENCE

1. Srivastava, A.K. and Shyam, Singh. 2002a. World citrus: Climate and soil analysis. In Citrus: Climate and Soil. Eds. 1-290. International Book Distributing Co., Lucknow, Uttar Pradesh, India.

2. Srivastava, A.K., S. Singh, and L.G. Albrigo. 2008. Diagnosis and remediation of nutrient constraints in citrus. Hort. Rev. 34: 277-363.
3. Srivastava, A.K., Shyam Singh, A. D. Huchche, and Lallan Ram.2001. Yield based leaf and soil test interpretations for Nagpur mandarin in Central India. Communications in Soil Science & Plant Analysis 77(6): 363-5.
4. Srivastava, A.K., Singh Shyam and K.N. Tiwari. 2006. Site specific nutrient management for Nagpur mandarin in (Citrus reticulata Blanco). Better Crops 88: 22-25.
5. Srivastava, A.K., and Shyam, Singh. (2001). Development of optimum soil property limits in relation to fruit yield and quality of Citrus reticulata Blanco cv. Nagpur mandarin. Tropical Agriculture (Trinidad) 78(3):174-81.
6. 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.
7. Srivastava, A.K., and Singh, Shyam. 2002b. Soil suitability criteria.Citrus: Climate and Soil, pp 291-38. International Book Distribution Company, Lucknow, UP. India.
8. Srivastava, A.K., P.S. Shirgure, and S. Singh. 2003. Differential fertigation response of Nagpur mandarin (Citrus reticulata Blanco) on an alkaline Inceptisol under sub-humid tropical climate. Trop. Agric. 80(2): 91-96.
9. Srivastava, A.K., S.K. Malhotra, and Krishna Kumar, N.K. 2015. Exploiting nutrient-microbe synergy in unlocking productivity potential of perennial fruits: A review. Indian Journal of Agricultural Sciences 85:459-81.
10. Srivastava, A.K., S. Singh, A.D. Huchche, and L. Ram. L. 2001. Yield based leaf and soil test interpretations for Nagpur mandarin in Central India. Comm. Soil Sci. & Pl. Anal.32 (3 & 4):585-599.
11. Srivastava, A.K., S. Singh, A.D. Huchche, and L. Ram. 2001. Yield based leaf and soil test interpretations for Nagpur mandarin in Central India. Communications in Soil Science & Plant Analysis USA 32: 585–599.
12. Srivastava, A.K., S. Singh, and K.N. Tiwari. 2006. Site specific nutrient management in Nagpur mandarin (Citrus reticulata Blanco). Better Crops 90(2): 22–24.
13. Srivastava, A.K., and Shyam Singh.2004c. Zinc nutrition and citrus decline – A review. Agricultural Reviews 25:173-88.
14. Srivastava, A.K., and Shyam, Singh. (2003b). Diagnostic of citrus nutrition (in) Citrus Nutrition, pp 1-236. International Book Distribution Company Lucknow, UP, India.
15. Srivastava, A.K., and Shyam, Singh. 2003a. Plant and soil diagnostic norms for optimum productivity of Nagpur mandarin (Citrus reticulata Blanco). Fertilizer News 48(2): 47-63.
16. Srivastava, A.K., and Shyam, Singh. (2002b). Soil analysis based diagnostic norms for Indian citrus cultivar. Communications in Soil Science and Plant Analysis 33:1689-1706.
17. Srivastava, A.K., Kohli, R.R., H.C. Dass, A.D. Huchche and Lallan Ram. 1999. Evaluation of the nutritional status of Nagpur mandarin (Citrus reticulata Blanco) by foliar sampling. Tropical Agriculture (Trinidad) 72(6): 93-8.
18. Srivastava, A. K., and Shyam Singh. 2004b. Soil and plant nutritional constraints contributing to the citrus decline in the Marathawada region, India. Communications in Soil Science and Plant Analysis 35:2537-550.
19. Srivastava, A. K., and Shyam Singh. 2006. Biochemical markers and nutrient constraints diagnosis in citrus: A perspective. Journal of Plant Nutrition 29: 827-55.
20. Srivastava, A. K., and Shyam Singh. 2007. DRIS-based nutrient norms for Nagpur mandarin (Citrus reticulata Blanco). Indian Journal of Agricultural Sciences 77:363-65.
21. Srivastava, A. K., and Shyam Singh. 2008a. Citrus nutrition research in India: Problems and prospects. Indian Journal of Agricultural Sciences 78:3-16.
22. Srivastava, A. K., and Shyam Singh. 2009b. Citrus decline: Soil fertility and plant nutrition. Journal of Plant Nutrition 32:197-45.
23. Bould C (1984). Diagnosis of mineral disorders in plants-principles. Pp.1-96. Chemical Publishing, New York.

24. Srivastava, A. K., and S. Singh. 2008b. DRIS norms and their field evaluation in Nagpur mandarin (Citrus reticulata Blanco). J. Pl. Nutri. 31(6):1091-1107.
25. Srivastava, A. K., and S. Singh. 2009a. Zinc nutrition in 'Nagpur' mandarin on haplustert. J. Pl. Nutri. 32(7): 1065-1081.
26. Srivastava, A. K., and S. Singh. 2009b. Citrus decline: Soil fertility and plant nutrition. J. Pl. Nutri. 32(2):197-245.
27. Srivastava, A. K., and Shyam Singh. 2008. Citrus nutrition research in India: Current status and future strategies. Indian Journal of Agricultural Sciences, 78(1):3-16.
28. Srivastava, A. K., and Shyam Singh. 2003b. Plant and soil diagnostic norms for optimum productivity of Nagpur mandarin (Citrus reticulata Blanco). Fertilizer News, 48: 47-63.
29. Srivastava, A. K., and S. Singh. 2005. Diagnosis of nutrient constraints in citrus orchards of humid tropical India. J. Pl. Nutri. 29(6):1061-1076.
30. Srivastava, A. K., and S. Singh. 2005. Zinc nutrition, a global concern for sustainable citrus production. Journal of Sustainable Agriculture 25(3): 5–42.
31. Srivastava, A. K., and S. Singh. 2006. Citrus nutrition and biochemical markers. J. Pl. Nutri. 29(5):827-855.
32. Srivastava, A. K., and S. Singh. 2006a. Citrus nutrition and biochemical markers- A review. Journal of Plant Nutrition 28(2): 827–55.
33. Srivastava, A. K., and S. Singh. 2008a. Analysis of citrus orchard efficiency in relation to soil properties. J. Pl. Nutri. 30: 2077-2090.
34. Sautoy, N. D. 1992. Field trial evaluation of Valencia fruiting terminals leaf P, K, and Mg norms for a low base status loamy sand. In: Proceedings of the International Society of Citriculture, eds. E. Tribulato, A. Gentile and G. Refergiato, Vol. 2, pp. 547–555. Acireale, Italy: International Society of Citriculture.
35. Srivastava, A. K., and S. Singh. 2002. Soil analysis based diagnostic norms for Indian citrus cultivar. Communications in Soil Science & Plant Analysis 33: 1689–1706.
36. Srivastava, A. K., and S. Singh. 2003. Diagnostics of citrus nutrition. In: Citrus Nutrition, pp. 237–285. Lucknow, India: International Book Distribution Company.
37. 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 J. Agric. Sci. 73(4):209-211.
38. Srivastava, A. K., and S. Singh. 2004a. Soil and plant nutritional constraints contributing to the citrus decline in the Marathawada region, India. Communications in Soil Science & Plant Analysis 35: 2537–2550.
39. Srivastava, A. K., and S. Singh. 2004c. Soil and plant nutritional constraints contributing to the citrus decline in the Marathawada region, India. Communications in Soil Science & Plant Analysis 35(17/18): 2 537-50.
40. Chapman, H.D. 1964. Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and planting crops. Indian Journal of Horticulture 21: 97 – 119.
41. Srivastava, A. K., and S. K. Malhotra. 2014. Nutrient management in fruit crops: Issues and strategies. Indian Journal of Fertilisers 10:72-88.
42. Srivastava, A. K., and S. Singh. 2001b. Development of optimum soil property limits in relation to fruit yield and quality of Citrus reticulate Blanco cv. Nagpur mandarin. Trop. Agric. 78(3): 174-181.
43. Srivastava, A. K., and S. Singh. 2001a. Soil properties influencing yield and quality of Nagpur mandarin (Citrus reticulata Blanco). J. Indian Soc. Soil. Sci. 49(1): 226-229.
44. Srivastava, A. K., and S. Singh. 2001a. Soil properties influencing yield and quality of Nagpur mandarin (Citrus reticulata Blanco). Journal of Indian Society of Soil Science 49(1): 226–229.
45. Srivastava, A. K., and S. Singh. 2001b. Soil fertility limit in relation to optimum yield of Nagpur mandarin (Citrus reticulata Blanco). Journal of Indian Society of Soil Science 49: 758–762.
46. Srivastava, A. K., and Shyam Singh. 2002. Soil analysis based diagnostic norms for Indian citrus cultivar. Communications in Soil Science and Plant Analysis 33:1689-706.

47. Srivastava, A. K., A. D. Huchche, L. Ram, S. Singh. 2008. Performance of irrigated monocropped versus intercropped Nagpur mandarin orchards on basalt derived tropical soils. Trop. Agric. 82(3): 159-163.
48. Srivastava, A. K., A. D. Huchche, Lallan Ram, and Shyam Singh. 2007. Yield prediction in intercropped versus monocropped citrus orchards. Scientia Horticulturae 114:67-70.
49. Srivastava, A. K., and E. Ngullie. 2009. Integrated nutrient management: Theory and practice. Dynamic Soil, Dynamic Plant 3: 1-30.
50. Srivastava, A. K., and P. S. Shirgure. 2018. Nutrient diagnostics and fertilizer prescription in Citrus: A perspective analysis. Journal of Eco-friendly Agriculture 13(2): 1-17.
51. Zekri, M., and T. A. Obreza. 2003. Plant Nutrients for Citrus Trees. SL200. Gainesville, FL: University of Florida Cooperative Extension Service.
52. Srivastava, A. K. 2013d. Nutrient deficiency symptomology in citrus: An effective diagnostic tool or just an aid for post– mortem analysis. Indian Journal of Agricultural Sciences 2: 177-194.
53. Srivastava, A. K. and Shyam, Singh.2003a. Plant and soil diagnostic norms for optimum productivity of Nagpur mandarin (Citrus reticulata Blanco). Fertilizers News 48(2): 47-63.
54. Srivastava, A. K., A. D. Huchche, and D. Kumar. 2010a. Development of INM module for sustained productivity of Nagpur mandarin. Annual Report, National Research Centre for Citrus, Nagpur, pp. 60-66.
55. Obreza, T. A., A. K. Alva, E. A. Hanlon, and R. E. Rouse. 1993. Citrus grove leaf tissue and soil testing: Sampling, analysis and interpretation. Citrus Industry 4: 68–71.
56. Srivastava, A. K. 2010b. Integrated nutrient management in citrus: Frontier developments. Indian Journal of Fertilisers 6:34-44.
57. Srivastava, A. K. 2013b. Site-specific nutrient management in citrus. Journal of Agricultural Science 2:1.
58. Srivastava, A. K. 2013c. Recent developments in diagnosis and management of nutrient constraints in acid lime. Indian Journal of Agricultural Sciences 2:86-96.
59. Srivastava, A. K. and S. Singh. 2008b. Citrus nutrition research in India: Problems and prospects. Indian Journal of Agricultural Sciences 78: 3-16.
60. Srivastava, A. K., and S. Singh. 2004b. Zinc nutrition, a global concern for sustainable citrus production. J. Sustain. Agric. 25(3):5-42.
61. Srivastava, A. K. (2011). Site-specific potassium management for quality production of citrus. Karnataka Journal of Agricultural Science 24:60-66.
62. Srivastava, A. K. 2009b. Integrated nutrient management: Theory and practice. Dyn. Soil, Dyn. Pl. 3(1), 1-30.
63. Srivastava, A. K. 2010a. Development of INM to harmonize with improved citrus production: Changing scenario. Advances in Plant Physiology 12:294-68.
64. Srivastava, A.K., Shyam Singh, and K. N. Tiwari. 2007. Diagnostic Tools for Citrus: Their Use and Implications in India. Better Crops –India, 26-29.
65. Srivastava, A. K., and Shyam Singh.2003b. Plant and soil diagnostic norms for optimum productivity of Nagpur mandarin (Citrus reticulata Blanco). Fertilizer News 48: 47-63.
66. Singh, A., A. K. Srivastava, H. C. Dass, and N. Vijayakumari. 1997. Screening germplasm of citrus rootstocks for salinity tolerance. Indian Journal of Horticulture 55: 283–287.
67. Srivastava, A.K. 2013a. Nutrient management in Nagpur mandarin: Frontier developments. Journal of Agricultural Science 2:1-14.
68. Srivastava, A. K. 2009a. Integrated nutrient management: Concept and application in citrus. In: Tennant P., Beakebhaia N (eds.) Citrus II. Tree and Forestry Sci. & Biotechnol.3, 32-58.
69. Srivastava, A. K., and S. Singh. 2006. Diagnosis of nutrient constraints in citrus orchards of humid tropical India. Journal of Plant Nutrition 29: 1061–1076.
70. Mongi Zekri and Thomas A. Obreza (2003a). Plant Nutrients for Citrus Trees. Extension Institute of Food and Agricultural Sciences. Pg. 1-5.
71. Srivastava, A. K. and Shyam Singh. 2004a. Zinc nutrition, a global concern for sustainable citrus production. Journal of Sustainable Agriculture 25: 5-42.

72. Srivastava, A. K., S. N. Das, S. K. Malhotra, and Kaushik Majumdar. 2014. The SSNM-based rationale of fertilizer use in perennial crops: a review. Indian Journal of Agricultural Sciences 84(1): 3-17.
73. Srivastava, A. K., and Shyam Singh. 2001c. Development of optimum soil property limits in relation to fruit yield and quality of (Citrus reticulate Blanco) cv. Nagpur mandarin. Tropical Agriculture 78:174-81.
74. Srivastava, A. K., and Shyam Singh. 2003a. Soil-plant nutrient limits in relation to optimum fruit yield of sweet orange (Citrus Sinensis s Osbeck) cultivar Mosambi. Indian Journal of Agricultural Sciences 73:209-11.
75. Ko, K.D. and S.K. Kim. 1987. Chemical properties of soil and leaf mineral contents in Jeju citrus orchards. Journal of Korean Society of Horticulture Science 28: 45-52.
76. Terblance, J.H. and S.F. Du Plessis. 1992. Leaf and soil analysis as a tool for determining fertilizer requirements of Citrus. Proc. Int. Soc. Citriculture, May 8-13, Vol 2. 744-745. Acireale, Italy.
77. Indira Sarangthem, L. Devarishi Sharma 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, Vol. 62, No. 2, pp 118-125