Nutrient optima-based productivity zonality delineation in citrus orchards of northeast India

A.K. Srivastava[A], Shyam Singh[B] and S.N. Das[C]

[A] National Research Centre for Citrus, Nagpur 440 010, Maharashtra, India, Email aksrivas_2007@yahoo.com
[B] National Research Centre for Citrus, Nagpur 440 010, Maharashtra, India, Email shyamsingh_5@yahoo.co.in
[C] Regional Remote Sensing Centre, Nagpur, Maharahstara, India, Email subratondas@rediffmail.com

Abstract
Spatial variability in soil fertility is important in identifying nutrient constraints vis-à-vis productivity zones to rationalize nutrient use and optimize productivity. Leaf analysis and fruit yield data bank 7 states across northeast India were analysed through a diagnosis and recommendation integrated system (DRIS) to determine leaf nutrient optima and a geographical information system (GIS) was used to develop a spatial variogram of nutrient constraints to delineate major production zones. DRIS interpretation revealed leaf nutrient optima as : 19.7-25.6 N, 0.9-1.0, P, 9.9-19.3 K, 19.7-24.9 Ca, 2.4-4.8 Mg as macronutrients (g/kg), 85-249 Fe, 43-88 Mn, 3-14 Cu and 17-27 Zn as micronutrients (mg/kg) vis-à-vis productivity of 33-56 kg/tree. Superimposing the variograms for nutrient constraints, three major citrus productivity zones were delineated as : zone I (26-27^0 8-25' 13-43" N latitude; 92^{0}23-59' 0.82-43"E longitude) without Zn-Mg-P-N constraint, with productivity of 69-104 kg/tree as the best productivity zone followed by zone II (26-27^0 25-26' 36-51" N latitude; 93^{0}23-58' 2-21" E longitude) having no Zn-P-N constraint with productivity of 52-68 kg/tree and zone III (26-27^0 6-44' 20-56" N latitude; 91-92^0 33-57' 6-17" E longitude) with no Zn-P constraint, having orchard productivity of 23-51 kg/tree.

Key words
Productivity zonality, nutrient optima, citrus, DRIS, GIS

Introduction
It is well recognised that crop behaviour and soils are not uniform within a given orchard (Srivastava *et al*. 2006) and growers have generally responded to such variability by taking appropriate actions such as improving drainage, changing fertilization time, source, etc. Advances in software aided decision support systems (DSS) like DRIS and GIS, have led to usage of newer interpretation tools having much wider application potential (Schumann and Zaman 2005; Zaman and Schumann 2006). Precision citrus farming basically depends on correctness of measurement and understanding of the in available supply of nutrients. This can be summarized in three steps viz., i. assessing variation ii. managing variation, and iii. evaluation. The available technologies enable us to understand variability and give site specific recommendations, the variability can be addressed precisely to enable precision citriculture, a viable management strategy. Efforts were made to identify major promising productivity zones for concentrated development of 'Khasi' mandarin orchards in northeast India.

Methods
Orchard setup and soil variability
An extensive survey of 108 'Khasi' mandarin orchards was carried out covering 590 sq.km from 50 georeferenced collection sites locations across 7 states (20^o-22'5' N latitude and 89^{o}37'-97-30^o E longitude). Soils predominantly belonged to soil orders Entisol (Haplaquent, Ustifluvent, and Udifluvent), Inceptisol (Ustochrept and Haplaquept), Alfisol (Rhodustalf, Paleustalf, Haplustalf, Orchraqualf, and Rhodustalf), and Ultisol (Palehumult, Haplustult, Plinthaqult,and Plinthustult). Mineralogically, these soils were grouped as illitic-kaolinitic mixed. Climate is characterized by annual rainfall of 120-1145 cm (mean 180 cm) with mean summer and mean winter temperatures varying between 24.6^{o}C - 32.8^{o}C (mean 28^{o}C) and 9.9^{o}C - 24.8^{0}C (mean 15^{o}C), respectively. Geology is dominated by sedimentary and metamorphic rocks grading from most ancient to recent.

Sampling and analysis
Six-to-seven month old leaves at second, third or fourth leaf positions from non-fruiting terminals covering 2-10% of trees at a height of 15-1.8 m from the ground were sampled and analysed for macro-(NPKCaMg) and micronutrients (FeMnCuZn). Two interpretation tools (DSS) viz., DRIS (Srivastava and Singh 2008) and GIS (Arc 9.3) were used in delineating citrus productivity zones

Results

Leaf nutrient optima

Validity of leaf analysis as a diagnostic tool lies in the total concentration of nutrients in leaf that relates with production output of the crop. Leaf macronutrient content (g/kg) showed a large variation, 20.5 – 26.5 N (median 24.7), 0.9 -1.3 P (median 1.1), 11.2 - 21.3 K (median 14.3), 18.2 - 24.2 Ca (median 19.8), and 2.2 – 4.2 Mg (median 3.4). Similarly, the micronutrients (mg/kg) varied as, 133.5 - 281.2 Fe (median 138.9), 51.6 - 100.3 Mn (median 60.2), 5.1 - 22.4 Cu (median 8.5), and 14.5 - 25.6 Zn (median 25.5), respectively. Using this databank, leaf nutrient optima (Table 1) for different nutrients were developed through DRIS-based software.

Table 1. DRIS based leaf nutrient criteria for 'Khasi' mandarin of northeast India

	Indices				
Nutrients	Deficient	Low	Optimum	High	Excess
N (g/kg)	< 16.7	16.7 – 19.6	19.7 –25.6	25.7 – 28.5	> 28.5
P (g/kg)	< 0.6	0.6 – 0.8	0.9 – 1.0	1.1 – 1.3	> 1.3
K (g/kg)	< 5.2	5.2 – 9.8	9.9 – 19.3	19.4 – 24.0	> 24.0
Ca (g/kg)	< 17.2	17.2 – 19.6	19.7 – 24.9	25.0 – 27.5	> 27.5
Mg (g/kg)	< 1.4	1.4 – 23.0	2.4 – 4.8	4.8 – 5.4	> 5.4
Fe (mg/kg)	< 22.6	22.6 – 84.5	84.6 – 249.0	249.1 –331.3	> 331.3
Mn (mg/kg)	< 18.6	18.6 – 41.5	41.6 – 87.6	87.7 – 110.6	> 110.6
Cu (mg/kg)	< 1.8	1.83 – 2.1	2.13 – 14.4	14.5 – 20.6	> 20.6
Zn (mg/kg)	< 11.1	11.1 – 16.2	16.3 – 26.6	26.7 – 31.8	> 31.8
Productivity (kg/tree)	< 19.1	19.1 – 31.5	31.6 – 56.3	56.4 – 68.8	> 68.8

Spatial distribution of nutrient constraints

Leaf nutrient criteria developed for 'Khasi' mandarin using DRIS-based software utilized for development of GIS-based maps nutrient constraints distribution maps (Fig. 1) showed that most of the Khasi mandarin orchards were optimum in N nutrition, low to deficient in P and optimum to high in K. Whereas, Ca and Mg nutrition were mostly severely deficient due to the poor supply of Ca and Mg in soil. On the other hand, Fe content was mostly high to excess. Copper nutrition showed deficiency levels, while Mn was mostly optimum to high with majority being at sub-optimum level.

Delineation of productivity zones

Maps for spatial distribution of nutrient constraints were superimposed, this delineated three most important citrus productivity zones. These are Zone I (26-27^o 8-25' 13-43" N latitude; 92^{o}23-59' 0.82-43"E longitude) showing no constraint of Zn-Mg-P-N with productivity of 69-104 kg/tree (areas identified as Navgaon, and Rangpara of Assam state); Zone II (26-27^o 25-36' 36-51" N latitude; 93^{o}23-58' 2-21" E longitude) without Zn-P-N constraint displaying productivity of 52-68 kg/tree (areas identified as Golpara of Assam state and Mirik, and Lisa hills of West Bengal state); and Zone III (26-27^o 6-44' 20-56" N latitude; 91-92^o 33-57' 6-17" E longitude) showing no constraint of Zn-P with productivity of 23-51 kg/tree (areas identified as Shergaon, Dirang, and Tengal Valley in the state of Arunachal Pradesh).

Conclusion

Integrated use of two diverse software-based DSS helped in identifying potential sites for sound land use planning using a systematic citrus development program in order to harness sustainability in quality production without any nutrient mining.

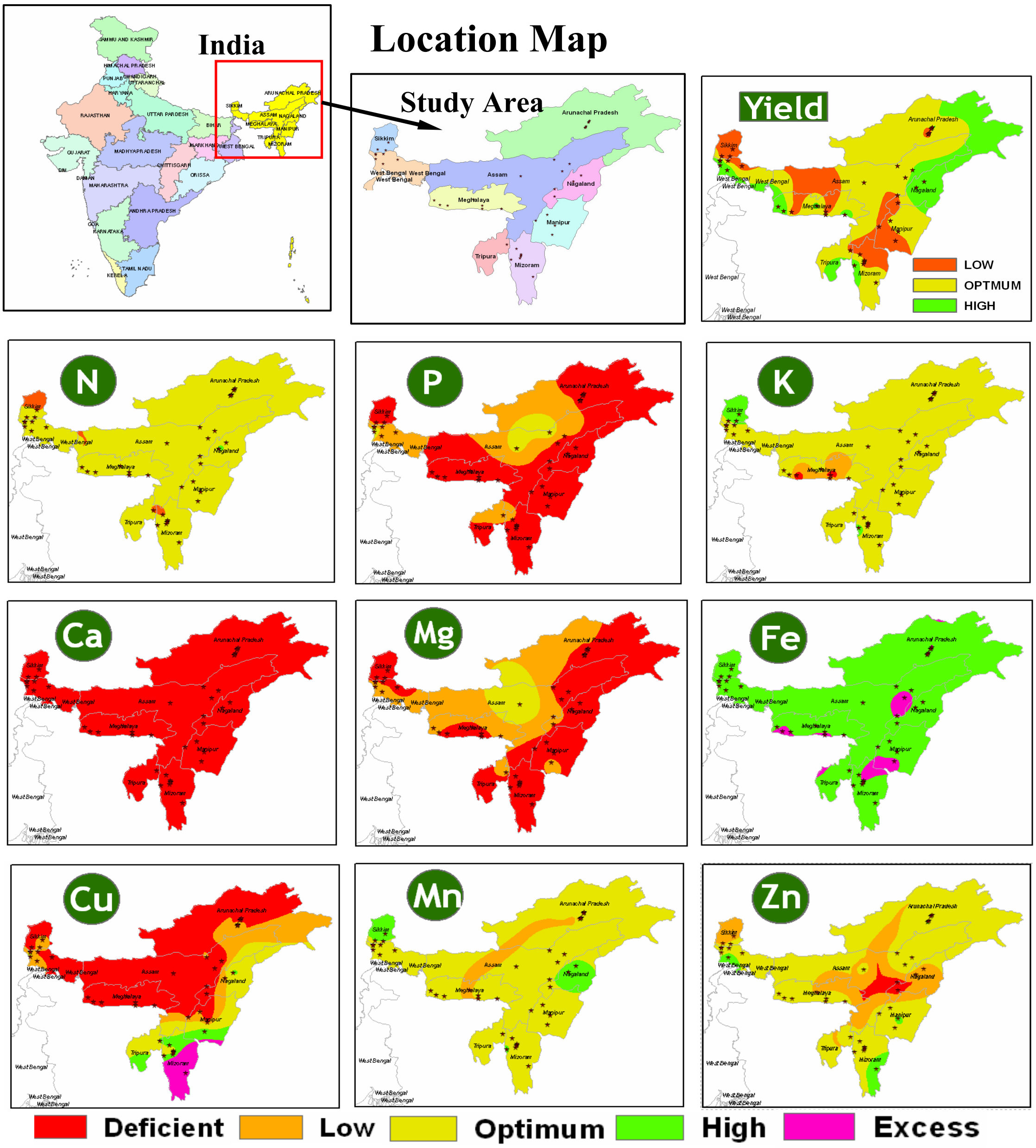

Figure 1: Spatial distribution of different nutrient constraints across seven states of north-east India

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